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Faculty of Engineering
Department of Textile Engineering

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PREFACE

Technical textiles have attracted more and more attention in recent years. These high performance materials are widely used in civil engineering, electrical engineering and electronics, agriculture, medical and automotive industries in addition to protective and military clothing.

Developed countries have focused their strategy on technical textiles to carry forward their competitive advantage and to control technical textiles market and consequently have held the global technical textiles market.

6th International Technical Textiles Congress is held in Izmir on 14-16 October 2015, where it started with 1st International Technical Textiles Congress. The congress targets to gather all the players of the industry; the experts and the researchers with the manufacturers, the consumers and the investors from Turkey and abroad. 6th International Technical Textiles Congress provides the possibility to share the industrial experiences and scientific investigations, which have very important contributions to the development of the sector.

We would like to thank to all sponsor companies, to all authors and participants for their kind supports. We hope that this international event will also generate an occasion to create new opportunities.

We are happy to welcome you.

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16 October 2015 Friday

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COST MP1105 - Workshop

POSTER PRESENTATIONS

14 OCTOBER 2015

ORAL PRESENTATIONS

STRUCTURAL HEALTH MONITORING FOR COMPOSITE STRUCTURES

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Abstract: Flexible polymers which incorporate conductive fillers can act as piezoresistive materials and are suitable for the design and fabrication of smart textile reinforcements for intelligent composites. Two applications based on coating of textile materials with carbon nano particles dispersed in polymers solutions for Non Destructive Evaluation (NDE) of glass laminate composites are presented. The first part presents a composite NDE system based on fibrous sensors. Polyethylene filaments coated with a sensing layer were placed inside textile reinforcements near top and bottom layers. After resin infusion, the resulted composite was subjected to bending tests. In the second part, a smart composite containing the sensing layer on the surface is presented. The strain response of the smart sensing layer has been recorded for composites with different defect configurations. The results proved that both variants of sensors are capable of detecting deformations and damage in composite structure.

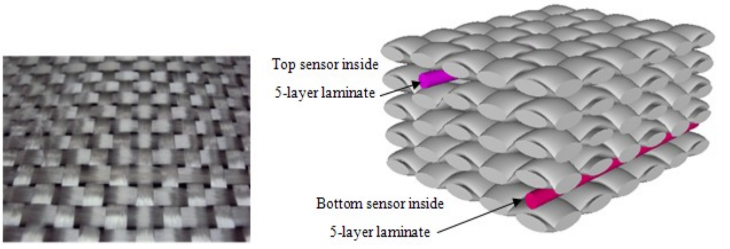
Keywords: piezoresistive sensors, structural health monitoring, non destructive evaluation

1. INTRODUCTION

Textile composites materials reinforced with long fibres are increasingly used as structural elements in industrial applications, automotive industry, aeronautics, wind energy management, sport, buildings etc., replacing slow but sure the traditional materials. Continuous fibres have become the dominant form of reinforcement in textile structural composites due to their effectiveness and a better control of orientation compared to short fibres reinforced composites (Ciobanu, 2011). Often operating in harsh environments and under heavy loads it is of utmost importance in structural composite parts to be able to monitor their performance in situ and in real time. Monitoring the state of a structural integrity, onset of flaws/damage and strain history mapping is often referred to as *Structural Health Monitoring* (SHM) (Balageas et al., 2006; Sohn et al., 2004). An integral part of any on line in situ monitoring system would be to integrate sensors in the structure at critical positions much like human nervous system (Chang et al., 2011). For all categories of textile composite materials, a solution to become sensitive to deformation is to use piezoresistive materials which incorporate conductive fillers (in form of micro or nanoparticles or nanotubes (Johnson et al., 2012 ; Zhao et al., 2010; Li et al., 2008; Thostenson et al., 2008; Hecht et al., 2007; Kang et al., 2006; Lee et al., 2006), at level of matrix or at the reinforcement. The fillers can be either incorporated inside the matrix by dispersing them using standard dispersion methods (Thostenson and Chou, 2006: ; Li et al., 2014) or can be used to make a smart filament (Sebastian et al., 2014; Risicato et al., 2014; ; Nauman et al., 2012; Nauman et al., 2011b; Nauman et al., 2011a) or reinforcement (De Baere et al., 2010; Hecht et al., 2007; Muto et al, 2001; Kupke et al., 2001; Abrie et al, 2001; Kaddour et al., 1994) which can be then impregnated with resin using traditional resin impregnation techniques.

2. FIBROUS SENSOR FOR COMPRESSION AND TRACTION DETECTION IN LAMINATED COMPOSITES

Polyethylene monofilaments (48.2 tex) were coated with a conductive polymer composite based on dispersion of Printex® L6 carbon black particles in Evoprene® 007 solution, using chloroform as a solvent (Cochrane et al, 2007). Two ply polyethylene filaments were coated with the polymer solution as described above. The two ends of the coated polyethylene filaments were additionally coated with silver paint in order to reduce contact resistance and fine copper wire was attached to the two ends with the help of this paint. In this way, secure connections were realized. In the case of five layers fabric reinforcements were placed over one another. The sensors were placed just under the 1st layer and just above the 5th layer during the lay up step so as to follow compression and traction loading respectively, during the 3-point bending test. A surface photograph of the plain woven 2D reinforcement is shown in Fig. 1(a), while the TexGen generated geometry of laminated composite specimen is shown in Figure 1(b).



(a) (b)

Figure 1. Glass fibre woven reinforcement. (a) surface photograph. (b) TexGen generated geometry of 2D reinforcements placed over one another having two sensors at the top and bottom

Afterwards the five-layer laminate structure with two sensors as described above was impregnated using a vacuum bag infusion process in order to make the composite part stiff. The resin employed was EPOLAM 5015 epoxy. The four connections of the top and bottom sensors which remain outside the reinforcement at the two ends were carefully separated from the rest of the mould. This was done by creating two vacuum sub-moulds inside the larger mould so that the resin would not impregnate the connections of the sensors. The impregnated composite samples were cut into slabs of required dimensions as shown in Figure 2. In this way each 12 cm × 3.0 cm glass composite specimen had two sensors, at the top and bottom, for compression and traction detection.

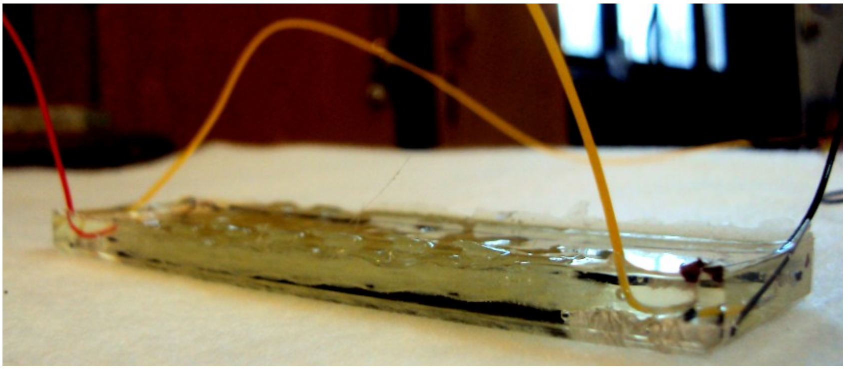


Figure 2. Glass laminated composite specimen with embedded sensors.

3. BENDING TESTS RESULTS

In Fig. 3, a glass composite specimen can be seen loaded on an Instron 1185 tester during a 3-point bending test.

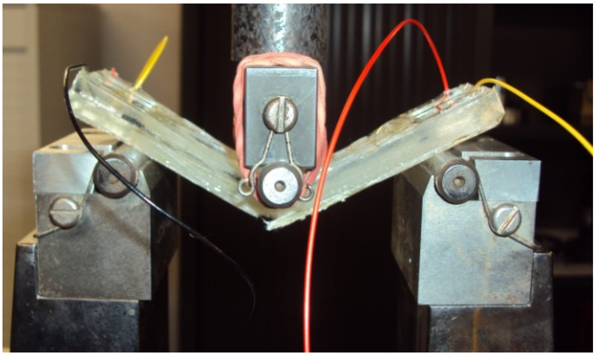


Figure 3. Glass laminate composite specimen with embedded sensors, loaded on an Instron 1185 tester for a 3-point bending test

4. CONCLUSION

Fibrous sensors developed as piecewise continuous systems (PCS) which can not only measure compression and traction, but are also capable of detecting distinctive fracture events in a composite structure, have been successfully integrated into a composite laminate during the lay-up phase. The sensors provide complete stress-strain history of the composite specimen. The 3-point bending test results have proven the feasibility of this approach. The sensors will have to be improved and optimized, particularly in terms of their bandwidth, sensitivity and compatibility with other high performance multifilament tows that are being widely used to design fibrous reinforcements for high performance composite structures. This will allow us to develop a pool of information about the deformation behaviour of different types of composites during different loading conditions. The strain response of a smart sensing layer, developed for structural health monitoring, based on Polystyrene/Carbon nano particles has been observed in the presence of defects. It was found out that the sensing layer reacts well to the presence of defects or stress raisers in the structure. The tensile test of a smooth specimen is characterized by the initial nonlinear response of sensing layer, followed by a linear response. It is believed that the linear response follows a certain amount of damage in the matrix of the composite. Even if the damage is produced at a distance from the sensor, the resistivity response shows it by a jump or peak in the curve. If however this damage occurs closer to the sensor, the peak in the smart sensing layer response is amplified. The sensing layer shows a linear response to the applied strain in the specimen after a certain amount of damage has occurred. We believe that this damage is mostly limited to the matrix cracking. In the linear region of the sensor response, the load is principally borne by the fibers. When the damage progresses i.e., the fibers break, the sensor records this as well, perfectly following the stress-strain curve right up to the complete fracture of the specimen. It would be interesting to normalize the absolute value of the change in resistivity so that this sensor could be used as a strain gauge as well as a damage detection tool. These results indicate that very useful information on composite "health" and about the phenomena occurring inside the structure under quasi-static loading conditions, related to crack propagation, fracture, delamination and other disturbances can be extracted. However, the data thus generated will have to be properly treated in order to extract all the supplementary information unavailable until now.

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FLAME RETARDANT CLOTHING FOR MOLTEN METAL APPLICATIONS

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Abstract: Protective clothing is important protection for workers exposing to molten metal; large splashes in foundries or small splashes when welding. EN ISO standards define the requirements and performance levels for the garments as well as methods for testing. Earlier predominantly natural materials like FR cotton, wool and aluminized rayon, wool were used for protection, but today more and more special blend fabrics of FR synthetic fibres with FR natural fibres are coming to the market having multilevel protection against different types of hazards.

Keywords: molten metal, testing, standards, materials

1. INTRODUCTION

Molten metal forms a hazard mainly in metal industry; in foundries large splashes of molten metal, in welding small hot particles, but also electric workers can expose to molten metal splashes during electric arc accidents. If the worker is not sufficiently protected he or she can get very serious burns. Protective clothing is one of most important protection needed.

2. MOLTEN METAL AS A HAZARD

Depending on the metal the melting temperature is different. Stainless steel and iron have the highest melting temperature and lead the lowest. But the temperature is not the only determining factor, also metal density, the size of splash droplets and the reactivity of the droplet surface. These factors are different for various types of molten metals depending on the metal; iron steel, copper, lead zinc or aluminum. The hazard and needed tailored solution depends on the following factors [1]:

- does the temperature of the molten metal drop ignite the fabric?

- does the density and hence mass of a drop enable the drop burrow into the fabric and char the fibres
- does the drop stick or slide from the fabric surface.

Exposure to welding drops depend on the type of welding; there are over 80 different types of welding and associated processes. Techniques involving heavy formation of spatters and drops are e.g. MMA welding, MAG and MIG welding [2].
During electric arc, the metal of the arc electrodes vaporizes and ionizes, and causes molten splashes.

3. PROTECTION REQUIREMENTS AND TESTING

The basic performance requirements for all kind of personal protective equipment are given in the Council Directive of 21 December 1989 on the approximation of the laws of the Member States relating to personal protective equipment (89/686/EEC) [3]. General requirements given in this Directive are then explained in harmonised standards. The directive defines protection needs for materials as well as complete PPE ready for use. The requirements for welders' protective clothing and workers exposing to large splashes of molten metal have been published in European and International level, for welders in EN ISO 11611 [4] and for workers exposed to molten metal in general heat protection standard EN ISO 11612 [5], in which the level of protection is determined in three performance levels for molten aluminum and for molten iron. For welders the protection against molten metal protection is classified to two classes. In addition to performance requirements the standards define specific design requirements for garments intended to use against molten metal hazards.

The main work to develop the test method in case of large splashes of molten metal took place in 1980. Two approaches are used in testing. The most often used method is to use PVC skin simulant to evaluate the performance level when defined amount of molten metal is poured on the fabric surface [6]. This method is referred in EN ISO 11612. The other approach is to measure the temperature on back side of the fabric by a calorimeter. This method is referred in ASTM standard [7]. It is not well known how well the PVC skin method correlates the normal exposure to molten metal. Also the method do not explain the basic requirements of the PPE directive. The development of the method has been on the table of the test house group of TC 162 WG 2 for years. Different layouts of board with copper calorimeters with sensors has been build. The problem is that when molten metal is poured on the sample, the pouring differs every time causing high variation in the pouring area on the samples.

The laboratories have discussed problems to design the calorimeter. The measuring area cannot be too small, also not big, and the measuring area should cover the whole specimen area. Solution could be to use totally different type method for measuring the temperature. Finnish Institute of Occupational Health (FIOH) has already performed some experiments measuring the temperature on the backside of the sample by Infrared camera with promising results. But because of funding problems for the development work the development work is now stopped.

Welding drop test method measures the insulation of the material when drops weighing 0.50 g fall on the same point at a velocity of 20 drops per minute. Steel rod is melted in the flame of an oxyacetylene welding torch. The number of drops required to rise the temperature of the sensor by 40 K is measured. Mean of 10 tests is calculated [8].

4. MATERIALS

In 1980 predominantly FR cotton, wool and aluminized rayon, wool, leather, and also asbestos were used for molten metal protection. General remark was that FR cotton fabrics worked well for iron and steel, but did poorly with aluminum against which FR wool worked well. In the beginning of 2000 new developments in materials against molten substances came to the market. Examples are: aramid blend ProFlex® consisting of Nomex® & Kevlar® & antistatic fibre P140, PR97® blend of Wool / Lenzing FR® Viscose / Cotton, blend of LENZING FR - WO – PA, VINEX® of 85% FR PVA and 15% polynosic, Therm Guard™ Molten Repel comprising of Teflon® and meta-aramid fibres, IBENA proFeel of 35% Teijin Conex®65% Viscose FR), IBENA proSafe of 55% Modacryl45% Cotton (Protex M™), proFlex4® of Meta-Aramid / Para-Aramid / Viscose FR, NOMEX® MetalPro and NOMEX® MetalPro Plus fabrics. Also new intelligent materials e.g phase change materials, and using nanotechnology can give more comfortable possibilities for personal protective clothing against molten metal. [9]

The performance levels are given normally only for the outer layer fabrics. To get sufficient protection stiff and heavy materials should be used. Mäkinen et al [10] measured the protective performance of fabric combinations for 8 hours use. The results from the laboratory tests showed that protection can be increased considerably from class 1 to class 3 (over 200 g iron) if flame retardant underwear is used and the material combinations are still comfortable for eight-hours use.

5. CONCLUSION

Today there are wide selection of different types of materials giving protection against molten metal. The trend seems to be the development of products, which offer multilevel protection, which in turn need to meet the ever-growing list of EN ISO norms. In addition to molten metal protection they may be antistatic, high visible, protect against small chemical splashes etc. For this purpose the fabrics are blends where good properties of different fabrics are combined.

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15 OCTOBER 2015

ORAL PRESENTATIONS

NEW DEVELOPMENTS AND TRENDS IN PROTECTIVE CLOTHING

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Abstract: Personal protective equipment (PPE) protects people from risks at work. PPE can only be put on the market if it complies with the health and safety regulations in EU Directive 89/686/EEC – exceptions are valid for the private use or for the use in a military environment. This essay provides a short overview of application fields of PPE, and will show several trends and new developments in material, design and manufacturing. Due to different trends, the textile and clothing industry faces the challenge to develop new equipment with integrated supplementary functions. The changed awareness of safety and health creates new possible applications for a variety of protective equipment.

Keywords: PPE, protective clothing, smart textiles, ergonomics, fitness for use

1. INTRODUCTION

In the past decades the security environment in the world has changed considerably. The threat of the cold war is no longer eminent – in contrast the threat of terroristic attacks and accidents is due to globalization constantly increasing. Experts are talking about an asymmetric threat scenario, in which incidents are unpredictable in time, location, frequency and intensity. Furthermore, on account of the industrial development and globalization, the number of accidents involving hazardous substances has also increased.

Therefore, civil and military defense forces are exposed to rising risks caused by accidents, disasters, terrorist or military attacks. Thus, they are exposed to extreme situations in harmful environments. Moreover, the shifted situation in concern of incidents is the reason why much more personnel are involved during operations. They have to be equipped with the most reliable and convenient personal protective equipment (PPE). In addition they must be prepared, through training, to perform perfectly in unaccustomed situations with polluted environmental conditions.

Due to the globalisation and industrialisation an increasing number of people are in workplaces where PPE is needed. The altered awareness of health and individuality combined with the shifted security situation leads to changes in requirements for protective clothing. Depending on the end-user and usage scenario different protection systems are required. The textile and clothing industry has to rise to this challenge and develop equipment with integrated supplementary functions.

2. TRENDS AND DEVELOPMENTS IN PPE

2.1. Overview of PPE application fields

Personal protective equipment affords the user protection from hazards encountered at work. In addition, there is PPE for protection at home or during leisure activities. PPE at work has to be provided in order to fulfill the fundamental right of health and safety in the workplace. The national and community legislation is intended to ensure the safety of employees and will be applied usually – except for military forces.

The European Directive 89/686/EEC gives a clear definition of the requirements for putting PPE products on the market. According to this Directive PPE must be clearly labelled with the CE sign and prove in this way, that they fulfil the essential health and safety protection requirements given in the Directive.

The PPE is intended to protect the wearer in different situations from numerous risks like physical, chemical or biological hazards. According to the Directive PPE is divided into three classes:

- class I protects the wearer against minimal risks e.g. gardening gloves
- class II is all equipment, that falls neither in class I nor in class III e.g. warning clothes
- class III is complex PPE designed for protection against mortal dangers or irreversible damage to health e.g. fire-fighting suits

Moreover PPE is classified according to the parts of the body where it is used e.g. head protection, eye protection, respiratory protection or whole body protection. [1]

2.2 New material developments

The trend of multifunctional protection leads to the need of new materials. One example is a multilayered textile fabric for protective clothing against fault arc. Another example will be chosen from the chemical protection area.

2.3. Application potential for smart textiles

Smart textiles are defined as intelligent textiles or textiles with an additional value for the wearer. This can be either integrated electronics and sensors or self-adapting materials. From both areas the author will show at least one example.

2.4. Usability, fitness for use and ergonomic aspects

In the guidelines for the European Directive 89/686/EEC the following information can be found: “The PPE must be so designed and manufactured that in the foreseeable conditions of use for which it is intended the user can perform the risk-related activity normally whilst enjoying appropriate protection of the highest possible level.”[1, p.44] In cooperation with the German Federal Institute for Occupational Safety and Health (BAuA) the author examined a study on usability and fitness for use of firefighting equipment. [2]

The wearing comfort has several aspects: the thermos-physiological, the skin sensorial and the ergonomic comfort. Comfort is one of the most important issues concerning the acceptance of the protective equipment. Yet, a considerably more important aspect is that a good wearing comfort leads to less deficit in physical and mental performance and in this way supports the ability of the wearer to fulfill his mission.

2.5. Potentials for sustainable textiles in PPE

The discussion about sustainability and environmental protection has increased significantly in the last years. That is one of the reasons why long lasting concept in the product life cycle as well as new ways of textile finishing are becoming more and more important. Certificates like STEP® or Bluesign® show the global approach to this topic.

3. RESULTS AND DISCUSSION

The lecture will focus on trends and special developments for applications in PPE. The general aim of new developments is to improve the protection and the wearing comfort in order to increase the safety level, because only clothing which is worn correctly can protect the wearer from the hazards in the workplace. The different topics will be illustrated with numerous examples and completed with information from different previous and upcoming research projects operated with the collaboration of the author.

4. CONCLUSION

The number of employees working in the textile industry has declined dramatically in the last decades, that is the reason why companies wanting to participate in the highly competitive market of technical textiles, had to find new ways of developing and producing creative and innovative, value-added products that can compete against cheaper commodity textile products from the low-wage labor markets.

In the field of protective textiles, innovation has resulted in a wide range of materials which are lighter, smarter and often multi-functional. These properties are mostly based on new fibers, new technologies and interdisciplinary teamwork. This leads to a wide range of engineered properties for different applications. However, the fabric alone is not enough for innovative products. Especially for PPE it is extremely important that the end-user is already integrated into the development process to guarantee that the equipment is fit for use and hence, the personnel can fulfill their mission with the support of adequate equipment. [3, 4]

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EMI SHIELDING AND UTILITY PROPERTIES OF WOVEN FABRICS CONTAINING CONDUCTIVE FIBERS

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Abstract: In recent years, conductive fabrics have obtained increased attention for electromagnetic shielding and anti-electrostatic purposes. One way how conductive fabrics can be created is utilization electrically conductive fibers. In this paper, the woven fabrics with different content of conductive component (Inox staple fibers) in hybrid polypropylene yarns are investigated. Electromagnetic shielding is characterized by the attenuation of electromagnetic field power density by using of simple device. Comfort is characterized by bending rigidity, drape, abrasion resistance, thermal characteristics, air permeability and water vapor permeability. It is experimentally verified that designed fabrics with increased resistivity to electromagnetic smog fulfill requirements for wearing thermo physiological comfort. Negative effect of addition of metal fiber causes decrease of abrasion resistance of fabric mainly.

Keywords: conductive hybrid yarns, electromagnetic shielding, comfort properties

1. INTRODUCTION

Everyone is exposed to a complex mix of weak electric and magnetic fields, both at home and at work. Sources of such emissions could include generation and transmission of electricity, domestic appliances and industrial equipment, telecommunications and broadcasting [1]. If the electromagnetic waves are not isolated effectively, they will cause interference with each other and result in technical errors. If somebody gets exposed under the electromagnetic, radiate environment, physical harms may occur on human body. In recent years, conductive fabrics have obtained increased attention for electromagnetic shielding. This is mainly due to their desirable flexibility and lightweight. One way how conductive fabrics can be created is utilization electrically conductive fibers. They can be produced in filament or staple lengths and can be mixed with traditional non-conductive fibers to create hybrid yarns that possess varying degrees of conductivity. The woven fabrics with different content of conductive component (Inox staple fibers) in hybrid polypropylene yarns are investigated in this paper. Electromagnetic shielding is characterized by the attenuation of electromagnetic field power density by using of simple device [2]. Comfort is characterized by bending rigidity, drapeability, abrasion resistance, thermal characteristics, air permeability and water vapor permeability. It is experimentally verified that designed fabrics with increased resistivity to electromagnetic smog fulfill requirements for wearing thermo physiological comfort.

2. MATERIAL AND METHOD

2.1. Preparation of fabrics

The woven fabrics containing conductive component (Inox staple fibers) in hybrid polypropylene yarns were prepared. Hybrid yarns were composed from polypropylene and different content of staple stainless steel (SS) metal fiber Inox (1 - 75 %). The aspect ratio (length/diameter ratio, l/d) of the SS used in this study is 6250, since the diameter of the SS is 8 μm and the fiber length of the SS is 50 mm. The yarn was designed at two levels of fineness: 25 and 51 tex.

Fabrics were twill weaves with weft and warp fineness 51 tex - warp sett 20 1/cm, weft sett 19 1/cm made of the hybrid yarn containing different portion of conductive phase.

2.2 Selected fabrics properties

Volume resistivity was measured according to the standard ČSN 34 1382, at the temperature T = 22,3 °C and relative humidity RH = 40,7 %. Volume resistivity is measured by applying a voltage potential across opposite sides of the sample and measuring the resultant current through sample. Electromagnetic shielding was characterized by the attenuation of electromagnetic field power density by using of simple device. Electromagnetic shielding was characterized by the attenuation of electromagnetic field power density by using of simple device. Basic parts of device are two waveguides. One waveguide is connected with receiving wire (antenna). Textile sample is placed on the entrance of second waveguide. The end of this waveguide is filled by foam saturated by carbon absorbing the electromagnetic field passed through sample. Sample is oriented perpendicularly the electromagnetic waves. Transmitting antenna is placed in front of first waveguide input. As source of electromagnetic field the ZigBee module working at frequency 2.4 GHz and 1.8 GHz is used. The total shielding effectiveness SE [dB], is calculated.Bending rigidity, drape, abrasion resistance, thermal characteristics, air permeability and water vapor permeability are evaluated by the conventional measuring techniques.

3. RESULTS AND DISCUSSION

The dependence of total shielding effectiveness SE on the percentage of conductive component P is shown in Fig. 1a. Thermal conductivity (see Fig. 1(c)), air permeability (see Fig. 1(d)) and water vapor permeability increases with increased content of conductive component. Abrasion resistance was decreasing with increasing content of metal fiber in sample; see Fig. 1(b).

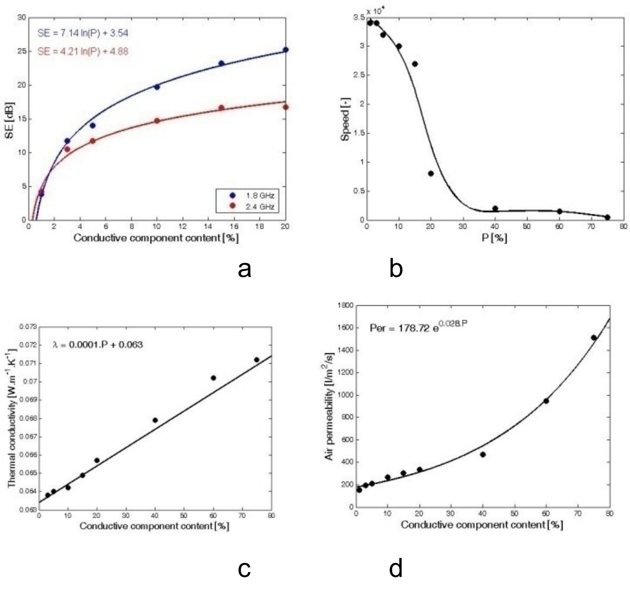

Figure 1. The dependence of shielding effectiveness (a), speed to first binding point failure due to abrasion (b), thermal conductivity (c) and air permeability (d) on conductive component content

4. CONCLUSION

Low cost conductive fabrics with sufficient electromagnetic shielding efficiency conserving the main properties, e.g. comfort properties, drape and process ability characteristics were created. It was found, that the portion of conductive component has a significant effect on increasing conductivity (decreasing resistivity) and improvement of electromagnetic shielding efficiency. The prepared fabrics with increased resistivity to electromagnetic smog fulfill requirements for wearing thermo physiological comfort. Negative effect of addition of metal fiber causes decrease of abrasion resistance of fabric.

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TESTING OF CLOTHING FOR PROTECTION AGAINST THE THERMAL HAZARDS OF AN ELECTRIC ARC

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Abstract: Each and every day electro-technical work is carried out worldwide at the risk of triggering an electric arc either by failure or due to a technical reason. The effects when an electric arc occurs can only be specified roughly. Even after the exposure of an arc it is quite difficult to indicate the released thermal energy. Moreover it is difficult in an electric installation to predict the direction of the arc due to the magnetic field caused by the short circuit flux.Thus a personal protection equipment (PPE) that works one hundred per cent against an electric arc is not possible.The properties and requirements to be fulfilled by protective clothing as well as the way and procedures for proving and testing have to be defined. Particularly, reliable tests are necessary to confirm the working clothing to be arc resistant and guaranteeing the protective level required.

Keywords: Electric arc, PPE, protective level

1. INTRODUCTION

There is a general hazard and potential risk of human injury due to electric arcs particularly in case of fault arcs which may internally occur with short-circuits in electric installations. These arcs cannot be avoided totally. In particular those people are concerned, working at, in or in the vicinity of these installations for professional reasons, particularly in case of live working. Their working clothing may essentially contribute to protect them particularly against the thermal arc consequences or be actually a base for the according protection. It is of greatest importance for the personnel mounting, repairing, maintaining or operating electrical equipment and installations to be safely protected in each situation actually. There may not result any unacceptable health risk, the suitability of clothing has to be analysed and proved. The properties and requirements to be fulfilled by protective clothing as well as the way and procedures for proving and testing have to be defined. Particularly, reliable tests are necessary to confirm the working clothing to be arc resistant and guaranteeing the protective level required. Test method, procedure, set-up and parameters must meet the according practical needs. The test conditions have to be selected and terminated in accordance with the relevant power network and installation ones, and the practical exposure scenarios as well. Furthermore, quantitative assessment and evaluation is necessary in testing. The calorimetric arc effects are to be measured, a calorimetric analysis of the tests has to be carried out.

2. STANDARS IN THE FIELD OF PROTECTIVE CLOTHING AGANIST ELECTRIC ARCS

2.1 Existing standards

EN ISO 61482-1 are split into two parts, which cover the methods for testing of clothing fabrics and garments that are designed to protect against arc flash EN ISO 61482-1-2, which now supersedes ENV 50354, have become known as the "box test". There exist two test method versions: The "material box test", which includes heat transfer measurements and Stoll curve differential analysis, and the "garment box test", which requires only a visual assessment of the garment performance.

The box-test standard defines two testing conditions, namely Class 1 and Class 2:

- Class 1 tests at an arc current of 4 kA and arc duration of 500 ms.
- Class 2 tests at an arc current of 7 kA and arc duration of 500 ms.

The box test gives a pass or fail result with respect to the selected specific box test conditions and assessment criteria and does not give the value of the incident energy (e.g. usually expressed calories per centimetre squared (cal/cm²) against which the fabric and therefore the garment shall have to offer protection. Nevertheless, the standard EN ISO 61482-1-2 enables garments to be CE certified with respect to their box test class performance.

This box test method is intended to be referred to for Low Voltage Systems only. For instance to replicate potential hazards in service entrance boxes, cable distribution, cabinets, distribution substations or comparable installations, where arc is directed to the front of a worker at the height of the breastbone.

EN ISO 61482-1-1 are the test method standards by which the garment manufacturer can assess the protective performance of a fabric according to Test Method A. Garments made of arc rated fabrics are then tested according to Test Method B. The protection property of a fabric or garment against the thermal effects of an electric arc event is defined as its Arc Thermal Protection Value, usually expressed in cal/cm². It is more commonly known as the ATPV.

3. RESULTS AND DISCUSSION

The test standard will have two different test methods. One of them, the box test is particularly of importance for European testing and certification. As shown by practice the test is well reproducible and accepted. It allows the classification of material and garments regarding the protection against the thermal hazards of electric arcs; two protection classes are defined. The classes are characterised by the level of electric arc energy. Quality assurance of testing as well as the estimation of practical hazards covered by the according test or class must be based on the electric arc energy and the direct exposure incident energy. Both risk assessment and classification have to be made by means of the arc energy.

4. CONCLUSION

EN ISO 61482 is applicable to protective clothing used in work if there is an electric arc hazard.This standard specifies requirements and test methods applicable to materials and garments for protective clothing for electrical workers against the thermal hazards of an electric arc based on

– relevant general properties of the textiles, tested with selected textile test methods, and
– arc thermal resistance properties, such as
the arc rating of materials (ATPV or EBT50), when tested with an open electric arc
under defined laboratory conditions according to EN ISO 61482-1-1, or the arc protection class of materials and garments (Class 1 or Class 2), when tested with a directed and constrained electric arc under defined laboratory conditions according to EN ISO 61482-1-2.

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POSSIBILITIES FOR PROCESSING OF RECYCLED CARBON FIBERS WITH THE WET-LAID TECHNOLOGY

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Abstract: Processing of recycled carbon fibers by wet-laid technology has many advantages. The fibers are implemented in water- no dusk formation. Further benefits are the light density of the fabric and the implementation of other layers (multilayer). First results of recycled carbon fibers from composite parts are showing good performances.

Keywords: Recycling, Carbon Fibers, wet-laid technology, CFRP components, composites

1. INTRODUCTION

Nowadays the industry has a high demand for recycling possibilities of carbon fibers and the realignment for recycled carbon fibers to new products. Carbons fibers are usually extracted from used parts or production scrap like roving or scrim. The recycled fibers have lower material performance than virgin fibers, but they still have good advantages to be used in non-structural products like seat shells. One big challenge of using recycled carbon fibers is the processing. Depending on the performance (fiber length, fiber fineness and resign residual) of the recycled carbon fibers there are several processing technologies that can be used.

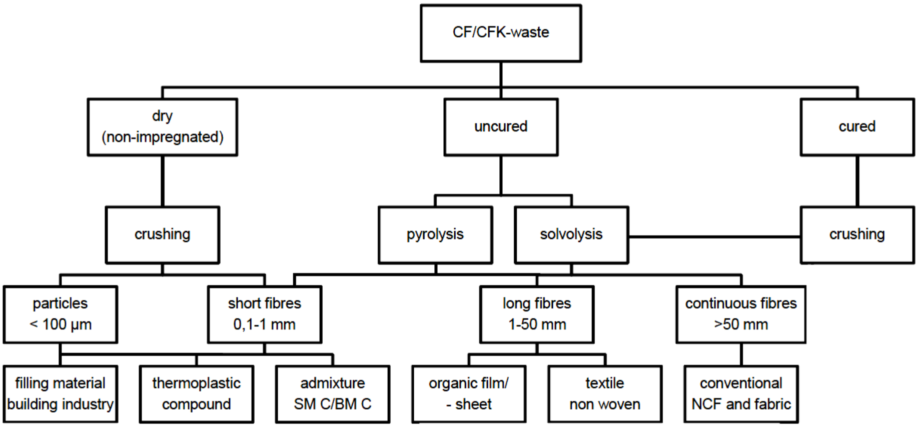

Figure 1. Recycling methods of carbon fibers/ CFRP components[1]

2. PROCESSING POSSIBILITIES OF RECYCLED CARBON FIBERS

Beside the use of cut or milled recycled carbon fibers as reinforcement fiber or filler for injection moulding components a promising processing possibility is the production of nonwovens. For the production of dry laid nonwovens the fiber length is very important. Short fibers (< 20 mm) can’t be used for the most dry laid technologies. Other disadvantages are the strong dust formation, the electrical conductivity of the dust, a skin and lung deposition and also damaging of the fiber (carded webs). Another alternative processing is the wet-laid technology. For this technology short fibers are used. Advantages of this technology for recycled carbon fibers are that the fibers are implemented in water (no dusk formation) and it is gentle to the fibers.

2.1 Wet-laid Technology

In the wet laid technology, as shown in fig. 2, the fiber material and a binder system is dissolved in a fluid medium, with special additives to ensure to have a homogeneous suspension. The suspension goes to an inclined wire and then the felt is built. After that through a drying process, the binder system fixes the felt to the desired tenacity.

1 Cf. Dieter Meiners, Bertram Eversmann, Recycling von Carbonfasern, Recycling und Rohstoffe Band 7 (2014), P. 371 - 378

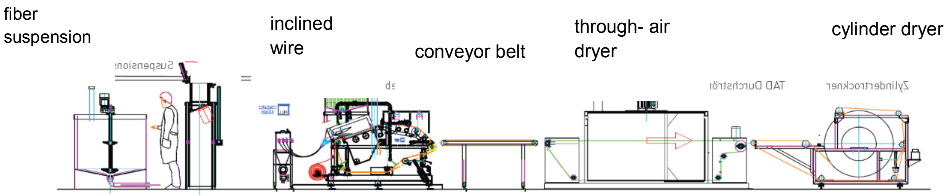

Figure 2. Processing levels of wet-laid nonwoven technology

3. RESULTS AND CONCLUSION

Advantages of the process are the light fabric density of about 5 to 10 g/m², and the homogeneous nonwoven surface. First results with recycled carbon fibers from composites parts are showing promising nonwoven structures. Several Applications like profiles for construction element or organic sheets are feasible. Additional benefit of processing wet laid nonwovens is the option to create multi-layer fabrics to implement additional properties.

Such nonwoven as shown in fig. 3 could be used for a layer of linear pultruded carbon filaments to increase the cross directional tenacity of the fiber composite material.

Figure 3. Wet-laid nonwoven made from production scrap

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EFFECT OF FIBER AND YARN PARAMETERS ON THE PHYSICAL TESTS OF WOVEN AUTOMOTIVE SEAT FABRICS

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Abstract: Automotive seat fabrics must meet different specifications regarding the different OEMs' (Original Equipment Manufacturers) requirements. In this study, effect of yarn linear density, fiber cross section, filament number and texture type on the properties of woven fabric was investigated. All the finishing parameters were kept constant in all fabric types. Thermo fixed fabrics were laminated with foam and scrim. Tests of tensile strength, elongation, fabric stiffness/softness, Velcro and whitening during abrasion were realized. Analyses of the test results showed that parameters investigated in the study have influences on different properties of the fabrics.

Keywords: automotive woven fabrics, fiber cross-section, yarn linear density, filament number, physical tests

1. INTRODUCTION

Automotive seat fabrics have three components in the structure. The face fabric which is located on the front side of the laminated seat fabric must have the esthetical view as well as high physical performance. Yarn parameters, fabric construction and the mechanical and chemical finishing processes are influencing the test performance of the final automotive seat fabric [1-4]. In this study, effect of yarn linear density, fiber cross section, filament number and texture type on the properties of woven fabric were investigated. Mechanical performance of the fabrics were tested and analyzed.

2. MATERIALS AND METHODS

In the study five different fabrics were produced with the same construction parameters. Five different %100 polyester filament yarns which have different properties were used.

2.1 Yarn properties

The yarn properties used in the study are given In Table 1.

Table 1. Yarn properties yarns used in the study

	Fiber cross-section	Filament number	Yarn linear density [denier]	Texturising Type
Yarn A	Round	96	300	IMG
Yarn B	Octolobal	96	300	IMG
Yarn C	Round	192	300	IMG
Yarn D	Round	96	450	IMG
Yarn E	Round	96	300	ATY

2.2 Fabric Production

In the study five different fabrics were produced in order to analyze the effect of fiber cross-section, filament number, yarn linear density and yarn texturizing type on the mechanical tests of the automotive fabric. The produced fabrics in the study are given in Table 2.

Table 2. Fabrics produced in the study

Fabric Name	Woven Construction	Warp Yarn	Weft Yarn	Warp Density	Weft Density
Fabric A	Plain	Yarn A	Yarn A	24	17
Fabric B	Plain	Yarn B	Yarn B	24	17
Fabric C	Plain	Yarn C	Yarn C	24	17
Fabric D	Plain	Yarn D	Yarn D	24	17
Fabric E	Plain	Yarn E	Yarn E	24	17

All the fabrics were produced in the same loom with same parameters. After the weaving process fabrics were dyed on the same dyeing bath with same parameters. Finishing of the fabrics were done with same parameters. Fabrics were laminated with 5 mm polyurethane foam and circular knit scrim on flame lamination process.

2.3 Tests

Laminated fabrics were tested. Tests of tensile strength, elongation, fabric stiffness/softness, Velcro and whitening during abrasion were realized. Weight of the fabrics were also measured.

3. RESULTS AND DISCUSSION

According to the all test results it was seen that the parameters investigated in the study have influences on different fabric properties. Fabrics produced with higher yarn linear density has higher tensile strength. Stiffness-softness test results showed that all the parameters influence this property of the fabrics in different ways. Air texturized yarns and the yarns having higher filament numbers have lower Velcro resistance than the other fabrics. Whitening tests of fabrics produced with higher filaments are the worst which is followed by the fabrics produced with high linear density yarns.

4. CONCLUSION

In this study effect of different yarn parameters on the mechanical performance of the automotive seat fabrics were investigated. As a result of the study it was concluded that fiber cross-section, filament number, yarn linear density and texturizing type have different influences on the fabric properties investigated in the study.

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DEVELOPMENT OF SUSTAINABLE FIBER FOR TECHNICAL TEXTILES

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Environmentally attractive raw-material base to produce regenerated cellulose for textile fibers can be found in certified forests. Ongoing developments are reported on the novel fibre type based on ionic liquids and results are convincing, however more work is needed to scale up and proven economics of the technology. For the manufacturing is however required economically feasible and ecologically sustainable process solutions.

There are also up-scaled novel processes, such as cellulose carbamate CCA, for production of more sustainable and high quality textile fibers. Already in the 1990s the CCA process was in its break through state but the market situation was not favourable for commercialization. However, the CCA process development continued at VTT Finland resulting in further cost-efficiency and new IPR. Due to changes in raw material markets, such as cotton and polyester, the time is now favourable for re-entry of CCA process.

Viscose produced in stand-alone factory in Europe is not competitive with imported viscose on current price levels of the product. The CCA process omits the CS_2 recycling step in the process providing a cost-benefit of compared to viscose. Further cost-saving of can be achieved by integration with a dissolving pulp production.

Next generation of regenerated fibres stand for quality, functionality and sustainability. A simple demonstration of the upgraded CCA technology takes place in an existing, but not operational viscose plant in Finland to prove the proposed benefits in demonstration scale in 2015. The novel developments open opportunities in novel fibre types and materials for hygienic and technical textiles. The novel cellulose materials are especially suitable e.g. for novel nonwoven materials.

TENSILE STRENGTH CHARACTERIZATION OF UD CARBON WOVEN PREFORM

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Abstract: Textiles are found to be among most efficient reinforcements for composite materials. A notable characteristic of preform is crimp which arises from its woven structure, plays an important role on the tensile strength of composites. In this study, different weave pattern of unidirectional (UD) carbon woven preforms (i.e. plain, twill and satin) were manufactured. In each weave pattern, polyester fine warp yarn is interlaced with carbon fibre tow-weft with different warp count (no. of warp yarns per cm). All UD carbon woven preform made with different weave pattern were tested for meso-mechanical analysis. The obtained result proved the importance of crimp. UD woven preforms with satin weave pattern shows higher strength comparing with other weave patterns. All UD woven preform samples were scanned using scanning electronic microscopy in order to analyses the tow geometry. It is observed that UD carbon woven preforms possess low crimp in carbon fibre tow direction and significant crimp in polyester yarn direction. This shows possibility for textile engineers to tailor the properties for desired application.

Keywords: UD woven preform, tensile strength, Carbon

1. INTRODUCTION

Textile woven preforms are finding widespread use for the composite application ranging from aerospace, sports, civil to wind turbine blade and off-shore application. Woven preforms possess excellent drape-ability but compromise mechanical properties due to crimp. Unit cell of tow geometry including crimp of woven (plain and woven) composite are modelled by number of authors [1-8]. Woven preforms often compete with stitched bonded non-crimp (NCF) fabric. NCF exhibits excellent in-plane properties in comparison with woven preform but suffer in compression strength due to stitching defect [9]. Recently, Mazhar and Potluri et al reported UD woven fabrics as special class of textiles and analyzed the tow geometry [10-11]. This work focuses on manufacturing the UD carbon woven preforms with commonly used weave pattern: plain, twill and satin as well as mechanical analysis of UD carbon woven preforms.

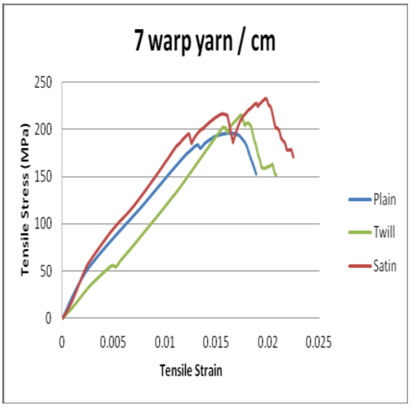
2. MATERIAL AND METHOD

UD woven Preforms consist of 12 K carbon tows in weft direction are interlaced with fine polyester yarn. The preforms with three common weave patterns: Plain, Twill and Satin consist of 3, 5 and 7 warp yarns per centimeter are investigated in this research work as shown in Table 01.

Table 1. UD Carbon Woven Preforms Specification

Types of Weave	Density of Fabric (warp/weft yarns per cm)	
	Warp Direction (Polyester)	Weft Direction (Carbon)
1. Plain weave	3	14
	5	13
	7	12
2. Twill weave	3	13
	5	16
	7	14
3. Satin Weave	3	15
	5	13
	7	13

Figure 1. Tensile Stress-Strain Curve of UD Woven Preform



The mechanical properties and crimp analysis of all preforms with different weave patterns were measured by ASTM Standard D 3039 and D3883-04 respectively. Further Scanning Electronic Microscopy has been used in order to analyze the two geometry of each weave pattern particularly tow waviness (in-plane / out of plane).

3. RESULTS AND DISCUSSION

In this research work, tensile tests were conducted on UD carbon woven preforms with different weave patterns along carbon tow and polyester yarn directions. Tests were carried out at specified standard at a temperature of 25^0 C ±1 and relative humidity of 40±5. Typical tensile stress-strain curves for is shown in figure 01. It is observed that almost in all weave pattern manufactured, the ultimate strength and modulus of UD woven preforms decreases with an increase of warp yarns per cm. The satin weave possesses higher tensile strength and modulus comparing with other weaves pattern. This is why the satin weave pattern is mostly attracted towards to high specific end application such as aerospace parts.

Table 2. Crimp analysis of UD Carbon Woven Preforms

Warp Density (yarns/cm)	Weave Design	Carbon weft tow Crimp (%)	Polyester warp yarn Crimp (%)
3	Plain	2.5	14
	Twill	3.0	8.0
	Satin	3.2	6.0
5	Plain	2.0	17
	Twill	2.5	12
	Satin	3.0	11
7	Plain	1.5	24
	Twill	2.0	20
	Stain	3.0	20

Crimp analysis of carbon tow and polyester yarn were also measured as shown in Table 2. It is noticed that Crimp percentage of carbon has an inverse relation with warp yarn/cm. The crimp percentage of carbon tow decreases with an increase of warp yarns per cm in almost weave pattern. All weave patterns with 7 warp yarns/cm possesses lowest crimp in carbon tow. However, decrease in crimp of carbon tow causes the crimp percentage increase in the polyester warp yarn. This is due to carbon tow allows polyester fine yarn to wrap around the carbon geometry.

4. CONCLUSION

Influence of fine warp yarns spacing on the geometry of carbon tow was presented. 7 warp yarns per cm is stable weave pattern among other weaves and contribute lowest crimp in carbon tow. This leads to increase of tensile strength and modulus in satin weave.

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DESIGN OF TENS ELECTRODES USING CONDUCTIVE YARN

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Abstract: Transcutaneous electrical nerve stimulation (TENS) is a commonly used technique in physical therapy. TENS treatment is typically applied with conductive hydrogel electrodes to the treatment zone where body nerves are stimulated by electrical current. Electrodes are placed on certain tissue locations which are desired to activate, electrical current is conducted with at least one pair of electrodes and a potential gradient is originated in the underlying tissue. Conductive hydrogel TENS electrodes reduce skin resistance however their viscous structure causes discomfort. Repeated use and being not washable are other disadvantages. In order to accomplish this problems, in this study, TENS electrodes are designed using conductive yarn and performances of electrodes are tested before and after washing.

Keywords: Conductive yarn, textile electrodes, TENS electrodes.

1. INTRODUCTION

In the early times of electrical stimulation metal plates covered with fabric structures were used as stimulation electrodes. Metal material is stainless steel or silver/silver chloride, covering fabric is often cotton fabric. When this type of electrodes is used, fabric must be wet with water or gel to obtain conductivity. However while fabric is drying out, unequally distributed electrical fields under the electrodes may cause skin burns. In order to prevent these risks carbon electrodes were developed. Carbon has a higher resistance than metal therefore high current concentration in small areas is prevented. In case of currents are higher than 10 mA, carbon rubber electrodes need gel or water as skin interface material. Despite the fact that in some cases this type of electrodes is still in use today, the most widely used type of electrode for TENS applications are self-adhesive hydrogel electrode. The disadvantages of self-adhesive electrodes are feeling of discomfort because of their viscous structure, unable to be washed and being not hygienic.

In this study, TENS electrodes have been designed with different properties using conductive yarn and their resistance values were measured. The designed electrodes are connected to a commercially available TENS device. Their conductivity has already been measured on the subjects before washing and it is planned to measure conductivity after repetitive washings.

2. MATERIAL AND METHOD

2.1. Sample Production

A woven fabric which has Nm 36/2 cotton yarn as warp and weft yarns was used as electrode base fabric. Electrodes in size of 5 cm x 5 cm were sewn on the fabric having dimensions of 6 cm x 6 cm. 310 denier X-static yarn was used for production of electrodes. For sewing operation JUKI DDL-5550N-3 sewing machine was used. Stitch density on the sewing machine was defined as 3 stitches/cm. For a better conductivity, conductive yarns were preferred as both needle thread and bobbin thread. Transmission cables 15 cm in lengths were used for the connection with the TENS device.

6 different electrodes with different sewing density were designed to change the quantity of yarn used. All electrodes were produced as pairs.

2.2. Testing of Samples

Resistance values of the designed electrodes were measured from the predetermined 20 points with a Thurlby 1503 Digital Multimeter.

Next, sample electrodes were connected with a TENS device and placed on the forearm of 4 subjects with velcros and tested current transmission subjectively.

In conclusion, the electrode pairs in different designs will be washed with sensitive programme in a domestic washing machine. 1, 5 and 10 repetition washing tests were planned and resistance values will be measured after each washing.

3. RESULTS AND DISCUSSION

Resistance measurement results are presented in Table 1. First results have shown that different designs give different resistance values.

Table 1. Resistance Measurement Results

Samples	Pair 1 (P1)		Pair 2 (P2)		Pair 3 (P3)		Pair 4 (P4)		Pair 5 (P5)		Pair 6 (P6)	
	P1-1	**P1-2**	**P2-1**	**P2-2**	**P3-1**	**P3-2**	**P4-1**	**P4-2**	**P5-1**	**P5-2**	**P6-1**	**P6-2**
Avg *(Ω)	0,2370	0,2325	0,3955	0,3615	0,5565	0,5795	1,7645	1,2430	2,6010	3,0480	8,8725	4,4180
SD *	0,0320	0,0313	0,0709	0,0804	0,0879	0,1080	1,7463	1,0610	2,2053	2,5684	11,2437	4,5115
CV *	0,1349	0,1345	0,1793	0,2224	0,1580	0,1864	0,9897	0,8536	0,8479	0,8426	1,2673	1,0212

*: Avg=Average, SD=Standard Deviation, CV: Coefficient of Variation.

4. CONCLUSION

When resistance measurement results were taken into consideration, it is concluded that all resistance values are quite small in comparison to commercially available electrodes. In trials with TENS device and designed electrodes on the subjects, it is noted that subjects had electrical stimulation from all designed electrodes. Also, according to these subjects' feedback there is not any discomfort feeling because of conductive yarn used in textile electrodes.

In further studies, developed electrodes are planned to integrate into a garment component for pain relief.

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FOREARM TEST FOR THERMAL SENSATIONS ARISED BY SKIN CONTACT OF ANTIBACTERIAL SWEAT PADS

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Abstract: In this study, subjective forearm test was carried out on fourteen males to investigate thermal sensations arising during skin-sweat pad contact. Sweat pads were designed for the foot and topsheet layers, constituting of polypropylene or polylactic acid nonwoven fabrics were modified by herbal antibacterial agents (cinnamaldehyde, geraniol, phenyl ethyl alcohol) directly or by using different polymerization methods. Besides subjective evaluations, some moisture absorption or transfer characteristics (Moisture Management Tester parameters, absorption time and capacity, etc.) which are affective on coolness and dampness to touch sensations were also determined. Thermal sensations arise according to the antibacterial topsheet finish and relationships between liquid absorption parameters and thermal contact sensations were obtained. According to the results, direct or polymerization based applications created significantly different coolness and dampness sensations when compared with raw PP and PLA fabrics. Significant relationships were obtained between coolness sensation and liquid spreading speed.

Keywords: foot sweat pad, forearm test, antibacterial topsheet finish, liquid transfer.

1. INTRODUCTION

Human skin is usually warmer than the clothing system surrounding it, so when there is a skin-fabric contact, the sensation of coolness arise as there is a transient heat and moisture transfer between fabric and skin. Thermal sensations result from the responses of thermoreceptors to constant temperatures and transient transfer of the heat from the skin (a cooling process) or to the skin (a warming process) [1]. Subjective forearm test is a tool to determine relationships between coolness and dampness sensations arise during fabric-skin contact and fabric characteristics.

Today, consumers prefer products that improve their life standards and hygienic absorbent products are among the materials enabling comfort and hygiene. Therefore, many scientists focus on functionalizing of these products; mainly baby diapers, feminine hygiene pads and adult incontinency pads [2]. Antibacterial treatments are one of the common applications as these products are in direct contact with skin for preventing growth of hazardous microorganisms such as bacteria and fungi during a usage period of several hours and natural-based antibacterial agents (chitosan, metallic salts, volatile oils, etc.) for disposable products [3-5]. Coolness and dampness sensations arise during first touch of an antibacterial coated topsheet layer of sweat pads has not been investigated before as far as we know.

2. MATERIAL AND METHOD

Forearm test was carried out with fourteen subjects on antibacterial modified foot sweat pads. Herbal antibacterial agents (cinnamaldehyde, geraniol, phenyl ethyl alcohol) were used directly or within a polymer for antibacterial modification of pad topsheet layers. During direct application, herbal antibacterial agents were applied directly with ethanol on polypropylene (PP) or polylactic acid (PLA) nonwoven topsheet layers having identical weights of 18.8 and 17.6 g/m^2 in turn. Solving, cationic monomer activated and photocationic polymerization methods were used for application of herbal agents within polymers (PLA or PCHO).Concentrations of the agents and polymerization parameters were optimized according to their antibacterial performances [2]. Within a national project, foot sweat pads were designed and produced in a shape suitable for feet and absorbent and topsheet layers were made of woodpulp/SAP and breathable polyethylene in turn. For the forearm test, 10x10 cm pads were produced and after conditioning under standard atmospheric conditions (20 °C, 65% RH), dry and wet (including 50% excess artificial sweat solution according to their absorption capacities) pads were contacted on forearms of the subjects for five seconds. Subjects (ages between 20 and 23 years, heights between 1.79 and 1.91 cm, and weights between 72 and 77 kg) were selected from students. Coolness, dampness and comfort evaluations were obtained for totally 14 pad samples (differing in their antibacterial topsheet modifications) in dry and wet states with five-point rating scales. The subjects were asked to make a comparative evaluation about coolness and dampness that sensation of the naked arm of the subject is accepted as “neutral” for coolness evaluation and the dry pad being in equilibrium with the environment was accepted as “dry”. Three replicates were carried out for each sample.

Besides subjective evaluations by forearm test, Moisture Management Tester (MMT) parameters, absorption time (ISO 9073-6: 2000) and capacity (ISO 11948-1) of the pads having antibacterial modified topsheets were also determined. SPSS 16.0 was used for non-parametric and parametric statistical analyses.

3. RESULTS AND DISCUSSION

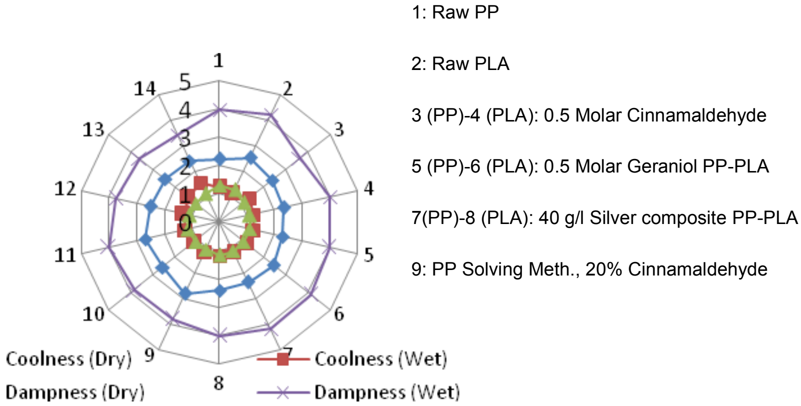

Figure 1. Subjective coolness and dampness evaluation results of the modified pads

According to the results, coolness sensation values of raw PP topsheet fabric were significantly higher than raw PLA fabric in dry form. As a general look, direct or polymer-including antibacterial applications generally gave significantly warmer sensations for PP fabric and cooler sensations for PLA fabric (which is preferable within a functional shoe) when compared with their raw forms. In wet form, PP and PLA fabrics gave identical thermal sensations in case of coolness. Contrary to the dry form, PP fabric became cooler when modified by antibacterial applications in wet form. Dampness evaluation results show that PP raw fabric gave drier feeling which is preferable. Moreover, for most of the antibacterial applications, both pads produced from PP and PLA topsheet fabrics were evaluated as drier than their raw form.

Liquid absorption and transfer results show that most of the applications did not create significant increases for liquid spreading speed and wetting time values (measured by MMT) of the pads for both PP and PLA fabrics. Absorption capacity which is crucial for a hygienic absorbent product was decreased significantly for some antibacterial applications. Significant relationships were obtained between liquid spreading speed and both coolness (-0.491*) and dampness (0.509*) sensations. Moreover, wetting time values are significantly correlated with spreading speed (-0.830*) obtained from MMT and drop test values (0.588*). Forearm test described in this study was used as a preliminary evaluation for the antibacterial modified pads before subjective wear trials within a national project. Foot sweat pads giving cooler and drier sensations are preferable by the users for a functional shoe during a certain activity. It is thought that, a disposable antibacterial sweat pad having direct contact with feet is a good solution for increased thermal comfort and to increase life period of a shoe. Good fragrances of herbal antibacterial materials are other advantages of the products.

4. CONCLUSION

It can be concluded that, hygienic absorbent materials such as baby diapers and sweat pads can be modified with herbal antibacterial materials and these applications change the thermal sensations arise during first touch and more important, dampness sensation in wet form. Most of the antibacterial applications did not deteriorate liquid absorption and transfer characteristics of the designed pads. PLA nonwoven fabric can be used as a biodegradable alternative as a topsheet for absorbent hygienic products. Antibacterial applications created cooler and drier sensations in wet form for PP fabric which is preferable for a functional shoe during a certain activity.

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SMART GLOVE DESIGN FOR DISABLED

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Abstract: Various solutions are offered by smart textiles in order to improve communication between people. Communication for disabled people is one of these distinguishing fields, where smart textiles can contribute. Communication between a “deaf and mute” person and an ordinary person can be very difficult. Besides, communication between a “deaf and mute” person with a “blind and deaf” is even much more problematic. While deaf and mute people use the sign language, blind people use the Braille writing system. The conceptual smart glove design in this study aims to create an aesthetic and useful tool to assist this communication problem by translating sign language or braille into voice, and voice into text or braille. This project differs from earlier examples of smart gloves in terms of the design of a thinner and more flexible glove with 3D printed smaller sensors. Another difference is that the glove has been designed specifically for Turkish users, where Turkish sign language and Turkish letters in braille system have been considered in the design process.

Keywords: Deaf/ mute/ blind people, smart glove, Turkish sign language, braille system

Communication for disabled people is a distinguishing field, where smart textiles can contribute. Communication between a “deaf and mute” **(DM)** person and an ordinary person can be very difficult. Besides, communication between a “deaf and mute” person with a “deaf and blind” **(DB)** is even much more problematic. While DM people use the sign language, blind people use the Braille writing system. Sign language for DM people is a system which conveys meaning by using hand gestures and orientation or body language. However, sign language is not universal; it differs from language to language [1]. On the other side, braille writing system is a tactile writing system which uses different printed combinations of six bit cells for communication. For the Turkish language, new symbols were composed in braille writing system, in order to shown the letters as ö, ü, ğ, ş, ç in the Turkish alphabet. According to data of 2012 from National Disabled Database of Turkish Ministry of Family and Social Policies, 156.573 deaf, 216.077 blind, 37.494 mute people were recorded in Turkey [2].

Considering these numbers, it is believed that developing a communication tool in Turkish language would have an important impact.

Therefore, in order to ease the communication and conversation problems between DM, DB and ordinary people and to bring them in the common communication ground, different smart glove projects or prototypes have been designed, some of which are still at research and development phase. **The Accele Glove** is an example of such gloves, which was designed as a tool to capture hand, wrist and finger gestures. It detects and transfers these gestures into text or voice by sensing through a set of accelerometers placed on the fingers and the back of the palm which report position as the vector and through the sensors placed on the phalanges on both sides of hand [3]. It then recognizes the letters which are correctly spelled by finger. The systems have also been codified for different languages. For instance, for Turkish sign language, Haberdar (2012) developed a system which recognizes 2000 signs from Turkish Sign Language by using "Accele Glove" [4].

Figure 1. Smart Glove for Deaf & Dumb

Another example is **Smart Glove for Deaf and Dumb**, which transforms finger movements into letters on an LCD and sound through the microcontroller based system. A related photo is given in Figure 1 [5]. As a local example from Turkey, **Talking Gloves** is project translating Turkish sign language into voice. These gloves are equipped with embedded sensors, which can capture hand and finger movements, and transfer them to voice through artificial intelligence algorithms [6].

Figure 2. Mobile Lorm Glove

Similar to the above given examples which were designed in order to translate sign language into text or voice or vice versa, there are also smart gloves examples for DB people.

The Mobile Lorm Glove (Fig.2) is one of them providing a mobile communication and translation for DB people. Pressure sensors were put on the palm area of the glove. These sensors provide DB users to transform Lorm alphabet into text messages by generating single letters and by sensing movements, and vice versa [7-8].

Braille Glove (2014) is another example of smart gloves helping to convert the Braille alphabet, into text and vice-versa. The sensors on the palm of the glove, transmits texts wirelessly to the receiving PC/mobile phone. Providing by small vibrating motors located on the back of the glove, tactile feedback patterns enable the user to comprehend incoming regular text messages (English) in Braille [9].

Designing a glove for the communication of disabled people is a challenging field and requires a highly developed technical background. All current examples are mostly in the research and development phase. Apart from the technical capabilities, most of the concerns are related with the practical use of these gloves in daily life and lack of design. Some of the problems in these gloves are noticed as:

-thickness,

-lack of breathability properties,

-weight,

-lack of a holistic approach to service all directions of communication in one glove

-energy source

Such factors result with discomfort to the user apart from the lack of aesthetic properties.

Keeping these problems in mind, this study suggests a design concept development of a smart glove for disabled people using Turkish language. In the suggested glove design, movement, distance between hand and body, strain and tactual information is detected, then the obtained data is defined into the system. The system analyzes the data and provides feedback as an output such as voice, text and tactile feedback by using essential devices and programs. Considering the design aspect, the smart glove is prepared as a thinner and more flexible glove. The micro sensors are created by using 3D printing technology. It is rather important to combine different technological developments for the use of alternative functions. It is seen as an added value to integrate 3D printing technology for this glove design project. With these small sensors, it is expected to provide great convenience for disabled people as the function wise, as well considering the aesthetic features. Another contribution of this glove design project is to create the opportunity to communicate in their own language and also in foreign language by the help of the translation program in the glove.

With the help of improving technology, smart gloves can become an important tool to remove the obstacles in deaf, mute and blind people's communication with ordinary people and between each other. Besides the additional technological capabilities, an important challenge will be to design a practical, comfortable and user-friendly glove for disabled. Suggested design solutions in this study consist of some complementary ideas for an aesthetic, but also a functional smart glove design.

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COMPARISON OF DIFFERENT PET DYEING METHODS WITH LIFE CYCLE ASSESSMENT

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Abstract: Fossil fuel usage, land use, deforestation and greenhouse gas emissions affect global climate change. In addition to global warming, soil pollution, water pollution, acid rains and ozone layer depletion contribute to awareness of environmental issues. Life Cycle Assessment (LCA) method is one of the important tools for determination of environmental impact. In this study, two most used method of textile dyeing were compared. Data was gathered from different production companies and evaluated by CML2 Baseline method via SimaPro. Results of the study obviously showed advantages of extrusion method according to yarn dyeing method.

Keywords: Life Cycle Assessment, Polyester, Yarn Dyeing, Dope-Dyeing, Environmental Impact

1. INTRODUCTION

Global climate change is the word which we are familiar to hear nowadays. The main reasons of climate change are fossil fuels usage, land use, deforestation and greenhouse gas emissions. Increase of the greenhouse gas emissions could have been expressly observed since industrial revolution. [1] Not only global warming but also soil, water and air pollution, acid rains and ozone layer depletion pin down to sustainable production for industry [2].

EU Environment Legislations, Montreal and Kyoto Protocols have obliged decision makers to environmentally friendly applications. Because of this reason all of the industrial branches have started to work on the sustainable production. Polyethylene terephthalate (PET) is the most wide used fiber in the world market among other synthetic fibers. Usage percentage of PET fiber is %74 within the world synthetic fiber consumption [3]. So environmental impact assessment of PET is more important than other synthetic fibers.

PET polymer basically can be dyed by two different processes. First way is dyeing at extrusion process, second way is yarn dyeing or fabric dyeing. In extrusion phase, it is no need to additional wet processing. Herewith wastewater does not occur at this process. The purpose of this study is comparing of both two dyeing methods with Life Cycle Assessment (LCA) according to some environmental impact categories.

2. MATERIAL AND METHOD

2.1. PET Dyeing Methods

Extrusion and yarn dyeing methods were compared in this study via LCA.

2.1.1. Extrusion Method

Masterbatches were included to extruder according to specified ratios for the intended color. Masterbatches contain carrier polymer and dyestuff. While melting of polymer granules and dyestuff, PET and dyestuff generates a mixture which can be used spinning of yarn directly.

2.1.2. Yarn Dyeing Method

In this method yarns were dyed in bobbin form. Yarn dyeing method more complicated than extrusion which includes some sub-processes like dyeing phase, washing, neutralization etc. Moreover drying process needed for the remove extra water and moisture from yarn.

2.2. Life Cycle Assessment

Life Cycle Assessment (LCA) is a tool for assessing environmental impact according to different impact categories. It is standardized by ISO 14040 series [4]. LCA focuses on entire life of products, processes or services. LCA method is divided some groups according to stage of the process:

1. Cradle to grave
2. Cradle to gate
3. Cradle to cradle
4. Gate to gate

Cradle to grave term expresses to LCA studies which covers the all life stages of the product or services [5]. Our processes stages were “Gate to Gate” in this LCA study. After gathering data, environmental impact calculated according to CML2 Baseline impact assessment method via SimaPro software and EcoInvent database.

3. RESULTS AND DISCUSSION

Both of methods evaluated according to ten environmental impact categories. Evaluated results showed that yarn dyeing method has more negative effects than extrusion method. These are steam consumption, waste water effluent, chemical usage and air emissions.

4. CONCLUSION

Contrary to today's needs, extrusion dyeing techniques require high production volumes; on the other hand low environmental impact provides advantage. Extrusion method can be used especially colours which are frequently preferred by customers for decreasing of environmental impact of textile industry.

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REDUCING ENVIRONMENTAL IMPACT IN AIR JET WEAVING TECHNOLOGY BY USING A HIGH VOLUME LOW PRESSURE RELAY NOZZLE CONCEPT BASED ON A METHOD TO EXPLOIT ENERGY EFFICIENCY AS CENTRAL PROPERTY IN DESIGN PHASE

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Abstract: The textile industry is an energy intensive branch of industry. Increasing energy costs and environmental impact are a challenge for textile manufacturers as well as for the developers of textile production machines. As example, air jet weaving is the most productive but also most energy consuming weaving method. Technological developments are always concerned about low energy costs, low environmental impact, high productivity and constant product quality. The high degree of energy consumption of the method can be ascribed to the high need of compressed air required by the relay nozzles during the weft insertion process. The relay nozzles of the air-jet weaving technology consume up to 80% of the air required by the weft insertion process. At ITA a new nozzle concept was developed. The developed geometry is a so called high-volume-low-pressure nozzle (HVLP nozzle), based on convergent nozzle aerodynamic theory. With this concept energy savings up to 30% are possible.

Keywords: relay nozzles, flow field interaction with reed, cfd simulation techniques, experimental validation, low manufacturing costs.

INTRODUCTION

Air jet weaving is the most productive but also the most energy consuming method in order to produce textile fabrics. The Increasing energy costs and environmental impact are still a challenging issue to be correctly defined for the manufacturers of such machines. Technological developments are always concerned about low energy costs, low environmental impact, high productivity and constant product quality. The high degree of energy consumption of the method can be ascribed to the high need of compressed air.

METHOD

Energy efficiency is taken as central property in the design process and it represents a new requirement/property to be defined in the phase of design problem/task definition. In contradiction with established methodologies, the approach includes an initial analysis of existing technical systems and the individuation and classification of their prior and relevant energy consumers (sub-systems and processes). The identified major consumers are afterwards systematically addressed to reduce their energy consumption: several options and solutions – the system characteristics – are determined and considered, starting with the complete elimination of the energy usage and ending with the option of recovering energy. A following step of analysis consists of the verification of the system design, predicting and evaluating the system behavior using several tools such as FEM analysis, CFD simulation models and experimental analyses. The design process provides one or more solutions if the accounted properties are met by the defined characteristics. A systematic approach for the development of energy efficiency machine tools, proposed by Neugebauer (Ref. 1), provides general concepts that can be applied to other type of industrial machinery and could be taken as reference in the possible definition of methodologies for the energy efficiency design of specific machines. This approach is based on the property-driven design methodology by Weber (Ref. 2), that defines the design process as a process which has to reach given properties (i.e. requirements) by defining characteristics to ensure this properties (e.g. geometries or materials). Since nowadays products become more and more multi-disciplinary by the constantly increasing integration of added functionality and product intelligence and since energy is a global design attribute which is influenced by all disciplines, the development of energy analysis methodologies, both numerical and experimental, requires an integrated research strategy. In the effort of reducing the ecological footprint of air jet weaving production process, effective and efficient analysis techniques and adequate measurement technologies are required to produce world leading products with a high energy-efficiency, without compromising functionality, safety and performance. This demand is not only driven by social awareness, but also by economic reasons, such as rising energy price. Combined with the increasing trend towards virtual design and prototyping, to reduce total cost of ownership and development times, the prerequisite for designing ‘green’ products creates an urgent industrial need for robust and volatile simulation and experimental validation methodologies in the analysis of the weft insertion process of air jet weaving technology. Therefore, differently from conventional approaches unable to identify energy potentials at early stage, this novel method combines energy efficiency, considered as a central requirement already in the design phase, with the state of the art finite element analysis and computational fluid dynamic techniques and CAE modeling which in the end led to a remarkable improvement of the environmental and holistic performance of machine itself. While designing their products, manufacturers will have to respect predefined measures, which aim to reduce the environmental impact of products throughout the whole product lifecycle (such as production, use and disposal). It must be noted that in general, energetic efficiency depends on how a machine is made ("design") and how it is used ("management"). These two aspects cannot be fully separated and a designer must take into account how the machine will be used and what will be the associated total cost of ownership and environmental impact. Therefore in next air jet weaving machine generations, by means of applying this energy efficiency approach already during the design phase, the ecological footprint is reduced without losing performance. This means that manufacturers will have to start taking energy efficiency features into account during the design cycle. In other words, the design process should move from a purely performance and capacity driven approach to an approach that includes energy efficiency as a key parameter. By combining the approach focused on energy efficiency with next-generation of FEM, CFD, CAE tools, the solution of the majority of problems will be shifted from the production and pre-production phases to the detailed design phase at the very least, representing a strong impact up for economic issues and entrepreneurial decisions. Such a new design paradigm is expected to lead to substantial energy savings during the products' lifecycles and to reduce total costs of ownership of the air jet weaving machines.

RESULTS AND OUTLOOK

In air-jet weaving, the largest share of energy consumption can be allocated to the pneumatic components. The relay nozzles as well as their valves cause the major share of energetic inefficiencies within the pneumatic system. In this context, a novel relay nozzle concept is the most promising measure to significantly improve energy efficiency of air-jet weaving. A novel nozzle concept has been introduced which provides similar driving force on the yarn at a reduced level of pressure. Different nozzle prototypes have been characterised on a weaving machine which enables higher mass flow rate values at a lower inlet pressure coming from the compressors. The combination of the preferred relay nozzle type is leading to an energy saving of 45% in comparison with current industry configurations.

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PLANT BAG DESIGNS FROM BIODEGREDABLE POLYMERS FOR BETTER BREEDING PERFORMANCE AND OPTIMUM USE OF AGRICULTURAL NUTRIENTS

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Abstract: In this study, plant bags consisting of a composite structure made of polylactic acid or cellulose and zeolite layers which are completely biodegredable, were used for controlled experimental plant growth groups to investigate their effects on breeding performance of a selected plant. Existing plant bags used in agriculture are usually produced form synthetic polymers which have disadvantages about environment and labor loss. Zeolite coated biodegradable plant bags were produced in tube form and under standart fertilization and irrigation conditions, pepper plants were cultivated within the structure under the same conditions for three months. Besides plant length and weight comparisons of the plants grown with and without bags, soil mineral analyses were also carried out to determine filtration efficiency of the bag structures for optimum use of agricultural nutrients. According to the results, water and mineral retention capacities were better for the groups including zeolite coated biodegredable plant bags.

Keywords: Agrotextiles, biodegradable polymer, plant bag, breeding performance.

1. INTRODUCTION

In agricultural applications, continuous agricultural processes in soil cause an accelerated reduction of organic and inorganic nutrients and decrease in plant growth performance is observed accordingly. Besides, great quantity of water usage causes cooling of soil, air decrease in roots and deterioration of roots by harmful microorganisms. Nonwoven structures are useful tools for drainage applications [1]. Agrotextiles enable efficient use of food supplements and water from ground, protection of plant growth and soil quality performance [2]. Zeolite is a soil conditioner improving required properties of soil and ensuring continuity [3]. Yakupoğlu et al (2010), determined that soil regulators improved the physical conditions of soil, increased the amount of organic substances and the scope of plant micro-elements [4]. Mulching covers, plant protection covers, wind, wild plant and insect barriers can be given as examples of agrotextiles [5]. Agrotextile applications from biodegradable polymers such as agricultural product packaging, accelerating plant breeding, UV ray protection, weed growth prevention, drainage and erosion control etc. has recently take great attention [6].

2. MATERIAL AND METHOD

This study investigates effects of plant bags made of zeolite coated/uncoated biodegradable nonwoven fabrics on breeding performance and optimum use of water and agricultural nutrients of pepper plant. Nonwoven fabrics made of viscose (CV) and polylactic acid (PLA) have identical weights of 40 g/m^2. Soil groups were prepared with three replicates for the growth of identical pepper plants. Codes of the groups were shown in Table 1.

Table 1. Codes of the experimental soil groups

Codes	**Fabric**	**Soil**	**Zeolite size** (µm)
1	-	Pure	-
2	-	Mixed with zeolite	100
3	Polylactic Acid (PLA)	Pure	-
4	Zeolite coated PLA	Pure	100
5	Viscose (CV)	Pure	-
6	Zeolite coated CV	Pure	100

Field capacity of the prepared soil groups were determined before planting to create irrigation programs. Field capacity is the amount of water which soil keeps against gravity after becoming saturated with water [7]. 50/50% zeolite/water mixtures were prepared and plant bag inner surfaces were coated with a certain amount of mixture arranged according to the soil weight (25 g zeolite per 1 kg soil). Plant bags were in cylindrical form having diameters and heights of 13 cm that can include 2 kg soil (Groups having codes of 4 and 6). Effects of PLA and CV fabrics on growing performances of plants were also evaluated. Control groups (1 and 2) were prepared with pure soil and zeolite/soil mixture (25 g per 1 kg soil). Plant fertilizers consisting of nitrogen, phosphor and potassium were prepared as solutions and they were given to the experimental groups according to a certain protocol.

Excess water is given to the plant bags and filtrated water solutions were analyzed after 6th and 12th weeks for to determine mineral retention capacities of the plant bags. Mineral analyses enable to determine the long-term effect of fertilizers used in plant on the breeding performances. Mineral analyses were also conducted on dry plant stems in the final form. Length measurements were conducted after 6th and 12th weeks on pepper plants which had identical heights at the beginning. Moreover, dry and alive weights of pepper plants were also determined after 12th week to have an idea about breeding performances.

3. RESULTS AND DISCUSSION

Results revealed that both zeolite applied nonwoven bags and bags without zeolite coating are capable to protect nutrient loss via drainage water. This effect was higher in the group including nonwoven fabric coated with zeolite. All treatments reduced micronutrient as well as macronutrient leaching. Nitrate that has negative effects due to its negative charged ions was also filtrated by the treatments. Therefore, biodegradable nonwoven bags may be used for protecting nitrate pollution of ground waters as well as sustaining plant nutrition. Plant lengths were measured throughout the experiment and length results also represent the beneficial effect of applications. The highest plant height recorded was the one including zeolite coated nonwoven fabrics, followed by bags without zeolite and soil/zeolite mixture without bag respectively. Although they are not evaluated quantitatively, denser root systems were observed phenologicaly in groups including nonwoven bags.

4. CONCLUSION

In this study, plant bags made of PLA and CV including zeolite as a coating or soil component had positive effects on breeding performances of pepper plants having identical physical properties. They increased nutrient leaching of the plant and prevented the nitrate pollution of the soil. Soil groups including nonwoven fabric bags also had better breeding performances. There is another advantage about using biodegradable nonwoven plant bags that there is no need to remove the textile structures from soil which decreases labor need. Summing up, besides positive effects of biodegradable nonwoven plant bags on breeding performance of plants and soil pollution, they also have ecological and economical advantages when compared to synthetic polymers.

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FABRICS MODELLING: 100 YEARS CONTINUOUS AND EXCITING EVOLUTION

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Abstract: Textile mechanics and especially the modelling of the fabrics started about 100 years ago mainly because of the needs of the technical applications of the textile materials. The stern requirements of the technical applications has driven the understanding of the importance of the prediction of the performance during the design phase. Various models have been proposed with different approach and precision approaching more and more the reality. In the current research work the originality of the existing models of woven fabrics is being discussed and the experimental work offers a thorough approach and evaluation of the modelling parameters. The variation of the modelling parameters and the variation of the structural data of the woven fabrics are finally correlated for the better prediction of the related mechanical behaviour.

Keywords: Textile mechanics, woven fabrics modelling, experimental analysis

1. INTRODUCTION

Some very important problems which occurred in the aviation field inspired and obliged early researchers to work in the field of the textile mechanics which was based on the mechanical modelling mainly of the woven fabrics. The mechanical modelling is directly based on the respective geometrical representation of the woven fabrics. Although the geometrical representation in the other engineering fields is more or less a trivial problem, the geometrical representation of the textile fabrics is extremely difficult because of the complexity of their structure and the compressibility appearing in general or on a local basis. However the importance of the textile mechanics and modelling is obviously very high [1], [2].

2. EXISTING MODELS

The early geometrical and mechanical models are characterised by the big number of assumptions such as circular cross sections of the yarns or the absolute and ideal elastic behaviour of the materials of the yarns. The non-realistic assumptions have simplified the computational load, however the remaining calculations were extremely complex, in such an extend that even today the arithmetic operations are very hard to be performed [3], [4].

The following models increased the representation precision by decreasing the simplification assumptions, however the computational complexity has been increased [5], [6], [7]. A sudden change happened in the last steps of the modelling evolution, by a very radical simplification of the representation of the woven fabrics [8]. It was based mainly on the assessment of the errors because of the complex calculations and the errors because of the simplification of the geometrical representation.

3. EXPERIMENTAL PART

Thirty different woven fabrics with parametric structural data have been used for the measurement of the cross sectional characteristics [9]. The cross section of the fabrics has been observed using an optical microscopy camera. The digital images derived have been used for the image analysis stage and the measurements using typical techniques.

An excessive number of measurements on the microstructure of the fabrics in both warp and weft directions has been used for the subsequent statistical analysis and finally to the statistical acceptance of the results.

4. CONCLUSIONS

The experimental results obtained show a characteristic trend which is in accordance to the expected values from the respective theoretical models and moreover to physical behaviour of properties related to the microstructure of the woven fabrics.

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NEW WASHING PRINCIPLE TO INCREASE WASHING PERFORMANCE OF WET-SPINNING WITH WATER NOZZLES

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Abstract: The wet-spinning process is very important for the production of new lightweight design materials. Therefore, the process of creating fibers with the wet-spinning method is analyzed and the washing process is determined as the most cost-expensive part. To overcome this deficiency a new washing concept is developed based on knowledge of existing washing concepts, which should have a more swirled flow than conventional methods for improving the washing performance. For this purpose, the washing concepts of conventional washing bath and washing channel are investigated by means of simulation and experiments to obtain process knowledge of these existing concepts. Based on this series a new concept for washing the fibers with the usage of nozzles is developed.

Keywords: wet-spinning, washing principles, particle image velocimetry, computational fluid dynamics

1. INTRODUCTION

Even though most of man-made fibers are melt-spun, the wet spinning process has gain a lot of influence during the last years. This is particularly due to its usage in high performance composite applications. More than 90% of carbon fibers are made from wet-spun PAN-precursors, because of the high homogeneity and circularity of the cross section. Typical products of the wet-spinning process are monofilaments from polyacrylonitrile (PAN), Multifilaments (PAN, Aramid, cellulose, elastane) and hollow fibers for special purposes like filtration. Worldwide ca. 17% of man-made fibers are wet-spun and this rate is increasing [1].

2. MATERIALS AND METHODS

The wet-spinning process consists of the four steps:

- Preparation of the spinning dope
- Solidifying of the fiber in the coagulation bath
- Washing out the solvent and drawing the fiber to increase its strength
- Drying and winding up the fiber

The preparation of the spinning dope is the first step and has a big influence on the quality of the fiber. The spinning dope consists usually of 20 – 30 % of polymer and 70 – 80 % solvent. To create high quality fibers additives and comonomeres are also added into the polymer during polymerization. Typical solvents used for solving PAN are dimethylformamide (DMF), dimethylacetamide (DMAC) and sodiumthiocyanate (NaSCN).

The solution is transported by a spinning pump with a defined mass flow into a spinneret. In the wet-spinning process the number of holes in the spinneret is typically only a few hundred, whereas this number is much higher in melt spinning (approx. 1000). In the conventional wet-spinning the spinneret is completely submerged in the coagulation bath, however, in the air-gap wet-spinning the spinneret is located just above the surface. With this small air-gap the spinning velocities can be increased up to ca. 100 m/min, whereas in the conventional the speed is limited due to the high water resistance.

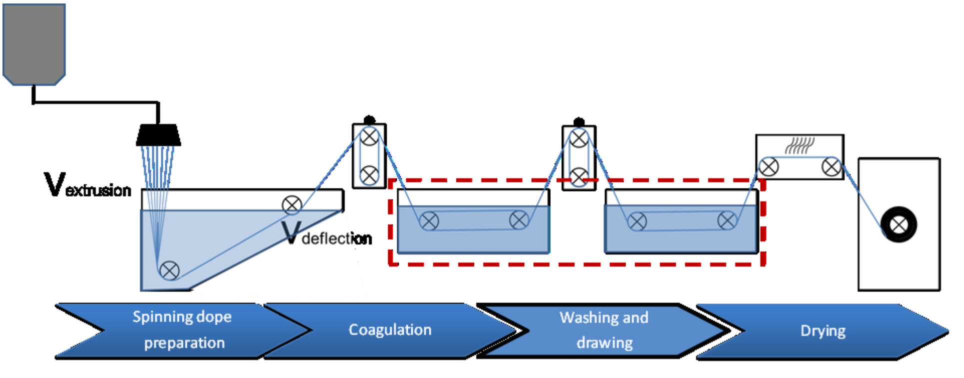

Figure 1. Wet-spinning process (from spinning dope to drying and winding up)

3. WASHING BATH

After the fiber structure is built in the coagulation bath the remaining solvent has to be removed. This is done in the washing baths. Because of the high water usage, this process is the most expensive in the wet-spinning process chain. To reduce the amount of water used to wash out the solvent of the fiber the water in the washing bath flows in the reversing direction.

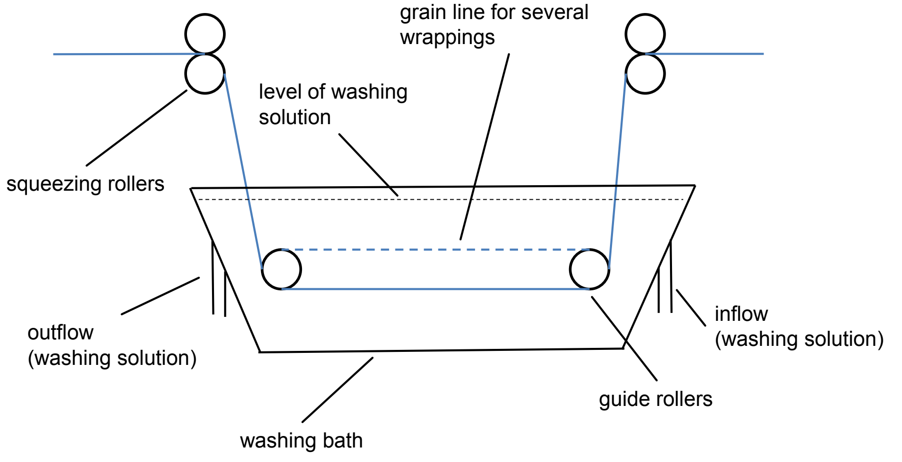

Figure 2. Main elements of a washing bath

Usually more than one washing bath is necessary to reduce the amount of the solvent to the desired levels. In every washing bath the amount of solvent is reduced more. Between every washing bath squeezing rollers are used to prevent the solver-water mixture to be taken into the next bath. The fiber in the washing bath is wrapped several times over guiding rollers to increase the washing performance.

The washing bath bears a high deal of optimizing potential. There are several concepts which have been developed during the last decades to improve the washing performance. However, most of them are complicated to apply, only useful for special application or just not efficient enough [2].

4. CONCLUSION

Therefore, a new washing method is investigated, which is easy to apply, cheap and efficient. The final solution will be able to attach to existing washing baths and increase their washing performance by using specially arranged water nozzles. The design and orientation of the nozzles is currently under development. For this the flow in the washing bath is analyzed by measuring methods like particle image velocimetry (PIV) and with numerical methods like computational fluid dynamics (CFD). With this approach it is easily possible to consider a lot of different variations of the number, orientation and position of the nozzles. The variations are then validated and the best design of the new washing concept is chosen. Thus, it will be possible to increase the washing performance of the washing bath with a new concept, which leads to cheaper and more efficient wet-spun fibers.

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CONVERSE PIEZOELECTRIC EFFECT ON PZT MEMBRANE

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Abstract: One of the main interests of current research is energy harvesting which consists of the collection and use of wasted energy from the surrounding environment. The piezoelectric phenomenon is the easiest and most accurate method for accumulating electrical energy from mechanical energy. This paper studies the converse piezoelectric effect where electrical energy is converted to mechanical energy. Experiments were conducted on the PZT film to compare and contrast the effects of the Sign and Triangle waveform on the displacement of the film and to find the resonant frequency, the frequency where the conversion efficiency from electrical energy to mechanical energy provides a maximum displacement.

Keywords: energy harvesting, converse piezoelectric, resonant frequency

1. INTRODUCTION

The phenomenon of piezoelectricity can be exploited as one direct method of energy harvesting, (no need for battery and so forth). The piezoelectric phenomenon was discovered by the Curie brothers in 1880, proving that mechanical energy can be converted to electrical energy using Quartz and Rochelle salt crystals. The converse piezoelectric effect was mathematically proven by Gabriel Lippman in 1881 and further proven by the Curies.[1]

Piezoelectricity is the easiest of the three basic vibration to electronic conversion methods of energy harvesting, the other two being electromagnetic and electrostatic. The advantage of the piezoelectric phenomenon is its large power density, easy application due to its application at macro and micro scale and is the only method which does not require any external sources. The output voltage is created directly from the membrane or a direct mechanical displacement is produced by supplying the piezoelectric membrane an electric field [2].

Piezoelectric materials are considered smart materials, in which two or more functions can be performed by a single material. A piezoelectric transducer operates as a sensor, converting mechanical energy to electrical energy, and as an actuator, converting electrical energy to mechanical energy. Piezoelectric transducers are divided into two subgroups, materials with perovskite structures and polymers, PZT and PVDF respectively being the most common. Comparing PZT with PVDF crystals, the former although it possesses a high dielectric constant it is brittle with low endurance, whilst PVDF is flexible and has a low production cost it possesses a low dielectric constant.[3]

The piezoelectric phenomenon has assisted in many fields, such as medicine and acoustics. With the development of small piezoelectric transducers, clothing or accessories have been embedded with sensors and actuators to collect electrical energy from human activities, such as motion or breathing.[4] The main area of study now is based on the fabrication of piezoelectric textiles, fibres and fabrics. Piezoelectric textiles can widely be applied to clothing and upholstery, from cars to airplanes.

This paper studies the converse piezoelectric phenomenon of a single layered PZT film in a monomorph setup, focusing on the effect of the form of the electrical signal that is sent to the PZT film. Sending the electrical signal, the mechanical energy in the form of displacement is recorded and analysed.

2. MATERIAL AND METHOD

A ceramic film (PZT) was connected to the Power Function Generator PFG605, where the Sign Waveform and Square Waveform were analysed along with the frequency. The maximum voltage output was set at 100Vpp.

3. RESULTS AND DISCUSSION

Throughout the experiment it was observed that the sign and square waveform produced different displacements. The square waveform produced a displacement acting as a direct impact factor.

A similar effect from the film was observed at 15Hz, where the Sign and Square Waveform produced a large displacement of 4mm and 5mm respectively. When the range of the frequency was set at 10, the Sign Waveform produced a minute and steady displacement of 1mm over the frequency values of 1Hz to 10.25Hz. Contrary to the Sign waveform, the Square Waveform again produced a large displacement of 4mm at 4.5Hz and 4.75Hz.

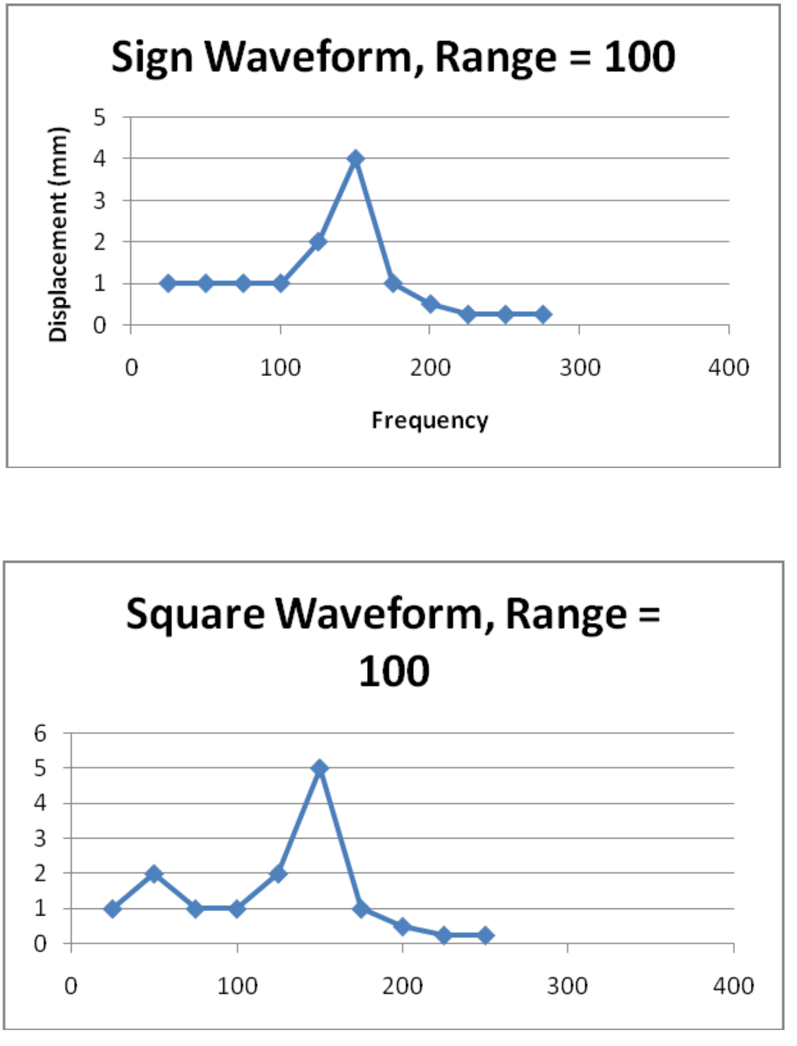

Figure 1. Typical examples of the piezoelectric material displacement: a. Sign Waveform, maximum displacement 15Hz, b. Square Waveform, maximum displacement 15Hz,

4. CONCLUSION

It can be concluded that event though at 15Hz, the sign waveform signal and square waveform signal produce a large displacement, this similarity does not appear for other frequencies. Setting the range to 10, the sign waveform does not appear to produce a large displacement as does the square waveform. From this observation is can be stated that for the square waveform a resonant frequency exists. Further studies will be conducted on other membranes noting that the Square Waveform produces the best piezoelectric effect on the PZT membrane.

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APPLICATION OF BORIC ACID ON WOOL AND WOOL/POLYESTER FABRICS FOR STRENGTH AND FLAME RETARDANCY FUNCTIONALIZATION

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Abstract: This research aims to enhance the tensile strength and flame retardancy properties of wool and wool/polyester blended fabrics by using boric acid. Two different cross-linkers were also used to enhance the adsorption of boric acid on the fabric surface. The wool and wool/polyester fabrics were chosen because of a steady increase in the demand for wool and polyester technical textile apparel. Tensile tests, flame retardancy, air permeability and colour value measurements were used to investigate the effects of the treatment. The fabric surfaces were also observed by Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR-ATR). According to the all test results, it can be concluded that boric acid is an excellent agent for improving the tensile strength and flame retardancy properties of fabrics.

Keywords: boric acid, wool, polyester, flame retardancy, tensile strength

1. INTRODUCTION

Turkey is one of the richest countries of the world in terms of boron compounds reserves. Turkey has roughly a 72 % part of the total boron deposit of the world at 803 million tones. These boron reserves are great in tenor and quality [1]. Wool fibre is increasingly being used in technical applications in which its unique properties and the opportunities for specific enhancements can be profitably utilized. Although the uses of wool fibre in technical applications have been more limited, owing to cost [2-3]. Polyester fibre has good mechanical properties, thermal stability and has a low production cost [4]. One of the main goals is to use wool/polyester blended fabrics to exploit the advantages of both of the fibers. This study contributes comprehensive knowledge of the literature about the possibilities of using boric acid in the finishing process for the functional properties of textiles.

2. MATERIAL AND METHOD

2.1. Material

The fabric was supplied by the Yünsa Textile Company (Turkey). The characteristic of the wool fabric were as follows: woven, 150 g/m². The warp and weft yarns density of these fabrics were 24 and 21 threads per cm, respectively. The characteristic of the blend fabric were as follows: woven, 160 g/m². The warp and weft yarns density of these fabrics were 30 and 36 threads per cm, respectively. Boric acid (BA) was purchased from ETI Mine. The fabric samples were washed by nonionic washing agents with laboratory type washing machine at 30 °C for 1 hour and then dried in air. Nano Polyurethane (Baypret Nano PU, particle size <100 nm) anionic dispersion was purchased from Tanatex Chemicals. N-methylolacrylamide (MEAA, Heraprint Mnr) was purchased from NF Chemical.

2.2. Finishing Process

Aqueous solutions of boric acid were impregnated on the wool and wool/polyester fabrics by using a laboratory-type padding machine. Nano polyurethane and n-methylolacrylamide were used as cross-linkers. The receipts that used were shown in Table 1 and pH values were adjusted to 5.5 using HCl. After impregnation process fabrics were at 80 °C for 4 minutes and cured at 150 °C for 5 minutes.

Table 1. Receipt contents of finishing solutions (%w/w)

Receipt ID	BA:Nano PU	Receipt ID	BA:MEAA
1	10:30	7	10:10
2	10:40	8	10:20
3	20:30	9	15:10
4	20:40	10	15:20
5	50:40	11	50:20
6	-:40	12	-:20

2.3. Characterization Methods

The determination of flame retardancy of the samples was performed by using 45° inclined flame retardant BV AFC Auto test İnstrument referenced by ASTM D1230-94 (2001). The tensile properties of the fabrics were performed on a Lloyd LR5K Plus electronic tensile strength machine according to TS EN ISO 13934-1. The air permeability test was done on Textest FX 3300 air permeability test instrument according to test method of TS 391 EN ISO 9237. A X-rite sp68 spectrophotometer was used to obtain the colour values (whiteness and yellowness values).

3. RESULTS AND DISCUSSION

Untreated and treated fabric tensile strength and flame retardancy tests were performed. The tensile strength test and flame retardancy test results clearly demonstrate that higher boric acid mass with the increase in high amounts leads to high values. The presence of boric acid in the fabric after treatment is verified with SEM analysis. FTIR spectrometer was used to obtain the infrared spectra of surfaces using an ATR sampler.

3.1. Flame Retardancy Results

To determine flame retardant properties of samples, the flame is applied to the fabrics for 2 seconds, according to the ASTM D1230-94 (2001). But this time is poorly for the tested samples, so the flame was used for 5 seconds. We record that untreated % 100 wool fabric was burned in 15.1 seconds and untreated Wool/Polyester fabric was burned 20.2 seconds. End of measurement there was not any burn in all treated fabrics. The flammability behaviors of optimum recipes were evaluated also using the limit oxygen index (LOI) method.

3.2. Tensile Strength Results

The tensile tests were performed on a Lloyd LR5K Plus electronic tensile strength machine according to TS EN ISO 13934-1. Fabrics were kept for 24 h at ambient conditions (20 °C and 65 % RH) before the tensile test.

Table 2. Tensile strength results

Sample ID	Tensile strength (warp,N)	Difference (%)	Tensile strength (weft,N)	Difference (%)	Sample ID	Tensile strength (warp,N)	Difference (%)	Tensile strength (weft,N)	Difference (%)
(Wool)					(45/55 Wool/Polyester)				
Untreated	312	-	189,3		Untreated	473,3	-	514	
1	339,3	8,8	198,1	4,6	1	482,3	1,9	526,4	2,4
2	342,4	9,7	201,1	6,2	2	515,2	8,9	533,8	3,8
3	346,2	11	203,5	7,5	3	517	9,2	532,8	3,6
4	347,2	11,3	205,2	8,4	4	523	10,5	545,9	6,2
5	362	16	214,7	13,4	5	534	12,8	553,9	7,8
6	315,4	1,1	190,9	0,8	6	490,6	3,6	517,3	0,6
7	313,1	0,4	196,5	3,8	7	501,9	6	538	4,7
8	317,2	1,6	200,5	5,9	8	503,8	6,4	550	7
9	329	5,4	208	9,9	9	506,8	7,1	551,5	7,3
10	333,7	7	209,7	10,7	10	511,6	8,1	552,3	7,5
11	358,4	14,9	221,6	17,1	11	519,8	8,9	572,4	11,4
12	312,9	0,3	191,2	1	12	483,6	2,2	519,3	1

Tensile strengths of fabric samples are shown in Table 2. It is observed that if boric acid and cross-linkers amount is increased, tensile strength both warp and weft direction will increase.

4. CONCLUSION

During this investigation, the effects of boric acid treatment of wool and wool/polyester blended fabrics were investigated. Using boric acid in finishing solutions, weft and warp direction tensile strength values were increased. The experimental results showed that boric acid may have efficient material for technical textile applications.

ACKNOWLEDGEMENTS

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DEVELOPMENT OF SYNTHETIC FILTER MEDIA BASED ON SUBMICRONIC FIBERS VIA ISLAND-IN-THE-SEA SPUNBOND PROCESS WITH HYDRO-FRACTURATION

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Abstract: The development of spunbond bicomponent island-in-the-sea (I/S) fibers with fracturation and fibrillation by high-pressure water jets is here presented as an alternative way (water and solvent free) to produce synthetic filtration media with submicron fibers at high production capacity. This study relates the key factors for the development of such filter media and show first filtration results. SEM images are used to observe the quality of the fibrous structure, the fiber cross section as well as the fracturation quality. BET measurements are used to estimate the specific surface area in order to quantify the fracturation rate of I/S fibers. The processing and the potential of such fibrous structures are presented and discussed.

Keywords: filtration, synthetic media, submicron fiber, island-in-the-sea fiber, spunbond nonwovens

1. INTRODUCTION

Nonwoven fibrous structures are widely used in filtration. For producing nonwoven media with submicron fibers, the initial way was the wetlaid technology by using glass fibers in blend with cellulosic fibers. However with the recent development of nanotechnology, new processes are able to create submicron synthetic fiber media [1]. The media produced with drylaid and spunlaid processes based on man-made polymers are called synthetic media. The combination of such processes can lead to a large range of structures with much lower fiber volume fraction (or packing density), also less sensitive to humidity compared to glass fiber-based structures obtained with the wetlaid technology. The three main technologies that could perform submicronic fiber-based structures are the electrospinning, the nano-meltblown, and the bicomponent I/S spunbond technologies [1-2]. The electrospinning technique is now commonly experimented for filtration media. This technique is particularly efficient for producing submicronic even nanometric fibers with a large range of polymers. Nevertheless the production rate is very low and the web is rather fragile and needs a substrate to be collected [1].

In this work, instead of using bicomponent I/S fibers associated to a dissolution process for eliminating the sea part, a mechanical process is chosen (hydroentanglement with high-pressure water jets) in order to fracture or break the sea part and then liberate submicronic islands in the web. This method presents several advantages: high production capacity, high web strength, solvent free, and no additional operation for dissolution [2]. In literature, there are only few studies on bicomponent I/S fibers with fracturation by hydroentanglement and even less for filtration purpose [2-3].

In filtration, one of the main objectives is to have the best efficiency for the smallest pressure drop. According to several studies [4-5], a solution can be the utilization of submicron fibers for fibrous media. These studies reported that the use of submicron fibers increase the quality factor, i.e. the ratio between efficiency and pressure drop. Indeed, a lower pressure drop results from the modification of the air flow due to submicron fibers generating a slip flow effect [5].

In this study, some filter media based on bicomponent I/S fibers spunbond and fractured by hydroentanglement to create submicron fibers are developed, characterized and discussed, also in comparison with the work of Yeom and Pourdeyhimi [3]. The island/sea polymer association (PA6/PE or PE/PA6), the initial filament fineness, the web basis weight and the fracturation quality related to water jet configuration is here specifically investigated.

2. MATERIAL AND METHOD

2.1 Formation of bicomponent island-in-the-sea filaments by spunbond process

A 500 mm width bicomponent spunbond process from Hills Inc. was performed for the formation of the nonwoven web at the CETI (Center of European Textiles Intelligence). The selected die block assembly for all experiments provides 37 islands-in-the-sea circular cross section shape filaments. Various nonwoven basis weights were tested from 30 to 150 gsm. The two selected polymers are: a polyamide 6 (PA6) (Ref.: Radici Radillon S 24E 100NAT) and a linear low-density polyethylene (LLDPE or PE) (Ref.: Dow chemical ASPUN 6834). Three different island/sea ratios are experimented: 25/75 (cf. figure 1a), 50/50 and 75/25.

In order to get the thinnest islands, there are three possibilities: decreasing the island-in-the-sea fiber diameter, increasing the number of islands or decreasing the island/sea polymer ratio. Our investigations have shown some results with a fiber diameter of about 10 µm with 37 islands and a 50/50 island/sea ratio, which theoretically leads to a final diameter of the islands close to 0.82 µm.

2.2 Fracturation by hydroentanglement process

The hydroentanglement process is used in order to simultaneously consolidate the nonwoven webs by entangling the filaments and fracture the island-in-the-sea filaments. A 500 mm width Andritz Perfojet hydroentanglement process is performed with one manifold (injectors) for pre-wetting, one manifold for pre-bonding and 4 manifolds for bonding/fracturing/fibrillating distributed on two cylinders. In this study were experimented various process configurations: number and pressure of injectors, strips with different nozzle diameters, etc.

2.3 Characterization of the nonwoven fibrous structures

The cross sections of the island-in-the-sea filaments are observed by a SEM and an optical microscope combined with a microtome. The fracturation is observed qualitatively by SEM and estimated via the measurement of the specific surface area using BET method. Two fracturation qualities are illustrated in figures 1b and 1c. Mechanical and filtration properties are also investigated. The filtration properties are given using an air filtration test bench with a Palas optical particle counter (Welas 2100), generation of 0.2 to 1 µm NaCl solid particles at different face air velocities.

3. RESULTS AND DISCUSSION

The study of the formation of island-in-the-sea fibers shows that the throughput of polymers and the temperature of each polymer in the die are crucial to obtain a correct shape section of island-in-the-sea. In some conditions, the islands merge or the distribution of the islands is not uniform. The quality of the shape section is in relation with the apparent viscosity of both polymers.

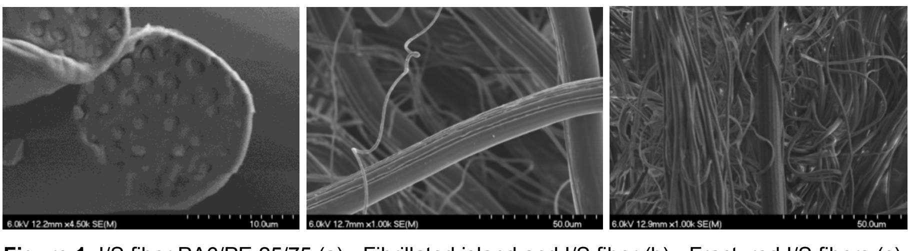

Figure 1. I/S fiber PA6/PE 25/75 (a) - Fibrillated island and I/S fiber (b) - Fractured I/S fibers (c).

The study of the fracturation of island-in-the-sea shows that the quantity of sea polymer, the pressure of injector, the number of operating injectors, the nozzle diameter of strips are key factors to create fracturation, in accordance with the initial filament diameter. Moreover this study shows the influence the fracturation rate and final filament organization on the filtration properties including permeability.

4. CONCLUSION

This study is the first step for the development of synthetic filter media with submicronic fibers based on bicomponent island-in-the-sea spunbond with hydro-fracturation. The objective is to provide a better understanding on the process conditions during the formation and the fracturation of the I/S filaments for meeting required specifications of filtration media.

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CARBON FIBRE REINFORCED POLYMERS USED TO RETROFIT RC STRUCTURES

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Abstract: The infill walls used in reinforced concrete (RC) structures have beneficial effects to overall behavior in terms of stiffness, strength and energy dissipation in the event of seismic actions. The rationale of this study is to determine the effectiveness of the carbon fiber reinforced polymer (CFRP)-based retrofitting technique so that intact infill walls of RC buildings are transformed into a lateral load resisting system. Most of the vulnerable mid-rise existing structures in Turkey are lack-off both engineering process and construction quality. In order to determine the effectiveness of the CFRP material, several 1/3-scaled RC frames were built and tested in Structural and Earthquake Engineering Laboratory of Istanbul Technical University (ITU) as bare and infilled control frames, and as cross-braced and cross diamond-braced retrofitted specimens. Accordingly, it was concluded that the cross diamond-bracing scheme is an effective retrofitting technique on increasing the energy dissipation capacity of the structures.

Keywords: CFRP retrofitting, infill Wall, infilled Frame, stifness, strength

1. INTRODUCTION

Past earthquakes and researches demonstrated that the masonry infill walls have many advantages in the improvement of energy dissipation as well as increase of stiffness and strength properties of the structure. Several experimental researches conducted on infilled RC frames also showed a significant improvement in the overall behavior. Shake table tests on infilled RC frames performed by Hashemi [1] resulted that the infill walls increased the structural stiffness by nearly 4 times, shortened natural period by nearly 50% and increased the damping coefficient from 4-6% to 12%. In many existing RC buildings, especially those designed and built before the contemporary earthquake codes, there is a lack of seismic detailing in structural load carrying system and structural members coupled with low material quality and workmanship [2]. In Turkey the low-rise building profile with infilled RC frames are both lack-off engineering process and construction quality. The most important point is that these kinds of buildings are not built according to the current design codes and standards. Some of these structures will need to be replaced since they are in such bad condition. But instead of re-building, at this point an innovative material called Carbon Fiber Reinforced Polymers (CFRP) has proven by many academical studies to be an effective material for strengthening of (reinforced) concrete structures, due to its low weight (easy to apply), non-corrosiveness and high strength. Direct observation of damaged structures, following the Kocaeli, Turkey 1999 earthquake, has shown that damage occurs usually at the beam-column joints, but some of them are not collapsed due to the fact that they include infill walls in it. These behaviors of the infilled RC structures were observed soon after the earthquakes. Infill walls in RC frames are essential stiffness, strength and damping sources as well as energy dissipation capacities to the overall structural behavior. Improvement of structural earthquake performance of the infilled RC frames by using Carbon Fiber Reinforced Polymers is a reasonable application area due to the fact that it is easily applied on the infill walls without disturbing the occupants inside the buildings.

In order to investigate the beneficial effects of Carbon Fiber Reinforced Polymers on the seismic response of infilled reinforced concrete (RC) frames a comprehensive experimental schedule has been carried out in Structural and Earthquake Engineering Laboratory of Istanbul Technical University. Numerous experiments both quasi-static and pseudo-dynamic tests were conducted on the 1/3 scaled retrofitted infilled RC frames. The present study investigates the suitability and effectiveness of carbon fiber-reinforced polymers (CFRP) in strengthening and/or repairing of infill walls in reinforced concrete frames which are subjected to in-plane seismic/cyclic loading. For this purpose, a detailed experimental program was conducted. The test set-up can be seen in Fig.1

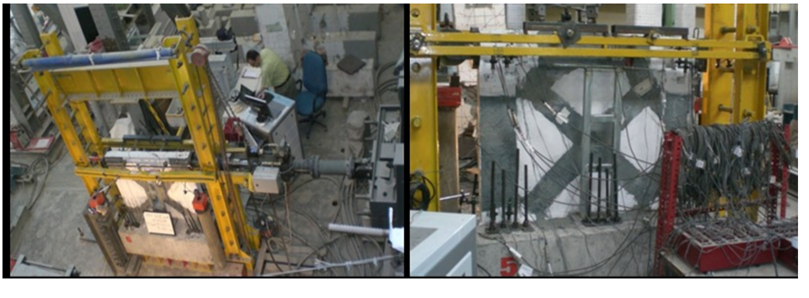

Figure 1. General view from the experimetal study

The main aim of this study is to determine the best energy dissipative retrofitting technique and is to determine the most effective strengthening technique of the infilled RC frames by the use of Carbon Fiber Reinforced Polymers sheets. The most practical and efficient way to increase the strength level and to decrease the damage level especially in seismic retrofitting of existing buildings is to increase the internal energy dissipative properties of the overall structure. This property can be achieved by especially retrofitting the infill walls used inside the frames. Because it is known that the infills called non-structural components which are the most energy dissipation source due to the friction between the structural components.

According to the test results, in general it can be said that the use of CFRP sheets as strengthening materials provides a degree of enhancement to the infill wall, upgrades its deformation capacity, and makes the wall work as one unit. These results thus show great potential for externally bonded CFRP sheets in upgrading and strengthening the infill walls under in-plane seismic loads. Both of the test results (static and dynamic) showed a significant increase in the yield and ultimate strength capacities of the frames with a decrease in relative story drifts, especially in the cross-braced and the cross diamond-braced type of retrofitting schemes. Both retrofitting technique can advise a high energy dissipation capacity with low damage propagation.

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STRATEGY FOR THE DEVELOPMENT OF SYNTHETIC MULTILAYER FIBROUS MEDIA DEDICATED TO ENGINE AIR FILTRATION WITH HIGH DUST HOLDING CAPACITY

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Abstract: In engine air intake filtration, a challenge is to obtain the highest dust holding capacity (DHC) in order to improve the filter medium lifespan. Such performance can be driven by the design strategy of the fibrous structure. Indeed, various microscopic and macroscopic structural properties can influence the behavior of the filter medium and the evolution of its properties during the clogging such as fibers characteristics, contact points type and distribution, porous structure, medium thickness, multilayer architecture, and mechanical properties. This work particularly deals with the multi-scale approach for the designing of an engine air intake filter with optimized dust holding capacity.

Keywords: Dust Holding Capacity – Depth filtration – Synthetic Filter Media – Nonwoven fibrous structure – Engine air intake filtration

1. INTRODUCTION

Numerous considerations come into play when designing a specific engine air intake filtration element. The improvement of the filter lifespan comes through the increase of the dust holding capacity which is the ability to capture a large quantity of fine or coarse particles for a critical increase of the differential pressure. A high efficiency is also required in order to protect the internal engine organs along with a good permeability which is essential to lower the pressure drop. The evolution of these parameters during the clogging depends on the mechanical behavior of the filter under the dust load in the course of aging. Since the final filter media are pleated in order to increase the filtration surface in a limited volume, stiffness and moisture resistance are primordial to prevent the collapse of the pleated architecture.

Most air intake filters are still made by wetlaid technology using cellulosic and glass fibers in blend. These cellulosic paper structures are very compact reducing the enhancement possibilities of the dust holding capacity due to the fast growth of surface clogging cake. The longevity of these filters is even more reduced because of their low moisture resistance. Paper filter elements have been challenged recently by synthetic multilayer filters made of nonwoven fibrous structures based on man-made polymers composed of randomly assembled fiber or filaments according to the possible combination of web forming technologies such as drylaid or spunmelt processes and assembled using consolidation technologies like needlepunching or spunlacing. Synthetic multilayer filter media are particularly interesting for gradient filtration by offering a progressive multi-stage filtration phenomenon that occurs throw the medium depth with a different specific role for each layer [1]. Synthetic composite filter media additionally present several advantages in comparison with cellulosic paper media such as higher dust holding capacity, better mechanical stability and moisture repellency over time [2].

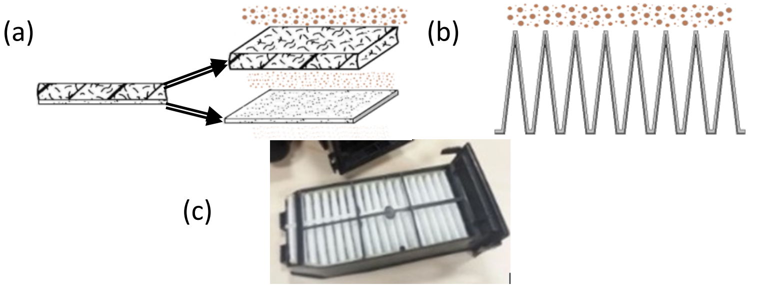

Figure 1. Structure of the bilayer nonwoven media, before pleating (a) – Pleated fiter media (b) – Final filter element (c).

In this work, a multi-scale approach is exposed for the development of a multilayer synthetic filter media. Different key factors can influence the media filtration performances from the fiber to the pleated final element. At the fibers scale, the control of the fibers associations with different types and morphologies enables to create various fibrous constructions inside the medium. The combination of fiber characteristics and manufacturing process parameters leads to the plane medium microscopic structural properties with different levels of complexity, heterogeneity and entanglement rate. At the plane filter medium scale, some macroscopic characteristics like thickness, compressibility and stiffness influence the pleats arrangement, shape and stability.

In the case of bilayer media, the first layer serves as a pre-filter, collecting the larger quantity of particles. The evolution of its thickness during the clogging plays an essential role in the filter lifespan. The second layer insures the fine particles capture; its characteristics determine the efficiency of the filter medium. The fine filtering layer must also provide the required stiffness to the filter medium for optimizing the pleating operation and keeping unaltered the pleats shape during the clogging. Thus, this layer plays an important role in the dust holding capacity of the final filter. Several associations of pre-filtration and fine filtration nonwoven structures are developed for the study. The next scale investigates the combination of the medium characteristics and the pleating layout such as pleats density, shape and height.

2. MATERIAL AND METHOD

2.1 Composition of the nonwoven structures

Each layer of the developed structures is implemented using different compositions of polyester-based fibers with a diameter from 10 to 40 microns. The use of fine fibers for instance increases the filtration efficiency by increasing the encounter probability between particles and fibers directly related to the total specific length and area of fibers inside the media. In another hand, using coarse fibers provides more stiffness and a three dimensional architecture to the media leading to an improvement of the dust holding capacity. The combination of the two types of fibers in blend show a better nonwoven filtration compared to the equivalent unimodal diameter structures especially in early stage of filtration [3][4]. Sheath-core bicomponent fiber containing low melt polymer are used in order to confer spatial rigidity to the fibrous material and setting the distance between fibers after thermo-processing

2.2 Nonwoven manufacturing process

All the nonwoven media are obtained using pilot production lines (CENT nonwoven platform / IFTH, France). The web is first formed by carding the different blends of fibers; a pre-needling is performed on the fine filtering layer before spunlacing. The pre-filtering layer is then cross-lapped over the dried fine filtering one. A needlepunching is then operated as an assembling/bonding technique for the double layer structure which is finally thermobonded.

2.3 Multi-scale characterization of the nonwoven fibrous structures

Microscopic internal fibrous properties such as pore size distribution, entanglement rate and number of free or bonded fiber to fiber contact points are estimated in this study and their impact on each layer behavior is analyzed. Scanning Electron Microscope observations of the internal fibrous structures are also realized. The measured macroscopic characteristics are thickness, basis weight and solid volume fraction. The compressive behavior and stiffness measurements are obtained using MTS traction/compression Bench. A Palas bench is used for the filtration tests with a Welas digital aerosol spectrometer for particles counting; dust feeding is carried out through the filtration chambers using a compressed air particles disperser. The measured filtration properties are air permeability, initial pressure drop, fractional filtration efficiency and dust holding capacity (DHC).

3. RESULTS AND DISCUSSION

The results show the relevance of a multi-scale approach. The pre-filtering layer impact on dust holding capacity is based on both individual fibers and global fibrous network contributions. Equilibrium has to be reached between these two contributions in order to increase its input in the filtration performances. The global efficiency and stiffness of the fine filtering layer can be maintained invariable for different levels of fractional efficiency according to the internal fibrous characteristics leading to the modification of the input of this layer on dust holding capacity.

4. CONCLUSION

The objective of this study is to provide a better understanding of the interactions between the different characteristics from the fiber to pleated element combining their contributions for meeting required dust holding capacity of the filtration media. Additional investigations and data analysis will confirm the interdependency of the pre-filtering and fine filtering layers which are working in tandem to reach the final filter specifications.

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COMPARISON OF MICRO- AND MACRO-TENSILE PROPERTIES OF NONWOVEN GEOTEXTILES AS PER TEMPERATURE DEPENDENCY

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Abstract: The total deformation at global macro-scale under extension or contraction loading for the fibrous geotextiles due to the heterogeneous internal structural formation is the cumulative result of filament/fiber deformation and internal structural rearrangement of the geo-textile for which the initial elasto-plastic type deformation is strongly temperature and strain rate dependent, while the long-term rearrangement type deformation is not. As far as the tensile testing of the geotextile at “micro-scale” level is concerned, the effects of the rearrangement of internal structure of the geotextile on the test results attained are avoided and the tensile behavior developed as well as the tensile strength parameters obtained are strongly dependent on the geotextile single filament polymeric properties. Consequently, the temperature effect on tensile strength behavior/properties of the fibrous geotextiles at “micro-scale” is more pronounced in the tests and vital to the results than that at “macro-scale” levels. Therefore, it is necessary to perform further micro-mechanical thermo-tensile tests at “micro-scale” and compare the results with those observed at global “macro-scale” to expand the understanding on the influence of temperature on micro-mechanical behavior (i.e. extension) and tensile strength properties of the geotextile single filaments at “micro-scale” level as compared to that at “macro-scale” level.

Key Words: *Nonwoven Geotextiles, Temperature Effects, Micro-scale Tensile Testing, Geotextile Filaments*

1. INTRODUCTION

Geotextiles being a fabric originally produced from several different varieties of polymer resins are widely used under load conditions in several construction projects including landfills, retaining walls, slopes, foundations and road subgrades in which they are subjected to tensile stresses throughout their service life [1].

2. THE ROLES OF FABRICS IN COMPOSITE LAYERED SYSTEMS

(MACRO-SCALE MECHANICAL ASPECTS AND ENDURANCE PROPERTIES)

The roles of fabrics (i.e. geotextiles) in composite lining systems were originally described by Martin et al. [2] such that geotextiles and geomembranes in geotechnical field applications are generally installed adjacent to each other as a composite system [2, 3].

3. FABRICS (FIBROUS MATERIALS) TENSILE TESTING PERSPECTIVES

Tensile strength testing has been a widely used method to evaluate the engineering properties of various geosynthetics such as geotextiles. This is attributed to the fact that many geosynthetics are designed to complement the relatively low tensile capacity of soils [1, 4].

4. PREVIOUS MACRO-SCALE TENSILE TESTS AT DIFFERENT TEMPERATURES

There is an important aspect of fibrous materials (e.g. geotextiles) which must always be considered when fabrics are tested in tension mode. The geotextiles can exhibit different tensile stress-strain behavior as well as show favorable versus adverse response to varied test conditions such as temperature and strain rate variations when tested at the "macro-scale" level versus when tested at the "micro-scale" level.

5. TENSILE BEHAVIOR OF GEOTEXTILE SINGLE FILAMENTS AT DIFFERENT

TEMPERATURES (MICRO-SCALE PERSPECTIVES AND RESPONSE)

5.1. Introduction and Scope

In order to investigate tensile behavior and the developed "micro-scale" stress-strain response of geotextile single filaments at different temperatures, laboratory tests were performed in this study by measuring filament thermo-mechanical properties using Dynamic Mechanical Analyzer (DMA) in controlled force/strain rate mode.

5.2. Micro-Mechanical Thermo-Tensile Tests on Geotextile Single Filaments

A total of 60 micro-mechanical thermo-tensile tests on single geotextile filaments were performed at temperatures ranging from 20 °C to 50 °C with 10 °C increments between different test temperatures and 15 tests at each test temperature to observe the repeatability of the developed tensile force-extension behavior as well as to see the reproducibility of filament tensile strength response at every test temperatures.

5.3. Modulus of Elasticity and Temperature

It is very well known that polymeric materials typically exhibit nonlinear stress-strain behavior, since stress relaxation occurs throughout loading. The observed force-extension behavior of PP filament specimens indicated that the fibers become stronger and stiffer as temperature decreases under tensile load application. The elastic portion of force-displacement curve rotates “clockwise” demonstrating the reduction in stiffness; hence, modulus with increasing temperature.

5.4. Tensile Strength and Temperature

A polymer type (i.e. polypropylene (PP)) used as a base material to produce geotextile fibers do not retain tensile strength and robustness properties with temperature change to which most geotechnical engineering applications are exposed. It was observed as a result of micro-scale thermo-tensile tests on geotextile single filaments that tensile strength, (τ) for PP filaments decreased with increasing temperature with lower strength measured at higher elevated temperatures.

6. COMPARATIVE ANALYSIS AND DISCUSSION

This research study reports on the characterization of the tensile behavior of NPNW-PP single geotextile filaments with a change in ambient temperature at the “micro-scale” level compared to the tensile behavior observed at the “macro-scale”. At the “micro-scale”, the tensile failure takes place due to breakage of filaments whereas at the global scale, the slippage between filaments and the structural deformation due to inherent internal geotextile void space which is governed by fabric manufacturing and fiber processing type, dominates. Globally, full mobilization of tensile capacity of geotextile fabric is associated with full mobilization of filament tensile strength at micro-scale. Consequently, the development of force-elongation response of a fibrous material (i.e. geotextile) based on its characteristic tensile stress-strength-strain behavior is a multi-scale phenomenon.

7. CONCLUSIONS

Based on micro-tensile test results obtained from polypropylene filaments at different temperatures at “micro-scale” level as compared to the experimental findings at “macro-scale” level, fiber/filament strength can be considered as the major factor controlling geotextile micro-scale, and consequently, macro-scale tensile strength properties.

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SMART COMPRESSIBLE MEDICAL GARMENT WITH SHAPE MEMORY ABILITY

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The development of smart medical garments with shape memory ability, enhanced mechanical properties and unique deformation mechanism is targeted in this study. I would offer potential to improve quality of life of many cancer survivors with Lymphedema affects. The affected tissues may continue to swell, and can become hardened or fibrotic and susceptible to infection if they left untreated. To help sustain the reduction in swelling and discomfort obtained through concentrated treatment, medical grade compression garments are usually required.

Keywords: Smart materials, shape memory, deformation mechanism, Lymphedema, mechanical properties.

1. INTRODUCTION

Lymphedema is a common but often misunderstood condition that affects the quality of life of many cancer survivors. It is caused when protein-rich lymphatic fluid accumulates in tissues, engorging and enlarging vessels and often causing visible swelling, tenderness, and often pain. Left untreated, the affected tissues may continue to swell, and can become hardened or fibrotic and susceptible to infection [1]. Compression therapy is the universally accepted treatment for the management of visible swelling, tenderness, and pain due to Lymphedema [2]. Therefore, it is necessary that compressive garments should be comfortable to wear for long periods of time [3]. Comfort is related to the material's interaction with the body which is based on how the material's behavior matches better with the body's shape. In recent years the use of textile technology to fabricate auxetic textiles has attracted more and more attention. It is reflected in the extent of research work exploring the auxetic potential of various textile structures [4]. Auxetic textiles have excellent formability due to their unique deformation, tailored enhanced mechanical properties, flexibility to cut into any required size and shape [5-6]. Auxetic compression garments can transversally extend when stretched [7] and dome shape on bending. Therefore, development of an auxetic compressed garment is targeted in this study to sustain the reduction in swelling and discomfort obtained through concentrated treatment. In recent years auxetic as attracted more and more attention. It is reflected in the extent of research work exploring the auxetic potential of various textile structures. Therefore, our objectives in proposed research studys includes to: *(i)* develop and characterize novel compressed auxetic garment; *(ii)* implement auxetic pattern to make it smart material; *(iii)* analyse mechanical, thermal characterization and functional performance and *(iv)* prove accuracy and validity of obtained experimental results through mechanical and theoretical modeling.

To our knowledge auxetic compressive garment with auxetic pattern to enhance functional performance specifically flexibility is not studied.

2. MATERIAL AND METHODOLOGY

To achieve objectives our study is organized in four folds: *(i)* Selection of Material –different synthetic fibers such as polyamide, polyester because they are compatible to fabricate compressive garments due to their changeable properties; *(ii)* Development of Structure –knitting techniques such as warp or weft knitting system will be used in the fabrication of auxetic structures*; (iii)* Characterization and validity –dimensional, comfort properties and tensile, compressive testing and *(iv)* The accuracy and validation of fabricated samples will achieved through analytical and mechanical modelling using finite element analysis.

3. RESULTS AND DISCUSSION

The expected results from proposed study includes – *(i)* The novel fabricated compressive garments will become wider on stretched, and thinner on compressed and synclastic on bending. This novelty is achieved due to unique deformation mechanism and enhanced mechanical properties of auxeticity hence it will offer improved flexibility. (ii) Automatically adjustable with strength and thickness in response to applied forces will be offer because they have memory ability and return to its neutral state on dissipation of the stresses.

4. CONCLUSION

The successful fabricated innovative compressive garments using smart materials with high-tech technology and low cost processing will provide socio-economic benefits, affordable. They would improve quality of patients.

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LAYER BY LAYER ASSEMBLY OF ANTIBACTERIAL INCLUSION COMPLEXES

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Abstract: In the project, it is planned to create a textile material that captures the volatile active agent which shows antibacterial activity and resistance to environmental conditions, as well. Therefore, an inclusion complex of carvacrol and β-CD is generated by kneading method and deposited on the cotton fabrics by using a nanofabrication method named as Layer-by-Layer deposition method (LbL). Attenuated total reflectance Fourier transform infrared spectroscopy (FTIR), Scanning electron microscopy (SEM), Antimicrobial efficacy test of fabrics against washing and some physical tests (water vapour permeability, air permeability) were performed on the fabrics before and after the treatment with CD to evaluate the effect of the LbL process on cotton fabric properties.

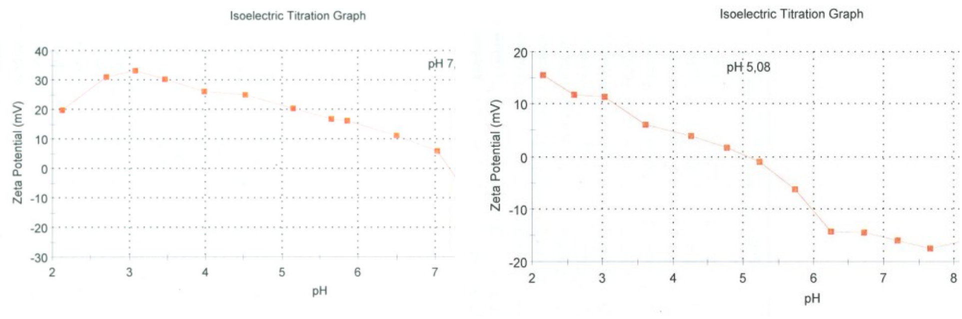
Key Words: antimicrobial textiles, carvacrol, inclusion complex, β-cyclodextrin, layer-by-layer deposition.

1. INTRODUCTION

Textiles can be exposed to contamination with micro-organisms, especially at appropriate humidity and temperature in usage. The microbial attack of textiles leads to quality losses (colour and appearance changes), reduction in strength, causes in unpleasant odour formation, contamination and infection. Recently, increasing public concern about hygiene has been driving many investigations for anti-microbial modification of textiles by using natural materials because of possible harmful or toxic effects of many chemical anti-microbial agents [1]. Carvacrol which is existed in essential oils of plants such as oregano, thyme, marjoram, is a phenolic antimicrobial compound [2]. B-Cyclodextrin (β-CD) is a cyclic oligosaccharide obtained by enzymatic starch degradation and consists of seven anhydroglucose units [3].

2. MATERIAL AND METHOD

An inclusion complex of carvacrol and β-CD is generated by kneading method. The preparations at 1:1 (Car CD 1), 2:3 (Car CD 2) and 1:2 (Car CD 3) β-CD: Carvacrol (M/M) ratio is characterized by SEM, DSC and FT-IR analysis. The optimum inclusion complex formula is selected and applied to textile material using a nanofabrication method named as layer-by-layer deposition method (LbL). The label process is based on the alternating adsorption of charge cationic and anionic species onto a charged substrate [3]. For a cationic surface charge, cotton fabrics were pre-treated with a cationic agent by pad-batch method. For the multilayer film deposition process, the isoelectric point of CD and CD:Car complex were determined by zeta potential measurements (Figure 1).



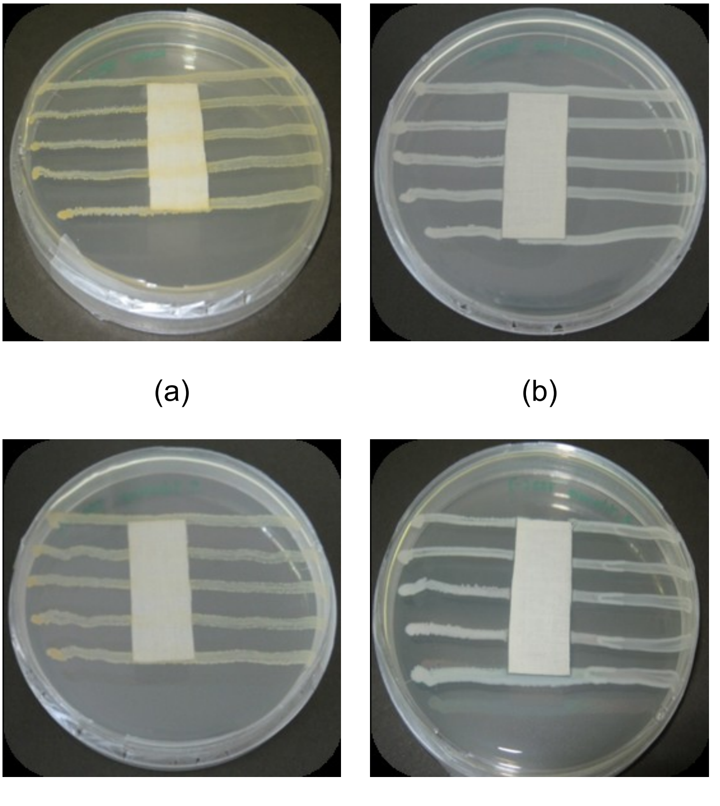
CD CD:Carvacrol complex

Figure 1. Zeta potential graphics of CD and CD:Carvacrol complex

The pH of CD suspension was adjusted to 3.5 for cationic layer and the pH of CD:Car complex solution for 7,5 for anionic layer by using HCl and NaOH. Aqueous solutions of CD and CD:Car were prepared at 5 g/ l, 10 g/l and 20 g/l. The CD/CD:Car multilayer film deposition process, the cotton fabrics were applied in the following solutions alternately; (a) the cationic CD solution, (b) the deionized water, (c) the anionic CD:Car solution and (d) the deionized water. 16 CD/CD:Car multilayer films with 3 diffent concentrations were deposited on the cotton fabric by using a laboratory-type padding machine. Multilayer film coated cotton fabrics were dried and cured at 105 °C for 5 min. Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (FTIR-ATR) and Scanning Electron Microscopy (SEM) were used to verify the presence of deposited CD layers. Antimicrobial efficacy test of fabrics is performed using AATCC Test Method 100-1998 [4]. Some physical tests (water vapour permeability, air permeability and whiteness values) were performed on the fabrics before and after the treatment with CD to evaluate the effect of the LbL process on cotton fabric properties.

3. RESULTS AND DISCUSSION

In order to determine the antimicrobial efficacy of fabrics with or without washing, AATCC Test Method 147-1998 was performed [1]. The antibacterial test results of molecular capsule treated fabrics were given in Figure 2. In the experiments, Klebsiella pneumonia and Staphylococus aureus were employed as gram-negative and gram-positive bacteria, respectively. The observations took place over 24 hours have shown the antibacterial activity was existed in the contact zone of fabrics for both gram-negative and gram-positive bacteria. It was stated that the antibacterial effectiveness is endured for all the fabrics after 1 and 10 washings.



(a) (b) (c) (d)

Figure 2. Antibacterial test results of fabrics against to gram-positive bacteria: (a) untreated cotton fabric, (b) 5g/l CD/CD:Car multilayer film deposited fabric, (c) 10g/l CD/CD:Car multilayer film deposited fabric, (d) 20g/l CD/CD:Car multilayer film deposited fabric

4. CONCLUSION

An attempt was made to create an antibacterial textile material with an inclusion complex of carvacrol and β-CD by using Layer-by-Layer deposition method (LbL). The presence of deposited CD layers on the cotton fibers were verified by FTIR-ATR and SEM analyses. It was clearly concluded that deposited CD layers showed excellent antibacterial activity against to both Klebsiella pneumonia and Staphylococus aureus bacterias.

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DESIGNING BIO-INSPIRED SUPERHYDROPHOBIC NONWOVEN MATS

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Abstract: Superhydrophobicity is a phenomenon that can be defined by two criteria (a) a very high contact angle (more than 150^0) and (b) very low roll off angle of a water droplet on the surface. This makes the drop to roll off easily on the surface along with the impurities present on it, thus giving a self-cleaning effect or well-known “lotus effect”. Inspired by the “dual- scale” characteristics of lotus leaf, this research work aims at developing ZnO nanorods on the surface of viscose fibre based nonwoven mats using hydrothermal process. Subsequently, the contact angles of these nonwoven mats were determined and the samples were also characterized using various physical characterization techniques. A preliminary model to predict the superhydrophobic characteristics of dual-scale nonwoven mats has also been presented and compared with the experimental results.

Keywords: superhydrophobic, nonwoven, self-cleaning, hydrothermal, dual-scale

1. INTRODUCTION

Human kind has successfully mimicked some of the natural occurring materials such as wings of butterfly, water strider legs, geckos’ feet or leaves of lotus plants, etc. by understanding their chemistry and surface characteristics. This extreme water repellency is therefore manifested in the form of superhydrophobicity, which has been successfully developed on various types of materials having regular surface characteristics. However, the material such as nonwoven mat is quite irregular and heterogeneous in nature as it essentially consists of fibres orientated randomly or directionally which are not regularly spaced and distributed in a stochastic or non-stochastic manner. This heterogeneous nature of nonwovens can significantly enhance their hydrophobic characteristics due to the protuberances caused by the defined regions covered by overlapping fibres [1]. Thus, the main objectives of the research work are to design, develop and model the superhydrophobic characteristics of dual-scale nonwoven mats. Since, these nonwoven mats have constituent fibres with secondary features in the form of nanorods.

2. MATERIALS AND METHODS

Initially a viscose fibre based needlepunched nonwoven fabric (mass per unit area of 600 g/m2) was produced and the zinc oxide (ZnO) particles have been prepared by mixing 1 mM zinc acetate solution in 20 ml of 2-propanol under vigorous stirring at 50^{o}C. The solution was then diluted to 230ml with 2-propanol and cooled. Subsequently, 20 ml of 20 mM sodium hydroxide was added drop wise to the cooled solution of 2-propanol under continuous stirring. The nanorods of Zinc Oxide (ZnO) rods were generated on the surface of constituent viscose fibres of a nonwoven mat by means of hydrothermal process. These rods are inherently hydrophilic in nature and these nonwoven mats consisting of ZnO nanorods have been treated with chemical such as octadecanethiol solution of absolute ethanol for 24 hours in order to obtain hydrophobic surfaces [2]. Scanning electron microscopy (SEM) was used to obtain the images of nanorods. Furthermore, the contact angle measurements were carried out using the Kruss goniometer (Kruss GmbH,Germany). A droplet of distilled water (6 and 10 micro litres) was deposited on the nonwoven surface with a precision syringe. Furthermore, the energy-dispersive X-ray (EDX) was performed to confirm the presence of zinc element.

3. RESULTS AND DISCUSSION

Figure 1 displays the SEM image of viscose fibres based nonwovens having nanorods. It can be clearly seen that the nanorods are having random orientation characteristics on the surface of constituent fibres. This random arrangement of nanorods creates "dual-scale" characteristics which eventually trap the air beneathe the surface of these nanorods. Furthermore, there are pores within the nonwoven that enhances the well-known "Cassie" effect resulting in high contact angles with water droplet. The dimensions of nanorods depend primarily upon the concentration of precursor and accordingly, the magnitude of contact angle varied. Furthermore, the analytical model for predicting the superhydrophobic characteristics of nanostructured low surface energy nonwoven mats has been proposed and validated with the experimental results.

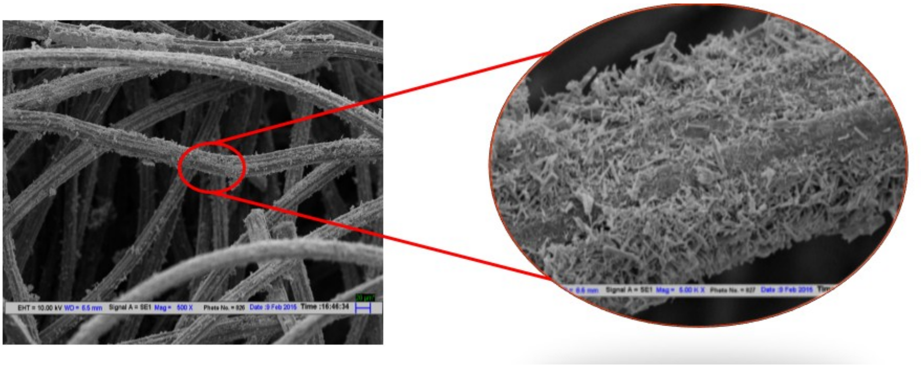

Figure 1. SEM image of a nonwoven mat displaying ZnO nanorods grown on the surface of viscose fibres.

4. CONCLUSIONS

The following conclusions can be drawn from this research work.

• ZnO nanorods have been successfully grown on the surface of viscose fibre nonwoven mats leading to superhyrophobicity.

• Superhydrophobicity can be obtained in the nonwoven mats with "dual-scale" characteristics having a coating of low surface energy material.

• A good agreement was observed between the theoretical and experimental results of superhydrophobic characteristics of nanostructured low surface energy nonwoven mats

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OPTIMIZATION OF LIGHT EMITTING TEXTILES WOVEN WITH OPTICAL FIBERS FOR PHOTODYNAMIC THERAPY

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Abstract: The Photodynamic Therapy (PDT) with panels doesn't distribute a uniform light on the skin due to the anatomical complexities of the human bod. Therefore a successful PDT obligates a homogenous and reproducible light delivery. For an efficient and less painful photodynamic therapy (PDT) to treat Actinic Keratosis, a light emitting fabric (LEF) was developed. This new fabric is woven with a special pattern and inserted plastic optical fibers (POF). First light intensity results achieved the expectations for the minimum temperature evolution with a good intensity but the emitted light was not homogeny. So, Doehlert Experimental Design is applied to optimize the intensity and the homogeneity. Fifteen experiments performed to analyze the response surface. Light properties of the prototypes were evaluated. With the obtained results, the optimal trial is calculated to acquire a fabric with a good intensity and homogeneity of light.

Keywords: Light emitting fabric (LEF), Plastic Optical Fibers (POF), Photodynamic Therapy (PDT), Doehlert Experimental Design, Response Surface Method (RSM)

1. INTRODUCTION

Medical textiles offer an opportunity that could provide more comfort and reliability during specific treatments. In this study a medical textile was developed with the aim of efficient and less painful photodynamic therapy (PDT) for Actinic Keratosis (AK) treatment. For a successful PDT a homogenous and reproducible light delivery is very important. The complex shapes and the anatomical particularity of the human body exposed to light sources used traditionally within PDT treatments deliver a non-uniform light distribution on the skin surface [1]. A development of woven based flexible light sources integrated plastic optical fibers (POFs) seems an alternative option to a great light delivery

[2]. An optimal weaving process has been set up to predetermine macrobendings of the POFs, which introduce side emission of light when the critical angle is exceeded. It is possible to control the bending angles of macrobendings of POF, as a result of weaving process, by modifying the weave pattern or adjusting the tension on the warp yarns to modify their side emitting property. Two LEFs were carried out with different but similar patterns (5x21cm²). The first sample was woven with adjusted tension on the warp yarns. It gave good results of the light intensity but the light delivery was not homogeny enough. Second sample with a balanced yarn consummation pattern repeat was carried out without adding tension on the warp yarns. Light delivery homogeneity was found very interesting, but the light intensity was weaker than first sample. So that, an experimental design method, Doehlert design, is applied for developing a statistical model to achieve response surfaces of the effect of the tension on the light properties of LEF.

2. MATERIAL AND METHOD

2.1. Weaving Process

Optical fibers are not side emitting in their natural state, but may get the side emitting property with the macrobendings. Bending an optical fiber changes the incident angle of the injected light if it exceeds the critical angle the radiative losses occur [3].

In this work woven based textile structures carried out to create macro bends on the optical fibers using weaving process. Figure 1 shows the leaking light from the bended POF.

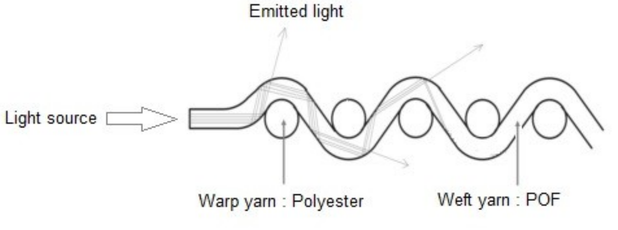


Figure 1. Schema of the inserted POF into a woven based textile structure

The light intensity of fabrics woven with different pattern repeats was evaluated. Two samples were developed with different specific pattern repeats, to allow the light leading along the POF with same powerful loss, to obtain puissant and homogeny emitted light. A LEF sample is shown in Figure 3.

Figure 3. LEF sample connected to lasers by two ends

2.3. Doehlert Design

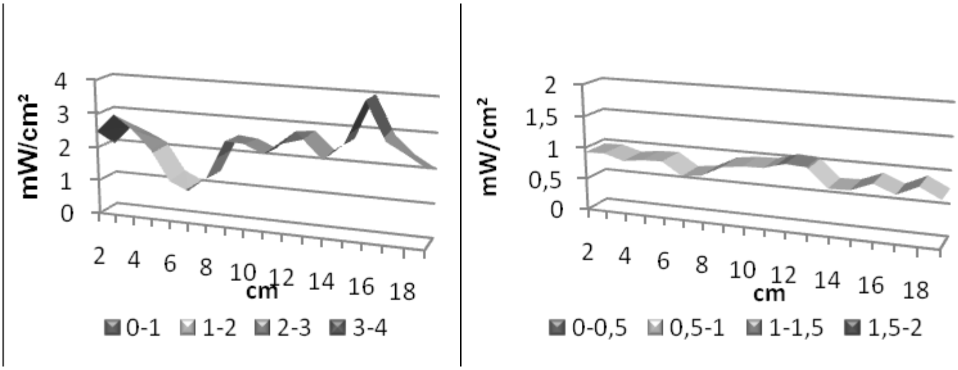
The Doehlert design is used to optimize the light intensity and the homogeneity of the LEF weaved with optical fibers. This design is chosen because of its flexibility, which means by adding new points it is possible to explore more the domain without losing quality of the model.

Firstly, the most influential factors on the responses were chosen according to precedent experiences. Then fifteen samples performed to compare the predicted and experimented results to create a correlation between and discover the optimal domain.

3. RESULTS AND DISCUSSION

To begin with, Dohlert Design method is applied on the first sample, which is woven by added tension on the warp yarns. Fifteen flexible light emitting fabrics were produced with the calculated tension settings in order to predict the responses of the light puissance and the delivered light homogeneity of the LEF. The experiments were performed in random order, and the central point experiments were repeated three times to observe test repeatability.

Figure 2 shows the light distribution of two LEF samples. Figure 2 (a) shows the results for the first sample woven with adjusted tension and Figure 2 (b) shows for the second sample woven without tension but a different pattern repeats. As it seems on the figure, first sample has a good light intensity but a poor homogeny, and the results are inversely for the second sample.



(a) (b)

Figure 2. Light distribution of the two samples with different pattern repeats.

4. CONCLUSION

The present study involves the application of the RSM using the Doehlert experimental design of experiments to develop a mathematical correlation between the tension on the warp yarns and the light intensity and the light diffusion homogeneity of the fabric diffuser.

According to the experimental results of fifteen samples a model has designed with Doehlert matrix. Predicted values correspond to the experimental values of the light intensity of the LEF, so the model has been a powerful tool for optimizing the designed fabric, but it was less suitable for the light emission homogeneity. As a consequence, the method can be applied on the second sample, which has already a good homogeneity, to increase its light puissance.

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EFFECT OF MATERIAL PARAMETERS ON THERMO-PHYSIOLOGICAL COMFORT PROPERTIES OF 3D SPACER KNITTED FABRICS

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Abstract: The thermo-physiological comfort properties of knitted spacer fabrics fabric have been evaluated by varying the thickness, density of the fabric, raw material and type of spacer yarn. The study established that the raw materials, fiber composition of yarn, density and thickness have a significant influence on the air permeability of 3D knitted fabrics. The main influence on the water vapor permeability of these fabrics is the kind of raw material i.e. the wetting and wicking properties of fibers. It is also found that the thermal conductivity and effusivity are closely related to the fabric density. Also these findings shows the fabric characteristics show significant effect on the thermal conductivity of spacers. The Pearson correlation between moisture capacity of the fabrics and water vapour permeability was found using statistical software named QC expert trilobite and Darwin. These findings are important requirements for the further designing of clothing for extreme environmental conditions.

Keywords:- spacer fabrics, air permeability, thermal conductivity, effusivity, OMMC

1. INTRODUCTION

Thermal insulation properties and performance of different textile materials have been already investigated [1,2]. In last few years, extensive research has been carried out on knitted fabrics for thermo – physiological comfort clothing [3]. Nowadays development and increases in demand of 3D knitted fabrics made researcher to do vast research for various technical application. 3D knitted spacer fabrics are like a sandwich, consisting of two complementary fabrics with a third layer tucked in between. Spacer fabrics are used because they are known as three-dimensional (3D) textiles. They can produce with different thicknesses and be used in thermal insulation applications because of their higher thickness compared to woven and knitted fabrics. Spacer fabrics are lightweight and breathable structures. They have good physiological and thermal comfort. So, this work has been made an attempt to understand the thermo-physiological characteristics of 3D knitted spacer fabrics. In this present study, the effect of material parameters on thermo physiological properties has been analyzed, particularly on heat, air and water vapour permeability of spacer fabrics were investigated rigorously.

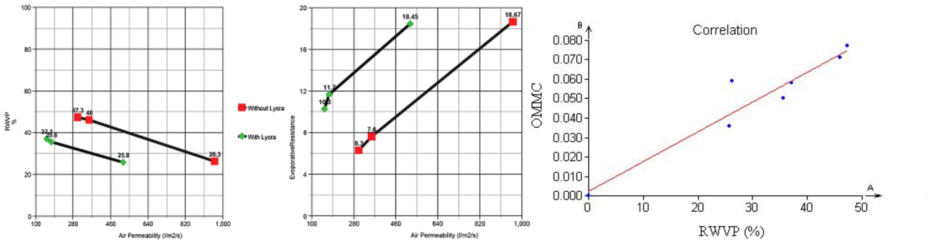
2. MATERIALS AND METHODS

Six different spacer fabrics were developed using Mayer & Cie, OVJA 1.6 E 3 WT circular knitting machine with 5 feeders, 14 gauge and 32 inch diameter. These six fabric samples were classified into two groups for convenient analysis of results, the first group has been developed using Polyester/Polypropylene blend with three different proportions and second group with Polyester/Polypropylene/Lycra blend having another 3 different compositions. As a spacer yarn, three different types of 88 dtex Polyester monofilament yarn and Polyester multifilament yarns (167 dtex and 14.5 tex) were used. 14.5 tex Polypropylene and 44 dtex Lycra multifilament yarns were also used for the face and back side of the spacer fabrics.

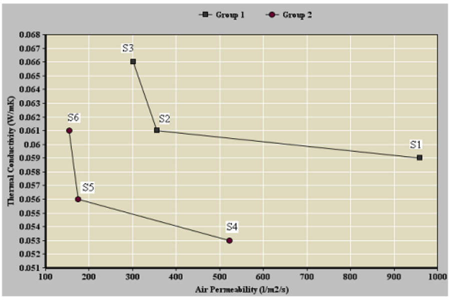
2.1. Evaluation of spacer fabric characteristics

Structural properties include the Yarn linear density and fabric weight per unit area, density and thickness was determined according to ASTM standards. **Air permeability** Tests were performed according to standard ISO 9237 using a Textest FX-3300 air permeability tester. **Water vapour permeability** of the samples has been measured using the PERMETEST. **Thermal conductivity** measurements were performed using the modified transient plane source technique employed by the C-Therm-Thermal Conductivity Analyzer. The **Moisture Management behavior** of samples was tested using moisture management tester (MMT) according to AATCC TM 195 test method. Evaluation of these test results was made using statistical software named qc expert trilobite and darwin. To determine the statistical importance of the variations, ANOVA tests were applied and for correlation between the parameters person correlation was used.

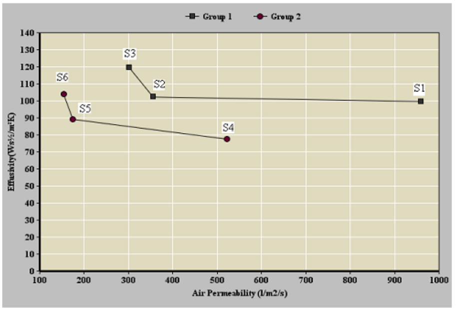
3. RESULTS



Influence of Air permeability on RWVP and R_{et}



Influence of air permeability on thermal conductivity



. Influence of air permeability on effusivity

4. DISCUSSION AND CONCLUSION

The warp knitted spacer fabric has significant effect on air permeability when the fabric parameters like density, thickness and structure varies. In contrast to water vapour permeability, air permeability is a function of spacer fabric thickness and density the water vapour permeability is greatly influenced by the raw material, whereas in the case of the blended fabric with artificial or synthetic fibres, these differences increased with rising moisture content in the fabric. This was dictated by the fact that in the fabrics with hydrophilic fibres most of the moisture absorbed was ‘jammed’by the fibres, whereas in the case of blended hydrophilic fabrics with hydrophobic fibres the moisture was ‘jammed’ into the structure of the fabric, creating a partially continuous film on the surface of the wet fabrics properties.

The main influence on the water vapour permeability of warp knitted spacer fabrics is the kind of raw materiál i.e. fibre wetting and wicking. Also there is no corelation between air permeability and water vapour permeability. It is found that both air permeability and thermal conductivity are closely related to the fabric density. It is also believed that the fabric characteristics of spacer fabric show significant effect on the air permeability and thermal conductivity of spacer fabric.

Overall Moisture Management Capacity of the spacer fabrics depends on the tightness or stitch density of both the surface of fabrics, types of spacer yarn and raw material and thickness of the fabric. Also OMMC is directly correlated with the water vapor permeability of the fabric.

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DESIGN OF AN ELECTRONICALLY EQUIPPED SAILING GARMENT FOR FALL DETECTION

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Abstract: Scope of this study is improving the safety of sailors by using an electronic device on their garments. For this purpose, an electronic fall detection system has been developed. This system is designed to find the absent sailor on the boat. By giving an instant alarm in case of falling, this system is expected to speed up the rescue operations and enhance the effectiveness of rescuing.

Keywords: presence detection, electronic system, safety enhancement, functional garment, sailing.

1. INTRODUCTION

In the last decades, various smart garments with electronic functions were developed to be used in medicine, army and entertainment areas. Some of these garments contained classical electronic devices and they were called as wearable computers. Besides, some studies were done by introducing the functional properties directly to the textiles [1,2]. But these researches are limited and still in progress because of the durability problems of the functional effect and other technical problems [3]. In this work, an electronic system is developed to be used in a functional sailing garment. Miniaturized sized electronic components were used to be able to integrate the total system onto the garment. The aim of the study is to enhance the safety of the sailors. This system is designed to detect the sailor's presence on the boat and give an alarm in case they fall overboard. For this purpose microprocessors, Bluetooth modules and power supplies were used to build the system. Both hardware and software designs of the system were done. As the detection principle, the communication ability of the Bluetooth system was used.

Before the system development, a scenario was created. According to the scenario, the presence of the sailors on the boat will be searched in certain time intervals within an area of "r" radius. "r" is the half length of the boat and the area in “r” radius is considered to be safer for the sailors. If any of the sailors are not found in the boat, then an alarm will be given on the boat with the name of the crew (Figure 1). So, before getting far away from the fallen sailor, a quick response will be able to be given and rescue operation can be done immediately.

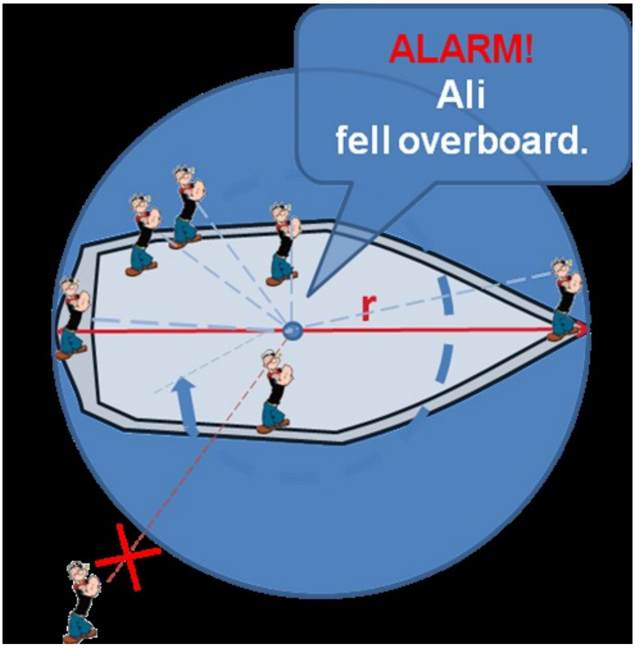

Figure 1. The summarizing figure of the scenario

2. MATERIALS AND METHODS

Materials and methods of the study are consisted of hardware and software design of the fall detection system. Details of the hardware and software are given in part 2.1 and 2.2.

2.1 Hardware design

The critical point, in determining the components of the electronic device to be used in garments, is selecting the optimally sized and weight devices in order to avoid giving extra weight, extra volume and reducing the mobility and performance of the sportsmen. Therefore, miniaturized sized components were selected for creating the fall detection system.

The fall detection system is consisted of two main parts: master and slave systems. Master system is the part which will be mounted on the center of the boat. This system contains a master Bluetooth, a microprocessor and a battery. By suitable connections and software support, this system searches for the presence of the sailors on the boat.

The second subsystem part, namely, slave system is consisted of a slave Bluetooth, a microprocessor and a battery. This part of the system is designed to be mounted on the sailor’s garment. By the communication of the master and slave Bluetooth modules, the electronic system is able to detect the fallen sailor. In hardware design, proper connections of the specific modules both on master and slave systems were done by cabling.

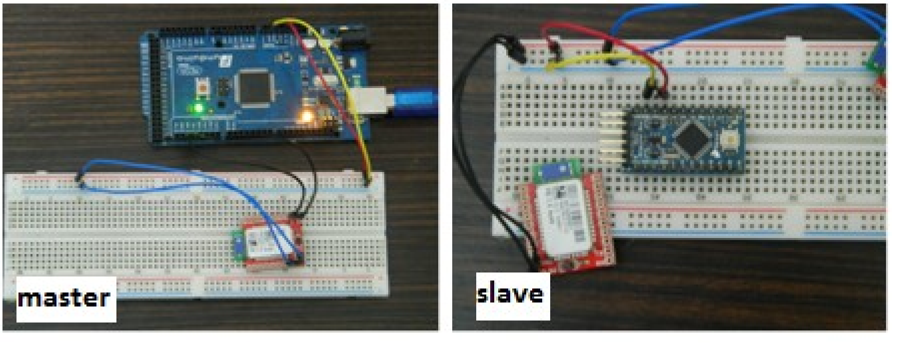

Figure 2. Finished prototypes of master and slave modules

2.2 Software and system design

A detailed software study was done on microprocessors to control the specific devices of the system.

Firstly, the main part of the presence detection, the master Bluetooth, was placed to the master system by making connections with microprocessor and writing suitable software to work in harmony. This master Bluetooth device scans the “r” radius chamber. It finds the seven slave modules (crews) by Bluetooth connection. Names of the sailors are introduced to microprocessor of master module to avoid confusing of the crews. If a sailor falls from boat, its Bluetooth communication will be lost. Then, an alarm will be given on the boat about the fallen crew.

3. RESULTS AND DISCUSSION

In the scenario, seven discrete slave modules presenting seven crews on the boat are designed. Within the concept of prototyping, the hardware and software design of one slave module and the master module is done successfully. When the device is run, all the components worked compatible and the emergency alarm was taken when the slave module was out of range. The total dimension of the compacted master system is about 5cm x 5cm x 3cm and the size of slave system is smaller. The systems were obtained in suitable dimensions to be used in sailing garments.

4. CONCLUSION

The prototyping of the system is made successfully. As a next step, a GPS (Global Positioning System) module and a GSM (Global System for Mobile Communications) module will be integrated to the electronic system. By these additions, it will be possible to detect the falling position and falling time of the crew. Last state of the electronic system will be mounted on the sailing garment. The best place on the cloth will be determined by literature search. This system is believed to enhance the safety of sailors due to decreasing the response time of rescue operation. Also by further studies, with learning the falling position and time of the crew, the saving operations will be done more effectively.

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STUDY ON THE COMPRESSION BEHAVIOUR OF KNITTED FABRICS - INFLUENCE OF THE ELASTIC YARN

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Abstract: In the present work, compression behaviour of knitted fabrics has been studied. Plated jersey fabrics were produced using seamless technology with a polyamide yarn 78 dTex with 23 filament as ground material, varying the linear mass of the elastane yarn, the type of polyamide covering and linear mass of the polyamide yarn. The performance of the developed knitting fabrics was assessed in terms of compression performance. It was observed that the compression performance improved significantly with the increase of the elastane linear mass used as core yarn, and the increase on the polyamide linear mass and the type of covering process (simple, double and airjet) used as yarn covering.

Keywords: Compression, knitting, seamless and elastane.

1. INTRODUCTION

The study of elastane yarns behavior is becoming increasingly important for the structural design for knitted seamless products with different levels of localized or graduated compression. Different research works have been conducted to study the influence of various factors such as elastane types and knitted structures on the mechanical properties of knitted fabrics, like strength and energy absorption.[1][2][3][4] The yarns used in compression garments are made with elastic fibers that are artificial fibers. According to M. Senthilkumar et al spandex fibers may have an extension-at-break higher than 200%. In general, elastic yarns are covered by inelastic materials, and the elastic fibers remain in the nucleus [5].

2. MATERIALS AND METHOD

2.1 Knitting

Plated jersey knitted fabrics tested is produced with 80% Polyamide and 20% Elastic of using technology seamless 13". The jersey of the basic structure is

Polyamide 78 dtex with 68 filaments.Tree types of coverage elastic yarns have been used air-covering, single covering and double-covering, and many types of elastic yarns in core.

2.2 Compression methods

The compression tests were performed according to a method of procedure. The methodology consists in adjusting the distance between the moorings of the dynamometer to the perimeters of the study measures as can be seen in Figure 1. Adjust the dynamometer to a zero pre-tension in each measurement and put knitted to study the dynamometer (5 cm in contact with the stick, noting the value of the charge. Then convert the values to mmHg. The contact area is 5 cm times the perimeter of the sample stick. In this trial it was decided to extend 50% of the initial diameter of knitted this because most of the elastic sleeves that exists in the market has lower dimensions.

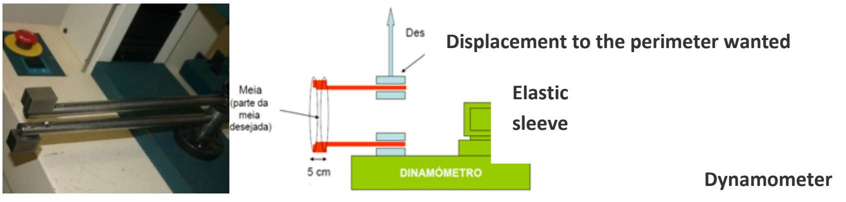

Figure 1: Equipment for the compression test

3. RESULTS AND DISCUSSION

These results present the relationship between compression and extension. As can be seen elastic yarns with double cover have higher linear density but also more variability compressions with small mass changes to both the elastane (core) as the covering.

4. CONCLUSION

The performance of the developed knitting fabrics was assessed in terms of compression performance. It was observed that the compression performance improved significantly with the increase of the elastane linear mass used as core yarn, and the increase on the polyamide linear mass and the type of covering process (simple, double and airjet) used as yarn covering.

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ENHANCING UV PROTECTION OF THE TENT FABRICS BY NANOSTRUCTURED POLYMER COATINGS

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Abstract: Nanoparticle embedded acrylic polyurethane coatings that can absorb copious amounts of UV radiation yet scatter little were developed to protect base fabrics from sun-induced degradation. In this study nano size titanium dioxide particles were used. Nano sİze particles (5 w%) were dispersed in acrylic polyurethane emulsions. Ultraviolet protection performance was investigated as a function of urethane, silicone polymer concentration incorporating nano size titanium dioxide particles. The tent fabrics were coated by knife-over-roller method with 50 µm and 100 µm coating thickness. Mechanical tests as well as infrared, visible and UV spectroscopy were used to characterize nano particle embedded acrylic emulsions and coated tent fabric. The results suggest that the UV protection function of the tent fabric is improved with the addition of TiO_2 nanoparticles.

Keywords: acrylic polyurethane, silicone polymer, UV protection, water-proof, tent fabrics.

1. INTRODUCTION

Ultraviolet radiation is known to have detrimental effects on synthetic polymers as well as on human skin which is a natural polymer [1]. Commonly used polymers, like nylon, polypropylene and polyethylene terephthalate, also degrade surprisingly fast in sunlight [2]. Sun emits three types of UV radiation; UV-A, UV-B, and UV-C [3]. Atmosphere absorbs most of the noxious radiations and only 5% of the harmful radiations reach to the earth's surface, ranging from 280 to 400 nm in wave length.

The main reason for the outdoor degradation of these polymers is the absorption of UV radiation from sunlight, with energies ranging from 300 to 450 kJ/mol. Textile materials must demonstrate effectiveness in the 300–320nm range [3]. Polymers can be protected from degradation by using various UV pigments or UV absorbers [4]. Chemical UV stabilizers appear to have a limited lifetime. On the other hand, it is also possible to protect high performance fabrics by coating with UV resistant polymers. Polymeric coatings used to protect base substrates like fabrics can be prepared by adding various inorganic particles[4]. These inorganic nanoparticles, for example TiO_2 and ZnO, have the same function as pigment particles, although they are much smaller in size and are hence more or less transparent. Studies have shown that both ZnO and TiO_2 are effective in protecting the substrate from UV degradation [5,6].

2. MATERIAL AND METHOD

The coating material was prepared by dispersing nano titanium dioxide particles and 86,5% aryclic binder in deionized water, using a Thermo Scientific Haake Viscotester 6 plus, for 15 minutes at 100 rpm. The dispersion was prepared in three concentrations as 40g/L, 60g/L and 80g/L. In order to prevent the creation of particle aggregates in coating bath, titanium dioxide dispersions were achieved by adding 0.5% non-ionic dispersing agent and by mechanically stirring by ultrasonication probe for 10-15 minutes. Ultrasonication probe was performed in a water at room temperature at 20-50Hz. Dispersing agent is an ethoxylated aliphatic alcohol. This agent being the hydrophilic moiety is compatible with nanoparticles and the hydrophobic moiety is compatible with acrylic polymer coating. Thus, the dispersing agent helps to improve mixing of the nanoparticles in the acrylic resin.

2.2Mechanical Properties

UV Protection Measurements

Before and after coating ultraviolet protective properties of the tent samples were measured using the Solascreen spectrophotometer according to the UV Standard 801.

3. RESULTS AND DISCUSSION

The UPF of tent fabric coated with 21 nm titanium dioxide particles in comparison with UPF values of uncoated tent fabrics (table 1) and UPF range corresponds to the standard 801 rating

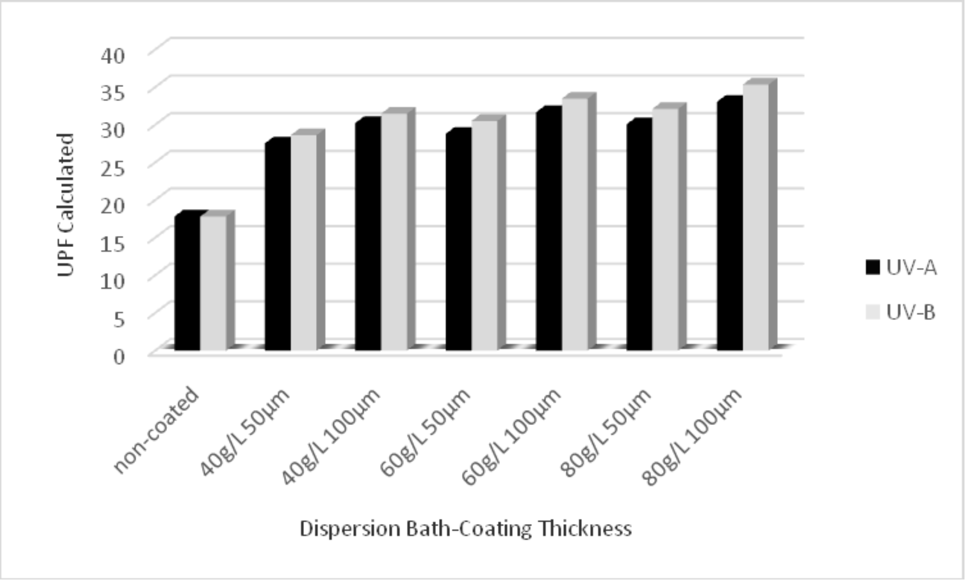

Figure 1. Comparison of calculated UPF of samples withy different dispersion bath and coating thickness

4. CONCLUSION

Nanosized oxide particles scatter less visible light and absorb more UV light than do their micron-sized counterparts. For that reason in this study, we used TiO_2 nanoparticles which average particle size of 21 nm. In the case of UV protection function, the tent fabrics treated with TiO_2 nanoparticles have better UPF values. According to the requirements of standard for all coated tent fabrics, the lowest UPF value shall be not less than 40 UPF.

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15 OCTOBER 2015
COST MP1105-WORKSOP
ORAL PRESENTATIONS

THE COST ACTION MP1105 ON FLAME RETARDANCY OF TEXTILES AND RELATED MATERIALS: A EUROPEAN MULTIDISCIPLINARY KNOWLEDGE PLATFORM

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Abstract: The COST Action MP1105-FLARETEX entitled ‘Sustainable flame retardancy for textiles and related materials based on nanoparticles substituting conventional chemicals’, aims to form a European multidisciplinary knowledge platform on ‘Sustainable Flame Retardancy’. The objective is to facilitate the rapid development of fire safe textiles and related materials of low toxicity and ecotoxicity, using all the available/novel technologies. The Action comprises 28 signatory COST countries and 2 non-COST members and organises about. 7 events per year (Workshops, Conferences, Training Schools, Working Group meetings …). The list of attendees is a good mixture of academics and industrialists. Furthermore, Short-Term Scientific Missions are funded to give the chance to young scientists to have a working experience abroad. . An overview of activities arranged in past 3 years including major outcomes and plans for the last year will be presented in this lecture, together with some remarkable scientific outputs.

Keywords: flame retardant textiles, multidisciplinary knowledge platform, networking, nanotechnology, sustainability

1. INTRODUCTION

Replacement of existing flame retardants (FR) with sustainable and environmentally friendly alternatives for textiles in domestic, safety, transport (automotive, rail, aerospace and marine), civil emergency and military, construction and other industries requires a multidisciplinary approach from textile technology to the physics and chemistry of fire. This COST Action aims to create an international multidisciplinary scientific and technology network on Sustainable Flame Retardancy developing new innovative flame retardants with low fire toxicity and environmental impacts. In particular, this platform helps to promote cooperation in flame retardancy research between researchers from different scientific disciplines, efficiently exchanging ideas and strategies in order to lead developments in fire safety, fire retardants and environmentally friendly fire retarded textiles and related materials, and to accelerate growth to keep Europe leading the world in this crucial area, taking into account sustainability, safety and health, and to facilitate its commercial exploitation in Europe.

COST MP1105 stimulates European cooperation and technology transfer to industry with valuable input from (inter)nationally funded research via Working Group meetings, Workshops, Conferences, Training Schools and Short-Term Scientific Missions (STSM) for Early Career Investigators (ECI), etc.

2. OBJECTIVES

The main **aim** of the COST Action FLARETEX is to **form a European multidisciplinary Knowledge Platform on Sustainable Flame Retardancy.** To reach this goal the following **objectives** are set :

a) To identify and bring together various research activities occurring in this area in different academic and industrial sectors and different scientific disciplines (such as chemistry, physics, materials science and engineering).

b) To address aspects related to technical, environmental, economic, medical and societal issues relating to the use of flame retardants.

c) To organise activities to allow the coordination of research on a European level, avoiding duplication of efforts and linking industry and (academic) research.

d) To facilitate the commercialisation of the novel research products/processes developed by academics through SMEs as well as influence the main European industrial flame retardant textile interest.

e) To facilitate the formation of consortia to develop new research projects for funding from national/EU funding bodies.

f) To establish a fully functional network where each participant is aware of the activities, expertise and previous experience of other members working in their area.

g) To establish a repository of published research on fire retardant textiles (to include books, journal articles, conference proceedings, patents, …).

h) To promote placements and exchanges of scientific personnel across the network.

3. SCIENTIFIC FOCUS

The following research directions are focussed on :

- Identification of the safer alternative to halogenated and antimony based FRs.
- Development of new and sustainable nanobased FR systems for application in textile and related materials.
- Analysis of their effectiveness, durability, (smoke) toxicity and particularly environmental impact.
- Improved surface treatment (plasma, enzymes, ultrasound, UV, etc.) and application processes (coating, spinning, sol-gel, micro-encapsulation, (photo) chemical, etc.) for FRs.
- Drawing up of testing methods, performance standards and durability requirements for FRs in different sectors (protective clothing, automotive, construction, packaging, etc.).
- Study of the synergistic effect of combining nanomaterials with conventional FRs.
- Development of a modelling tool, based on the existing knowledge of FRs and new scientific results, to be used by industry to predict the properties of newly designed products in an optimal way.
- Characterisation, safety aspects, quality assurance, property database.
- Scaling up and commercialisation.

The COST Action MP1105 is organised in **4 Working Groups** (WG) :

WG1 : **Novel flame retardants**: New and environmentally friendly (halogen-free) nanobased Flame Retardant systems are investigated and/or developed. Synergistic effects derived from combining nanoparticles with conventional FRs and their potential effectiveness are studied.

WG2 : **Toxicological/environmental aspects**: FRs obtained in WG1 are being investigated for their fire toxicity, ecotoxicological and environmental impacts (LCA). The risks and benefits of using flame retardants in consumer products are analysed both qualitatively and quantitatively.

WG3 : **Processing/Applications/Commercialisation**: Application processes (such as plasma coating, spinning, sol-gel, (photo)chemical, …) of the novel FRs to textiles or textile related materials are being studied, developed and optimised. The general aim is to minimise the amount of novel FRs but still assuring the best fire performances of the treated materials. Work in WG3 will facilitate the mechanism to commercialise the best products/processes through intensive cooperation with the industrial partners.

WG4 : **Testing/Standardisation**: According to the requirements needed for the different application (sub)sectors, new test methods and performance standards can be developed. Durability tests for the novel FR will be standardised as well.

4. SCIENTIFIC RESULTS

The following highlights in scientific output have been reported so far :

- The use of nanoparticles for flame retardancy, including natural and hybrid nanoparticles
- Increased use of P-based FRs as alternative for halogen based FRs
- The use of natural (= green) flame retardants.
- The use of layer-by-layer (LbL) deposition and sol-gel technology
- Intumescent flame retardants as alternative for halogen based FRs
- The use of multifunctional (nano)chemicals combining flame retardancy with other properties
- Improved surface treatment (UV, spray-drying micro-encapsulation, (atmospheric) plasma pre-treatment,
- Development of instrumental and computational tools for investigation of polymer nanocomposite flammability

5. INFORMATION

Duration : 4 years (23/05/2012 – 22/05/2016)

More information is available via the website : http://www.flaretex.eu

Questions can be sent to the e-mail address : COST.MP1105@UGent.be

6. ACKNOWLEDGEMENTS

cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

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DEVELOPING TEST METHODS FOR ASSESSING PROTECTIVE PERFORMANCE OF BARRIER FABRICS

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Abstract: In residential upholstered furniture, the polyurethane foam (PUF) is the most flammable component. Barrier fabrics (BFs) are often used to protect PUF from heat and flames. For this purpose, the barrier fabrics are placed between the cover fabric and the polyurethane foam. Range of barrier fabrics, including variety of fiber blends, flame retarding technologies, and textile structures, are commercially available. However, the test methods for evaluating barrier fabrics have been limited only as quality control (pass/fail) tool. None of these tests provides an effective tool for screening (quantitatively) BFs. The study is focused on flammability performance of BFs as a component as well as fire behavior of composites incorporating BF component. Effects of fiber content, BF structures, and other physical properties resulting from the structure of the BFs have also been investigated. The thermal protective performance index and smoldering index has been derived from experimental data to rank barrier fabrics.

Keywords: Barrier fabrics, upholstered furniture, fire protective performance, smoldering ignition, flammability

1. INTRODUCTION

The United States Consumer Safety Commission (CPSC) is developing a flammability regulation to reduce the number of deaths and injuries from residential upholstered furniture fires. The CPSC is considering a standard that would require upholstered furniture to be protected with a fire barrier for reducing the fire severity resulting from ignition. Barrier fabrics have been successfully used in mattresses and upholstered seating in mass transport vehicles to comply with open-flame flammability regulation [i,ii]. They are strategically interposed between a cover fabric and the soft cushioning to modify the thermal response of the upholstery by limiting heat and/or gas transfer in the upholstered assembly. In order to improve upholstered product fire safety, a BF must protect the cushioning layer from both flaming and smoldering ignition sources. This study provides insight into the quantitative properties of the BFs that define their flaming and smoldering propensity when used in combination with non-flame retarded, flexible polyurethane foam (FPUF) and cover fabric (CF).

2. MATERIALS AND METHODS

A range of commercially barrier materials including highloft, nonwoven battings, knitted, and woven structures have been studied.

Several different fire tests were performed to assess fire protective performance of barrier fabrics. Heat transfer measurements were made using the Thermal Protective Performance (TPP) test device. Cone calorimeter experiments were performed to distinguish between BFs with respect to ignition times, peak heat release rate (PHRR), total heat released (THR), and char yield. Additionally, fire blocking performance of barrier fabrics was tested with and without the CF using a new bench-scale composite test. The BF was placed between the CF and a FPUF. The back side of the foam was not covered with BF and the CF to duplicate upholstery sequence. The extent of damage to the underlying foam and flame spread was assessed qualitatively.

Smoldering propensity of BFs has been assessed in a small-scale upholstered seating using FPUF/BF/CF mock-up systems and smoldering cigarette was used as ignition source. Smoldering behavior is examined considering char lengths, the mass loss of the complete mock-up assembly, and the fraction of the FPUF used in the mock-up assembly which smoldered during a set time period. A smoldering index for BFs has been derived from the measured char volume fraction (CVF) of the FPUF by varying the BF component in the FPUF/BF/CF mock-up systems, while holding the other two components constant.

3. RESULTS AND DISCUSSION

The area density and thickness of BFs showed a strong influence on heat transfer properties. The process of heat transfer through the fabric is also affected by bulk heat capacity, bulk conductivity, fiber-to-air ratio and air void distribution. A derived parameter is therefore used to rank the BFs using protective index. Under forced flaming ignition conditions, as seen in cone calorimetry, the time to ignition data suggests that the physical thickness does not influence the time to ignition of BFs. All the BFs had relatively short TTI values, but self-extinguished quickly (flame out (FO) time < 60 s), have low PHRR, low TTP, and low THR values. The composite (PUF/BF) assemblies exhibited self-extinguishing behavior when tested in a modified ‘Mydrin’ test.

However, when tested in presence of a cover fabric, most BFs burned with the cover fabric and formed a char in place. Percentage mass loss of these test specimens provided insight into how well the BF has protected the PUF.

In smolder ignition tests, most BFs are smolder resistant when tested alone over a standard flexible polyurethane foam. However, when covered with a smolder-prone cover fabric, most BFs show self-sustaining smolder behavior. The smolder-prone cover fabric is capable of releasing sufficient heat to initiate the char-oxidation smoldering process of some of the BFs and subsequently transmit the heat to the underlying FPUF. A smoldering index for BFs is derived from the measured char volume fraction (CVF) of the FPUF by varying the BF component in the FPUF/BF/CF mock-up systems, while holding the other two components constant.

4. CONCLUSION

This work has demonstrated that the modified TPP test method allows critical BF heat transfer characteristics to be monitored and provides fundamental insight into BF thermal response as it relates to thermal protection of cushioning components (e.g., PUF) in upholstered products. Thus, measurements of heat transfer rate in barrier fabrics are useful in assessing their effectiveness as fire barrier materials. When tested for heat transfer characteristics, the area density and thickness of barrier fabrics have a strong influence. However, when tested as a composite in a mock-up assembly, the fire blocking barrier materials considered in this study showed a clear distinction between active and passive barriers.

Smoldering ignition studies suggested that sustained smoldering could only be initiated in the polyurethane foam when the barrier fabric was covered with a smolder-prone cover fabric. The smoldering propensity of the barrier and the amount of heat transmitted to the polyurethane foam varied depending on the BF structure, fiber content, air permeability, and bulk density.

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DEVELOPMENT OF WATER-OIL REPELLENT AND FLAME RETARDANT COTTON FABRICS BY TREATMENT WITHORGANI-INORGANIC HYBRID MATERIALS

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Abstract: In this study, water-oil-repellent and flame-retardant cotton fabrics were developed by sol-gel technique. With this aim, nanosols were prepared using tetraethylorthosilicate and hexadecyltrimethoxysilane as precursors, guanidine dihydrogen phosphate (GP) as flame-retardant agent, Guard AFB as conventional water-oil-repellent agent, solvents and chelating agents. Then VA7110 as polymeric additives, with FX8000 and urea or urea/formaldehyde (U/F) as cross-linking agents, were added some nanosols to improve washing fastness of the fabric samples. Cotton fabrics were coated with nanosols containing VA polymer by knife-over-roll-coating. Water-oil-repellent properties, flame-retardance properties, washing fastness, contact angle, whiteness, tear strength and add-on values of the coated fabric samples were determined. It was found that the cotton fabrics with good water-oil-repellence and flame-retardance properties with relatively durable properties could be produced using nanosols containing guanidine dihydrogen phosphate and urea, together with tetraethylorthosilicate (TEOS) and hexadecyltrimethoxysilane as precursors, and lower concentrations of Guard AFB as commercial water-oil-repellent agent as our previous research. However, the fabric samples were still not sufficiently durable when washed. In this sutdy, it was deduced that the durability of cotton fabric during washing is developed by means of treatment with nanosols containing VA polymer.

Keywords: Water-oil repellency, flame retardancy, cotton fabric, nanosols, polyvinyl acetate.

1. INTRODUCTION

Sol-gel technology as alternative application method was investigating in textile finishing process on recent decade. There are especially a lot of researches about gaining water-oil repellency properties [1-5] and flame retardancy properties [6-12] to textile materials by sol-gel technology. This paper studied the improvement of multifunctional textile materials with water-oil-repellent and flame-retardant properties by sol-gel technology. Furthermore, the washing durability of water-oil-repellent and flame-retardant properties of the fabric samples was also developed by combining inorganic nanosols with vinyl acetate polymer. In the literature, there is a lack of information about the production of organic-inorganic hybrid materials by sol-gel technology in textile processes. In the literature nanosols with vinyl acetate polymer additive as organic-inorganic hybrid materials were used firstly, to acquire durable water-oil-repellent and flame-retardant properties of cotton fabrics.

2. MATERIAL AND METHODS

Firstly, TEOS was dissolved in ethanol and distilled water to prepare the nanosols. Then aq. hydrochloride solution was introduced to the nanosols for acidic hydrolysis. The GP solution in water, HDMS, Guard AFB as 1/3 rate of concentration in conventional recipe were added to the solution, respectively. Furthermore, the VA 7110 as polymeric additives, with FX8000 or urea/formaldehyde as cross-linking agents, were added and stirred. Experimental parameters were the concentration of GP, the addition of U/F in the study. The fabrics were coated with the hybrid solutions, including nanosols and VA polymer by means of the knife-over-roll coating process using a coating machine (SV Model, Mathis AG, Germany). The coated fabrics were dried using a Nuve dryheat Sterilizer at 100 ^{o}C for 10 min and cured using laboratory type steamer at 160 ^{o}C for 3 min in air.

3. RESULTS AND DISCUSSIONS

In our previous research, it was proved the water repellency properties of fabric samples treated with F1 and F2 recipes without VA polymer addition [12]. In this study, our aim was to improve washing durability of fabric samples without any deterioration of the water-oil-repellence and flame-retardance properties by adding VA polymer to the nanosols. It should be kept in mind that the fabric samples treated with the F1 nanosol recipe have good water-/oil-repellence properties. An increase of the GP amount (F2) in the nanosol recipe containing VA polymer (F1) caused a slight decrease in the contact angle values of the fabric samples. These recipes were also modified by urea and U/F addition to the F1 and F2 recipes (F3, F4, F5 respectively) thus considerably improving their durability by means of the cross-linking effect of U/F. Good and durable water/oil-repellence properties were obtained for the fabric samples treated with F4 and F5 recipes. Their contact angle values were 148^{o} and 150^{o} before washing and then decreased to 144^{o} and 140^{o} after washing. These values were still higher than those for conventional processes, and polymer addition to the nanosols did not cause any deterioration in their water-repellence properties. Oil-repellence values of the fabric samples treated with nanosols with and without VA polymer addition were 8, 8, 8 before and after washing process.

The fabric samples treated with F2 and F5 recipes have durable flame-retardance properties as the vertical flame-retardance testing. Urea and U/F addition and increase GP amount in recipe significantly affected the the LOI values of fabric samples. The fabric samples did not exactly lose their flame-retardance properties after washing treatment (~23.54%). An increase of the GP amount in the recipes containing the polymers brought about a rise in the LOI values of the fabric samples. Better LOI values for the fabric samples after washing were obtained after additing the VA polymer to the nanosols (F1, F2). Then the F1, F2 recipes containing the VA polymer were modified with urea, U/F was added and the GP amount was increased (F3, F4, F5, respectively). The best washing durability for their flame-retardance properties (LOI values) was taken for the F5 recipe containing U/F and twice the concentration of GP (23.54%).

4. CONCLUSIONS

In conclusion, the fabric samples treated with the F4 and F5 recipes had better durable water-oil-repellence, as well as good flame-retardance properties The fabric samples treated with F5 recipe containing the VA polymer were not combustible, even after the washing treatment, according to the results of the vertical flame-retardance analysis. It was concluded that the fabric samples treated with F4 and F5 recipes, containing the VA polymer and U/F, have exhibited durable water-/oil-repellence and flame-retardance properties. In conclusion, a durable water-/oil-repellent and flame-retardant cotton fabric was developed by a one-step nanosol treatment. Using the nanosols has an advantage because a high concentration (400 g/l) of flame-retardant agent in conventional recipes could provide durable flame-retardance properties while the properties after treating with nanosols could be obtained by using lower concentrations of precursors.

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FLAME RETARDANT BACK-COATED FURNISHING FABRICS: THE CHALLENGE TO REPLACE BROMINE-CONTAINING FORMULATIONS

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Abstract: This paper discusses the first part of a study that analyses the strengths of brominated flame-retardants (BrFRs) that are currently used in textile back-coating formulations for upholstered furniture fabrics and challenges faced to replace them. This initial work provides a benchmark in order to assess the efficacy of innovative, bromine-free, alternative treatments. These latter specifically assess these alternative treatments' respective flame retardant efficiency, ability to meet the UK furnishing regulatory standard BS5852 and satisfy durability demands.

Keywords: flame-retardant, textile, bromine, back-coating, flammability, limiting oxygen index.

1. INTRODUCTION

Flame retardants for textiles have been developed over many years to decrease the risk of fire by inhibiting ignition of the material or low flame spread rate. Halogen-based flame retardant back-coatings are commonly used for furnishing fabrics [1, 2]. Currently, one of the most commonly-used synergistic formulations exploited comprises a combination of organobromine compounds with the synergist antimony III oxide due to the advantage of volatility of halogenated and antimony trihalide species. This however, has become the focus of environmental attention because of claimed ecotoxicological properties of brominated chemicals [3, 4, 5]. That said, in the specific case of textiles for domestic furnishing fabrics, flammability testing has been required to possess resistance to cigarette and simulated ignition sources since 1988 in the UK. The simulated BS5852 Source 1 or “match test'' originally developed by UK industry to test experimental fabric flammability in contact with unmodified flexible polyurethane foam [3, 6]. As a consequence of these concerns, flame retardant systems need to be developed to meet the constantly changing demand of new regulations, standards and test methods [7]. The two major brominated flame retardants used, hexabromocyclododecane (HBCD) and decabromodiphenyl ether (DecaBDE) are now scheduled to be withdrawn from use in the EU by 2015 and 2017 respectively. However, much of current research into novel treatments fails to estimate the magnitude of the challenge. This work addresses this in terms of the difficulty in achieving passes to the current UK domestic furnishing flammability requirements.

In this paper three different fire retardants from ICL Ltd have been studied and compared. Initially, an assessment of Sb-Br formulations based on decabromodiphenyl ether (DecaBDE), antimony III oxide (ATO) and an acrylic binding resin (Hycar T-91) have been back-coated on to a 100% cotton fabric to create a “benchmarking” set of flammability results against which future novel treatments may be judged. Flame retardants; TexFRon 9020 and TexFRon P^+, as an alternative to DecaBDE for use as a back-coating in furnishing fabrics, have been investigated in this stage and were compared with that for back-coated fabrics containing DecaBDE and completed a full database with which to compare more novel surface treatments for 100% cotton yet to be studied.

Subsequent work will investigate the novel surface coating techniques (sol-gel and layer-by-layer assembly) applied to different fabrics including cotton and polyester woven tested over both untreated and selected combustion-modified high resilience (CMHR) ether PU foams typically used in domestic furnishings.

2. RESULTS AND DISCUSSION

Three different flame retardants for back-coating on 100% cotton fabrics have been studied:

Decabromodiphenyl ether: Back-coated cotton fabrics were treated with the formulation; resin: DecaBDE: ATO dry mass ratio of 1:2:1 applied as an aqueous dispersion at various add-ons using a K-Hand Coater. Varied %add-ons on the cotton fabric from 40 to 80 wt.% have been tested on the fabric in order to achieve a match test pass. The first dry add-on of the DecaBDE/ATO back-coated fabric which passed the simulated test was determined to be 66 wt.%.

TexFRon 9020 (ICL): The advantage of using Texfron 9020 as flame retardant is the possible reduction of 30% Br and 50% ATO in the back-coating add-on levels. Back-coated cotton fabrics were treated with a resin: TexFRon 9020: ATO mass ratio of 1: 2.3: 0.7 with about 60 wt.% of the FR/resin wet formulations water. The first add-on achieved was 40 wt.% which failed the match test with an after flame time of 194s. By increasing the add-on % to 80, 90 and 107 wt.%, the match test after flame time decreased to 140s. This add-on was considered to be a sensible maximum and so we decided to assume this add-on as almost passed the test.

TexFRon P$^+$ (ICL): The advantage of this fire retardant is that there is no need to use an additional resin because it is already contained within the formulation. The "P$^+$" stands for the addition of an anti-afterglow (phosphorus-containing) additive. Back-coated cotton fabrics were treated with a TexFRon P$^+$: ATO mass ratio of 8:1 with about 45 wt. % of the FR/resin wet formulation comprising water. Numbers of back-coating with the add-ons between 28 to 64 wt.% have been treated and the first sample to pass match test had 56 wt.% add-on.

The full results including fabric and foam damaged length measurements are listed in Table 1. LOI values are plotted in Figure 1 as a function of nominal bromine content. The LOI values for DecaBDE and TexFRon P$^+$ for "match test" passes are almost the same (25 vol%). The TexFRon 9020 pass condition corresponds to a higher LOI value (~31%) in comparison with two other fire retardants. Although for the same add-on % (~40 wt.%), the LOI% values for all three fire retardants series are almost the same (TexFRon 9020 has a slightly higher LOI % value). According to Table 1 and Figure 1, TexFRon P$^+$ requires a lower %add-on and bromine content to pass the match test (10.2% Br) in comparison with TexFRon 9020 and DecaBDE (bromine contents of 15.3% & 16.3 % respectively).

Table 1. The dry add-on of back-coated fabric which passed the simulated test

Fire retardant	Add-on %	Br content %	LOI vol%	Fabric damage length (mm)	Foam damage depth (mm)
DecaBDE	66	16.3	24.8	55	17
TexFRon 9020*	107	15.3	30.7	50	13
TexFRon P$^+$	56	10.2	24.9	195	20

* TexFRon 9020 with 107 dry add-on % has not passed the ''Mydrin test'' (afterflame 140 s).

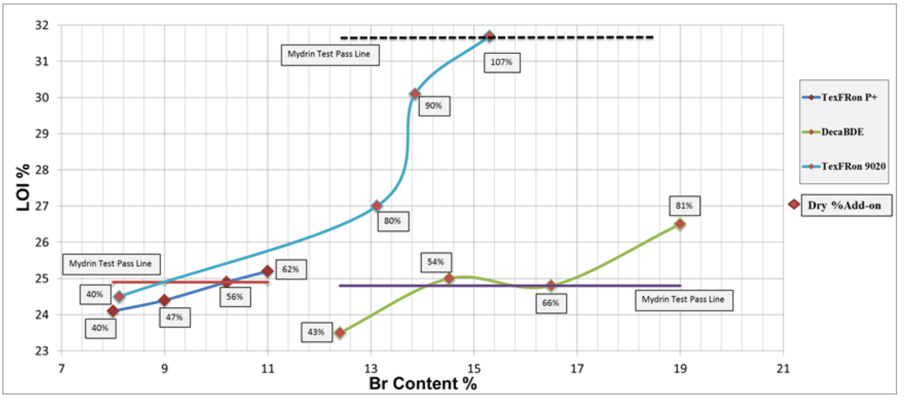

Figure 1. Effect of Bromine content on LOI values of DecaBDE, TexFRon 9020 & TexFRon P^+ series.

3. CONCLUSIONS

By using TexFRon P^+ 35% less bromine content is required in the back-coating formulation to obtain a pass in the simulated BS 5852 test even though the fabric damage length and foam damage depth is higher than that achieved with DecaBDE and TexFRon 9020 coated samples. This suggests that while bromine content can be reduced in the back-coating formulations, it is still a challenge to completely remove it in order to pass UK domestic furnishing flammability requirements. While other novel surface treatments such as sol-gel, layer-by-layer assembly and plasma coatings have been shown to improve textile flame retardant properties, whether they can pass the stringent BS 5852 test, is the topic of our current research.

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HALOGEN-ANTIMONY FREE SYSTEM FOR DURABLE – LIGHT WEIGHT Co AND Co/PES CONSTRUCTIONS

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Abstract: FR protection, comfort and durability – this is actually an acute triade of requested parameters on the emerging market. Existing conventional systems for durable 100% Co and Co/PES blends show usually the significant limitations, mainly negative influences on mechanical-physical and comfort parameters as well as a limited acceptability for PES rich blends. Search for new, technologically simple processing system opening doors for a reproducible, safe and environment- friendly solution was done. Results of study of the halogen/Sb free, low/ free formaldehyde system based on the cleaner P-N chemistry completed by an emerging enzymatic fixative post-treatment will be presented. The newly developed system is wash-permanent due to the simultaneous cross-linking of P/N FR system and its reaction with cellulosic fiber. Results signalize attainability of fully acceptable way to the new, simple technology suitable to be used in the industrial processing.

Keywords: durable FR, Co and PES/Co blends, cleaner production, FR protection and comfort

1. INTRODUCTION

Flameretardancy is one of top-actual functional - protective parameters of textiles. In raising number of applications, also an acceptable wearing comfort (users feeling) and a durability/service life of the treated fabrics after repeated laundry maintenance cycles became to be even so crucial as the protection. On the way to this, the lighter constructed 100% Co, and particularly Co/PES blends with a high PES content (50%) clearly signalizes their suitability to be accepted for various specific areas of use. Namely in case of PPE fabrics and health/elderly people service textiles, the combination of guaranteed FR and harmful substances free solution is necessary. Besides the choice of envi-friendly flame retarder system as such, also the optimum, efficient and safe conditions of the whole finishing system are of significant importance (curing, fixatives). Cleaner production principles lead also to the introductory studies of emerging enzymatic procedures.

2. MATERIAL AND METHOD

Light weight (145 and 190 g/sqm) 100% cotton and PES rich blends (Co/PES 50/50) were used as the testing fabrics – due to their positive improvement of users comfort and significantly longer service-life (by high number of industrial/hospital laundry cycles). Selected formaldehyde and halogen/Sb_2O_3 free flame proofing system for cellulosics and blends used as the FR-compound. The newly developed cross-linking P/N-based FR system was combined with an enzymatic post-treatment for improvement of the FR system fixing on the textile fibre to achieve a reliable wash-permanent FR effect (tested in repeated industrial laundry cycles at 60 °C). Resulting FR properties after the finishing and in course of the repeated washings were evaluated according to relevant FR standards regarding to the potential ends-use applications: EN ISO 15025, EN ISO 14116 (Protective clothing), EN ISO 6940 (Draperies, vertically oriented samples), EN ISO 12952-1, 2 (Bed-linen). Simultaneously the content of and organically bound phosphorus and nitrogen on textiles (Kjeldahl method) was assessed to observe the stability of the FR system on the fibre. The influence of The FR finishing on mechanical-physical properties of the finished fabrics (Tensile strength: EN ISO 13934-1, Tear Strength: EN ISO 13937-1, Stiffness ČSN 80 0835), physiological parameters (Air permeability: EN ISO 9237, Breathability: EN ISO 15496 and Moisture Transport: AATCC TM 195 - MMT SDL Atlas) and also on the colour shade (dE*) and whiteness degree (Berger) of fabric were evaluated. Properties of 100% cotton and Co/PES 50/50 blend were compared to evaluate the influence of PES content on resulting barrier properties and mechanical – physical and physiological parameters (service-life prolongation).

3. CONCLUSIONS

The introductory study of combination of selected P/N formaldehyde and halogen/Sb_2O_3 - free curing systems with suitable fixatives demonstrates that the viable, simple and reliable wash-permanent FR finishing alternative comparable with current FR finishing systems exists. The newly developed FR system is firmly fixed to the textile fibre (P, N content on the fibre remains the same after repeated washing at 60° C). The FR effect and its durability in washing reached at 50/50 Co/PES fabrics is the same as reached at 100% cotton. The content polyester in this blend results in a higher strength of the fabric compared with pure cotton which leads in better mechanical parameters and resistivity during use and maintenance cycles incl. the service life prolongation The acceptable touch, no influence on whiteness degree are the next supplementary advantages of the newly developed FR system. This open doors for technologically conventionally attainable method giving a new challenge for the comfortable and safe textiles for many end-use applications incl. textile for health care sector (patients and staff clothing, bed linen, drapes; PPE; hotels, etc.).

INORGANIC-ORGANIC HYBRID COATING BASED ON SOL-GEL PROCESS FOR IMPROVING FLAME RETARDANT PROPERTIES OF COTTON FABRICS

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Abstract: Inorganic-organic hybrid coatings composed of phosphorus-, nitrogen- and silicon-containing compounds were synthesized and deposited on cotton fabric through sol–gel process in order to improve the flame retardant properties. These inorganic-organic hybrid coatings were characterized by nuclear magnetic resonance. The hybrid coating system improved the thermal stability of the cotton due to the protective effect of underlying cotton from degradation, and also significantly improved the char yield. In a vertical flame test, fabrics coated with the hybrid coating extinguished the flame immediately upon removing the ignition source, while untreated cotton was burned out. The superior fire retardant performance is attributed to the formation of thermally stable char layer on fibers that could effectively inhibit the oxygen and heat permeation when burning. The work reported here will broaden the application of silicon hydrogel as a promising candidate for flame retardant coating system.

Keywords: inorganic-organic hybrid coating, cotton fabrics, flame retardant properties, sol–gel process

1. INTRODUCTION

The fire statistics in the past several years illustrate that fire accidents occurred in civilian homes have led to considerable fire-related fatalities and amount of property damage [1, 2]. Ignition of household textiles is one of the most common fire reasons accounting for the residential home fires, particularly with respect to upholstery and mattresses. Therefore, various textiles fire safety regulations and legislation have been made in order to save lives and protect property. Various strategies have been developed to obtain fire retardant fabrics: surface photo-induced grafting treatment [3], fire-retardant additives [4] or co-monomers [5] in synthetic fabrics, fiber blending [6], etc. In this work, inorganic-organic hybrid coatings were developed and deposited on the surface of cotton fabrics based on sol-gel technology. The fire resistance and the related mechanism were investigated by vertical burning test and thermogravimetric analysis technique.

2. MATERIAL AND METHOD

2.1. Raw Materials

Cotton fabric with a density of 800 g/m^2 was kindly supplied by Beijing Institute of Fashion Technology. 3-Aminopropyl triethoxysilane (APTES), phenylphosphonic dichloride (PPDC) and ethanol were purchased from Sigma–Aldrich and used as received. Deionized water is used for all experiments unless otherwise stated.

2.2. Synthesis of flame retardant hybrid coating

The flame retardant hybrid coating was synthesized from the reaction between APTES and PPDC, as shown in Figure 1. APTES (0.04 mol) was introduced into a three-necked round bottom flask equipped with the ice bathing. Subsequently, PPDC (0.02 mol) was added dropwise in 2 hrs and maintained the reaction at room temperature overnight. A transparent and viscous liquid named PPD-PTES was obtained.

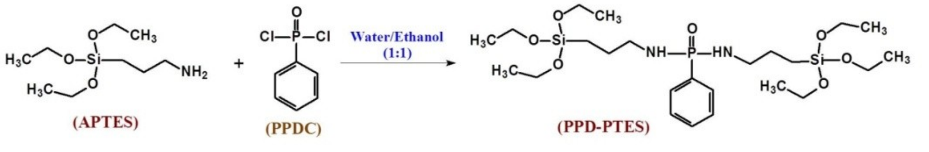

Figure 1. Synthetic route of the flame retardant hybrid coating

2.3. Preparation of coated cotton fabrics by sol-gel technology

PPD-PTES was added into a mixture of ethanol and water (1:1) to obtain a 10 wt% solution. The mixture was stirred for 4 h to allow hydrolysis and pre-condensation to form a silicon hydrogel. A piece of cotton fabric was immersed into the 10 wt% PPD-PTES solution for 5, 10, 20 and 30 min, and then dried under air. Thus, a series of flame retardant treated cotton fabrics were obtained.

2.4. Characterization

^1H-, ^{29}Si- and ^{31}P-NMR spectra were recorded on a Bruker AVANCE-500 NMR spectrometer operating in the Fourier transform mode using DMSO-d_6 as solvent. Thermogravimetric analysis (TGA) of the samples were performed on a Q50 thermal analyzer (TA Instruments, USA) from 30 to 700 ^oC at a heating rate of 10 ^oC min^{-1} in nitrogen atmosphere. The vertical burning characteristics of the samples were measured according to ASTM D 1230-94 standard method. Five parallels for each sample were processed and an average of the data was used for interpretation. The burning behaviour of the samples was also evaluated using micro-scale combustion calorimeter (Fire Testing Technology, UK) according to the ASTM D7309 standard. Surface morphology of un-coated and coated cotton fabrics after burning was observed with a scanning electron microscopy (SEM, EVO MA15, Zeiss, Germany). All the samples were coated with a conductive layer of gold prior to SEM observation.

3. RESULTS AND DISCUSSION

The flame retardant properties of the treated cotton fabrics are evaluated by vertical flame tests, and the images during the flammability test were taken, as shown in Figure 2. After removing the ignition source, the un-coated cotton burns very vigorously and completely consumes at 30 s. Treated by PPD-PTES for 5, 10, 20 min, the cotton fabrics still cannot stop the fire spread and finally the fabric burns to the top. However, the flame propagation rate on the fabric decreases after the treatment by the coating. In the case of the cotton-30min fabric, the flame extinguishes immediately upon removing the ignition source, leaving behind a small charred area. This phenomenon means that the char formed in cotton-30min is stable enough to inhibit additional cotton from burning.

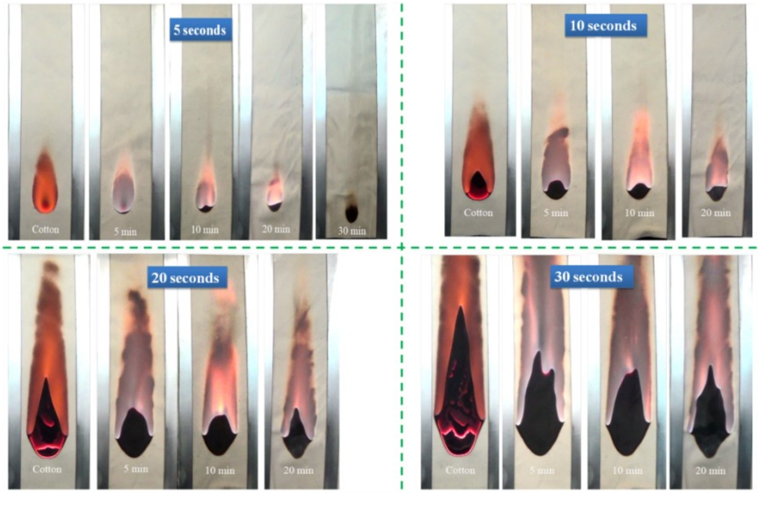

Figure 2. Snapshots showing vertical flame tests of the control and coated cotton recorded at 5, 10, 20 and 30 s.

4. CONCLUSION

In conclusion, hybrid coating composed of phosphorus, nitrogen and silicon elements was successfully deposited on cotton fabric through the sol-gel process technique. By applying this hybrid coating on cotton fabric, flame was immediately extinguished on fabric coated with PPD-PTES. The enhanced fire resistance by the presence of the hybrid coating was mainly attributed to the formation of thermally stable chars to shield the underlying materials from ignition. This study demonstrates the sol-gel method is an effective and environmentally friendly route to current flame-retardant treatments.

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MULTI-FUNCTIONALITY OF TEXTILE META-STRUCTURES

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Abstract: The paper presents the elements that are necessary and sufficient to the understanding of the notion of multifunctional meta-textile structure. The first part of the paper presents a synthesis of the results obtained in the field of “invisible” metamaterials (optical cloaks, acoustic cloaks, thermal cloaks) and a mathematical model of an invisible multifunctional meta-textile structure taking into consideration the design of such a structure. The second part of the paper presents the theoretical concepts of transformations thermodynamics to exemplify the dynamic flow of heat around an object as if no object was there.

Keywords: multi-functionality, textile meta-structures, optical/acoustic/thermal cloak.

1.INTRODUCTION

Advanced industrial technologies, directly or indirectly, exert their beneficial influence, generated by progress, in the fields of the social-economic life, in such a way that these fields seek to harmonize the development in view of a common benefit. Since, from the social and economic points of view, textile industry represents a major technology user; it is natural that it should try to address all challenges in a positive way. The benefit is mutual: technology identifies a user (*consumer*) that is directly interested, willing to make investments in order to adapt both the methodology and the manufacturing process to the new technical requirements, while the *consumer* (user) assesses the effectiveness of the envisaged investment, following that it should be recovered during application of the accepted flow (raw-materials-manufacturing process-trading).

Technological advances achieved over the past 25 years have led not only to great technologic results, but also to theoretical reconsiderations which were unimaginable 30 years ago. It is enough to mention here only two very conclusive examples, namely *metamaterial.*

"The concept of metamaterials was first introduced in the field of electromagnetic (EM) materials. Here it came to mean a material whose effective properties arose not from the bulk behavior of the materials which composed it, but more from their deliberate structuring. Therefore, metamaterials sit at the intersection of two classical categories, materials and devices. Our definition of metamaterials in this review is somewhat broader than what conventionally defined as it includes all MNSMs regardless of a relative scale ratio between the characteristic structural length and the wavelengths of EM or mechanical waves. In the conventional (narrower) definition of metamaterials, the characteristic length scale of their structures is one or more orders smaller than the wavelengths"[2].

2.1 THE MATHEMATICAL MODEL OF THE EXTERNAL LAYER FORMED OF AN INVISIBLE METATEXTILE STRUCTURE [1-2]

2.1.1 The material point hypothesis.

Each intersection between a warp yarn and a weft one is a distinct material point (figure 1), perfectly pointed out. This means that the two determined yarns have the same and only material point, as if they were connected. The mass of the material point results from the even distribution of the textile area mass on all over the material points above mentioned;

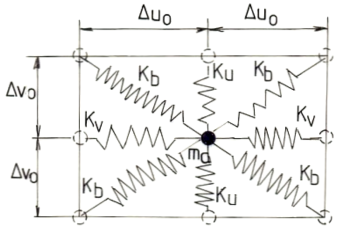

Figure 1: The cloth 'atom'

2.2 The hypothesis of the elastic bonds.

Each material point ("atom") is connected with at the most eight neighboring material points, two by two on each warp and weft yarn and with other four on biè (figure1).This connection is a perfect elastic bond when it is subjected to tensile stresses, following Hook's Law.

2.1.2 The hypothesis of the electrical properties of yarns.

The yarns are electro-conductibilities.

2.1.3 Equations of motion

$$\begin{cases} m\ddot{\mathbf{X}}_i = \boldsymbol{\phi}_{ij} + \mathbf{F}_i + \mathbf{F}_{\mathbf{i,em}} - \beta\dot{\mathbf{X}}_i \\ i = 1,2,\dots N_m,\ j \in V_i \end{cases} \quad (1)$$

$\boldsymbol{\phi}_{ij}$ – *elastic force*

$\mathbf{F}_i$ – *exterior force*

$\mathbf{F}_{\mathbf{i,em}}$ – *electromagnetic force* (*Lorentz*)

$-\beta\dot{\mathbf{X}}_i$ – *damping force*

$V_m - N_m$ *the number of free nodes that belong to the texti le field*

2.1.4 Equations of Maxwell

$$\nabla\mathbf{E} = \frac{1}{\varepsilon_0}\rho \quad (2)$$

$$\nabla\times\mathbf{E} = -\frac{\partial\mathbf{B}}{\partial t} \quad (3)$$

$$\nabla\mathbf{B} = 0 \quad (3')$$

$$\nabla\times\mathbf{B} = \mu_0\mathbf{J} + \mu_0\varepsilon_0\frac{\partial\mathbf{E}}{\partial t} \quad (4)$$

2.1.5 Constitutives laws

$$\mathbf{D} = \varepsilon_0\mathbf{E} \quad (5)$$

$$\mathbf{B} = \mu_0\mathbf{H} \quad (6)$$

$$T_{ik} = \varepsilon_0\left(E_iE_k - \frac{1}{2}\delta_{ik}e^2\right) + \frac{1}{\mu_0}\left(B_iB_k - \frac{1}{2}\delta_{ik}B^2\right) \quad (7)$$

where:

$\boldsymbol{E}$ - electric field

$\boldsymbol{B}$ - magnetic field

$\boldsymbol{J}$ - current density

ρ - change density

ε_0 - permittivity of free space

μ_0 - permeability of free space

T_{ik} - tensor of tension

e - electric charge

δ_{ik} - Kronecker symbol

The mathematical model obtained links variable to the electromagnetic variable permitting the interaction between the textile structure and the surrounding electromagnetic field.

Equations are written for each node (linking point) of the textile (structure) network therefore depending on the density there can be thousands of equations with partial derivatives to which the boundary conditions are added. It is clear that the solution to such a huge system of equations can only be found by GRID networks specific methodology, the only methodology that can lead to an acceptable numerical solution.

2.2. MATHEMATICAL MODEL OF THE DEFORMATION OF AUXETIC WOVEN TEXTILE STRUCTURES

The mathematical model used for the study of the deformation of auxetic textile structures can be, as a matter of fact, considered an adaptation of Butoescu V. model [3] to auxetic textile structures in a GRID network. In comparison with the initial model, the fundamental difference is the fact that GRID network equations accept millions of numerical solutions, and at the same time, it presents particular challenges for error control and for other specific characteristics of this work method. The fact that grid networks are compatible with the calculation of matrices of such dimensions leads us to formulate the essential work hypothesis which is that in this case each connection point is biunivocally represented in the model, so that each “atom” point is presented with the material specific characteristics. Because the study used the values obtained for parachute fabrics, this model eliminates the hypothesis of the existence of “oblique” reactions. Because the model is detailed in [3], we shall underline the essential elements specific to auxetic woven structures that can be solved as grid networks and the methodology for grid network calculation.

2.2.1 Description of the mathematical model specific to these auxetic woven structures

Butoescu’s model [3] shall be adapted to the grid network work method. Therefore, the work shall be done not with fictitious yarns, but with the yarns in the woven fabric, in this case the warp and weft yarns and the connection points shall be considered mass points – points in which the mass of each fabric “atom” is concentrated. Furthermore, rigidities K_u and K_b depend on Poisson ratio. The elastic forces in the yarns are given by the [2] expressions:

$$\mathbf{\Phi}_{ij} = \begin{cases} \boldsymbol{K}_{ij}(\nu)\left(1 - \dfrac{\left|\mathbf{X}_{ij}^{o}\right|}{\left|\mathbf{X}_{ij}\right|}\boldsymbol{X}_{ij}\right)\cdot\dfrac{\mathbf{X}_{ij}}{\left|\mathbf{X}_{ij}\right|}, & \boldsymbol{if}\ \left|\mathbf{X}_{ij}^{o}\right| \le \left|\mathbf{X}_{ij}\right| \\ 0, & \boldsymbol{if}\ \left|\mathbf{X}_{ij}^{o}\right| > \left|\mathbf{X}_{ij}\right| \end{cases} \quad (8)$$

in which *i,j* are indices for the connection point situated at the intersection of the "i" weft yarn with "j" warp yarn. The index *j* takes values for the neighbouring nodes of *i* node rigidity values must be linked to Poisson ratio, corresponding to *ij* region in the system. $\mathbf{X}_{ij}$, is the position vector of *(i,j)* point and "0" index, indicates the initial position of a point. The equations of motion for point *I* are:

$$m\ddot{\mathbf{X}}_i = \boldsymbol{\phi}_{ij} + \mathbf{F}_i + \mathbf{F}_{\mathbf{i,em}} \quad (9)$$

In which *i* takes values for all the network nodes and $\mathbf{F}_i$ is the external force acting in *i*.

2.2.2 Elastic equivalence of elastic membranes and certain textile structures [5]

There are many situations in which, in order to study certain characteristics (especially those related to elasticity and resistance) of the textile structures, we need to use numerical methods that evidence by means of calculations firstly, the "compatibilities" of the elastic behaviour of the studied samples.
This way we are led to the concept of elastic equivalence of two samples: when subjected to identical stresses, two geometrically identical bodies have identical behaviours. Thus, under identical loads we get the same results (tensions, deformations) for both. A concrete example is given by the walls of arteries in the human body – they are elastic and resistant walls that can be assimilated to an elastic membrane with similar properties. If there is a need to replace such arteries, one of the searched for characteristics is the elastic behaviour – a textile structure that, from an elastic perspective, behaves the same as the original artery. Once this concept is clear, we can work towards the proposed objective: a numerical model of the elastic behaviour of a membrane, a problem solved within the limits of the theory of elasticity by using dedicated products such as ABACUS, COMSOL MULTIPHYSICS. In the figure below the tension state is presented for two elastic membranes with opposite Poisson ratios – for the first case v is 0.3 and for the second case it is -0.3. We can now approach the problem of finding a textile structure that is elastically equivalent to the elastic membrane. It is a challenging problem, as the textile structure is a

discontinuous medium, therefore using the above products is forced upon this problem (meaning that in many instances the discontinuity of the textile structure leads to errors). There is a need for a closer method to have a correct modelling of the textile structures. One of the methods is the model presented in this paper. The work methodology shall be presented in the following part of the study.

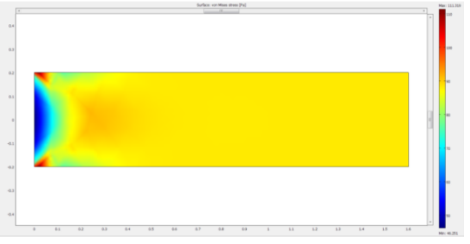

Figure 2 a) Conventional case

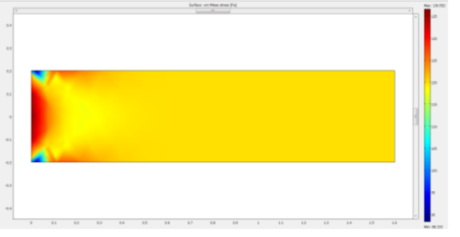

Fig. 2 b) Auxetic case

2.2.3 RESULTS AND DISCUSSION

For calibrating the model, parachute samples type T40-200 with the following characteristics were used: mass 60 g/m^2; thickness 0.13 mm, D_u = 628/10 cm; D_b = 615/10 cm; the yarn used was PA 6, warp yarn fineness was of 4.5 Tex and the warp yarn diameter was of 88 µm . As regards the weft yarn the diameter is 86 µm, fineness 4.5 Tex. Textile sample is treated as a membrane that is numerically simulated and then we compare the values obtained by the first method (the one using COMSOL MULTIPHYSICS) with those obtained using GRID networks. Some calculations are presented in Table 1. As can be seen in COMSOL MULTIPHYSICS product simulation (column 3 and 5), the values obtained in the auxetic case (Fig. 3 b) are superior to those obtained in the conventional case (Fig. 3 a.). As regards the second method, a number of 628x615 points were used for the connection points. It can be seen that generally the values obtained by GRID processing are ranging around the values obtained by the conventional method.

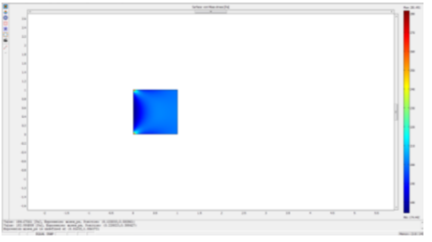

Figure 3 a) Conventional case

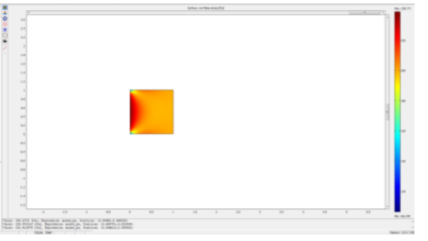

Figure 3 b) Auxetic case

We used the following values: density 1150 kg/m3 wire, 2e9 Young's coefficient [Pa] and the Poisson ratio is 0.2. Auxetic case was considered for the Poisson value -0.2.

Table 1. Values calculated by simulation on COMSOL MULTIPHYSICS and grid network

Coordinate x	Coordinate y	Conventional Von Mises [Pa]	Conventional Grid	Auxetic Von Mises [Pa]	Auxetic Grid
0.25	0.55	193.5	191.8	208.4	205.6
0.48	0.45	201.1	199.7	212	210.9
0.59	0.45	201.7	200.1	199	200.6
0.49	1	193.7	194	207	205.7
0.48	0	193.6	191.8	206	204.7
0.4	0	191.7	193.	207.2	205.3
1	0.46	201.4	200.5	198.53	200.7
0.01	0.01	282.2	283.1	278.1	276.5
0.08	0.62	212.5	213.1	229	227
0.04	0.6	226.7	227.1	232	231.4

2.3 Thermal cloak [6-17]

As similar to the invisible cloak and the acoustic cloak, the researchers are trying to design the thermal cloak. A first approach was the use of coordinate transformers. An interesting outcome is due to S. Guenneaux and his collaborators research within the German studies, which has been shown within the work [6]. The authors of the research design both an experiment device, as well as a model for thermal numeric simulation using Comsol. The results of the calculations are checked by the experiment measurements using a conventional of infrared thermal device (FLIR A320). Due to the experience in time, the authors have created a meta-material micro-structure with strong anizotrop nature from a thermal point of view.

They used relationships:

$$k_\theta = k_0\left(\frac{R_2}{R_2-R_1}\right)^2 \geq k_0 \quad (10_a)$$

$$k_r = k_0\left(\frac{R_2}{R_2-R_1}\right)^2 \left(\frac{r-R_1}{r}\right) \leq k_0 \quad (10_b)$$

where: k_0 is the heat conductivity of surrounding of the cloak, and $(k_\theta,\ k_r)$ azimuthal and radial components of the conductivity tensor $\overleftrightarrow{k}$ in the interval $[R_1,R_2]$.

The experiment device consists of a copper plate (see fig. 4 adapted after ref[6]) where same thickness rings were designed and the copper rings suffered some drilling of different holes so that each ring is anizotrop (from a thermal point of view).

The holes (which are white in fig. 4) have been filled with polydimetilxiloxane (PDMS), and the "i" metal section of each ring, indicated by f_i, allowed for a calculation of an efficient coefficient of thermal conductivity associated to the "i" ring (i,j=1-10 and $f_i \neq f_j$ for $i \neq j$) determined by the following relation $k_i=f_ik_{Cu}+(1-f_i)k_{PDMS}$. The following values have been used: k_{Cu}=394 W/(Km), k_{PDMS}=0.15 W/(Km), k_0=85W/(Km).

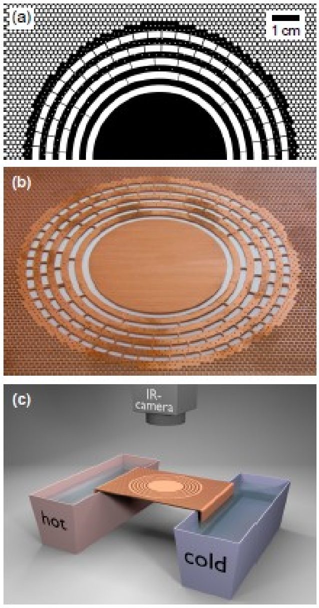

Figure 4

a) The black regions are bul copper, the white regions polydimethylsiloxane (PDMS) with heat conductivities of 394W/(Km) and 0.15W/(Km), respectively; b) the radial and azimuthal components of the effective local heat conductivity;c)scheme of experiment.

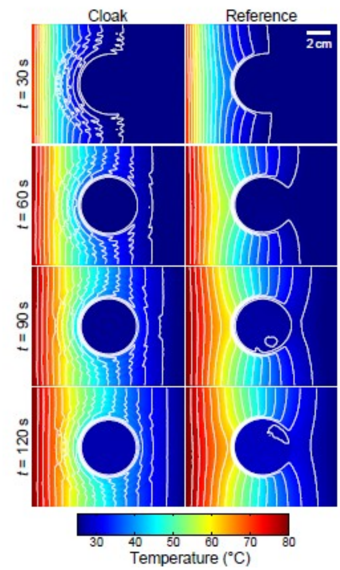

Figure 5. Measured temperature distributions at differenties as indicate (Ref[6])

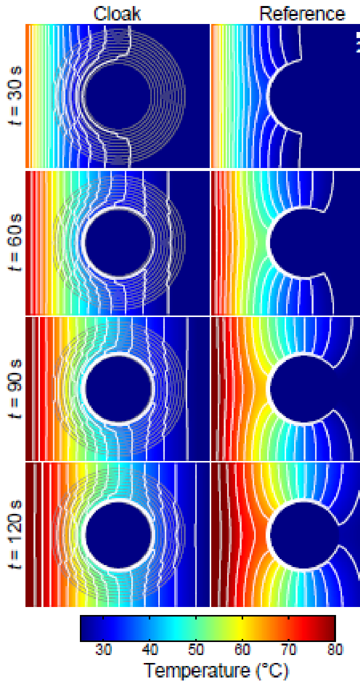

Figure 6. Calculated temperature distribution shown as the experimental in fig. 5

4. CONCLUSION

A hypothetical model of "multifunctional invisible" textile structure was presented. This structure is formed of two layers: an external one that ensures the "invisibility" of the textile structure as a whole and an internal one consisting of an auxetic structure. For the internal layer, a concrete case of design of such a structure will be presented (mathematical modeling and numerical results). For thermal cloak we use the theoretical concepts of transformations thermodynamics, and we realized a cloak that molds the dynamic flow of heat around an object as if no object was there.

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SILICA PRECURSOR FOR IMPROVING FLAME RETARDANCY OF COTTON TREATED WITH UREA/AMMONIUM POLYPHOSPHATE

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The cotton and its blends is the most commonly used textile material in the design and production of protective clothing. However, as the cellulose textiles are the most flammable materials it is necessary to improve its flame retardancy. The government regulations have been the driving force for developing durable flame retardants finishes for textile, to improve its performance and to reduce the negative impact on the environment.

Therefore, this paper investigates the effect of silica precursor (tetraethoxysilane - TEOS) added in bath with conventional flame retardant urea/ammonium polyphosphate for achieving environmental-friendly cotton flame retardancy. Silica precursors have excellent thermal stability and high heat resistance with very limited release of toxic gases during the thermal decomposition.

Thermal properties of treated cotton fabrics were determined by Limiting Oxygen Index (LOI), thermogravimetric analysis (TGA) and Microscale Combustion Calorimeter (MCC).

Keywords: cotton flame retardancy, urea, ammonium polyphosphate, TEOS, LOI, TGA

1. INTRODUCTION

Cotton is one of the most flammable materials. In the case of fire, cotton materials represent a major risk as burning strong and fast. Because of the usefulness of cotton and its blends, it is the most commonly used textile material in the design and production of protective clothing, temporary and permanent drapes, bed covers, mattress covers, furniture fabrics etc. Therefore, it is necessary to enhance flame retardancy of cotton fabrics.

According to Horrocks [1], all flame retardant cottons are usually produced by chemically after-treating fabrics as a textile finishing process. Depending on its chemical character and cost, it yields different flame retardant properties. Cellulosic textiles are treated with those flame retardants that increase char or non-combustible products, usually organic phosphorous-based flame retardants. Urea as synergist with phosphorous-based flame retardants helps them in phosphorilation process of cellulose catalyzing the dehydration of cellulose and increases the char [2].

This paper discuss about the improvement of cotton flame retardancy by using precursors of silicon alkoxides; tetraethoxysilane – TEOS. For that purpose, cotton fabric was treated tetraethoxysilane – TEOS without or/and with addition to conventional flame retardants – urea/ammonium polyphosphate in full and half concentration. Silica precursors have good heat-resistant property and produce high residue after burning process [3-5].

2. MATERIAL AND METHOD

Chemical bleached cotton fabric (untreated) of mass per unit area 208 g/m2 was treated by pad-dry-cure procedure in Benz Pad-dry system. The cotton fabric was impregnated in bath containing urea/ammonium polyphosphate in two concentrations (UREA240_APP100 and UREA120_APP50) , Tetraethoxysilane (TEOS15) in concentration of 15 ml/l was added in bath with conventional flame retardants urea/ammonium polyphosphate. In continuous process impregnated fabric having wet pick of 100% and it was dried at 110 °C for 5 min and afterwards cured at 150 °C for 2 min. The labels and the composition of flame retardant mixtures in padding bath are listed in Table 1.

Burning behaviour of fabrics was determined according to ISO 4589:1996 – Plastics – Determination of burning behaviour by oxygen index in LOI Chamber (Dynisco).

Synergistic effect (SE) was also take into consideration in discussion. It is calculated to the following equation in order to establish the real action of urea and TEOS.

$$SE = \frac{(Fp)_{fr+s} - (Fp)_p}{\left((Fp)_{fr} - (Fp)_p\right) + \left((Fp)_s - (Fp)_p\right)}$$

where (Fp) is a given flammability parameter, $(Fp)_p$ is the flame-retardant property of the neat polymer (cotton), $(Fp)_{fr}$ is that of the polymer treated with the flame retardant (cotton treated with two flame retardant - APP and second one urea/APP), $(Fp)_s$ is that of the polymer treated with the synergist (cotton treated with urea as synergist when only APP used as flame retardant and in another treatment when urea and APP used as flame reatardand TEOS was used as synergist), and $(Fp)_{fr+s}$ is that of the polymer treated with both flame retardants and synergist. In particular, SE>1 means synergy; 0<SE> 1 points out a simply additive effect; finally, SE<0 implies antagonism [5].

For better understanding of the change in cotton thermal properties under the heat Thermogravimetric analysis (TGA) and Microscale Combustion Calorimeter (MCC) were done. Thermogravimetric Analysis (TGA) was performed on TGA Pyris1 (PerkinElmer) where 5 mg of sample was stacked in an open platinum pan.

Table 1. The labels and the composition of flame retardant mixtures in padding bath

Label	**The composition of flame retardant mixtures**
0	Untreated chemically bleached cotton fabric
TEOS15	Sol-gel proces with 15 g/l TEOS disolved in 10% solution of ethanol
UREA240	Cotton fabric treated with 240 g/l urea
UREA120	Cotton fabric treated with 120 g/l urea
APP100	Conventional flame retardant treatment containing: 100 g/l ammonium polyphosphate
APP50	Conventional flame retardant treatment containing: 50g/l ammonium polyphosphate
UREA240_APP100	Conventional flame retardant treatment containing: 240 g/l urea and 100 g/l ammonium polyphosphate
UREA120_APP50	Conventional flame retardant treatment containing: 120 g/l urea and 50 g/l ammonium polyphosphate
UREA240_APP100_TEOS15	Sol-gel proces with conventional flame retardant treatment containing: 15 g/l TEOS, disolved in 10% solution of ethanol and 240 g/l urea and 100 g/l ammonium polyphosphate
UREA120_APP50_TEOS15	Sol-gel proces with conventional flame retardant treatment containing: 15 g/l TEOS, disolved in 10% solution of ethanol and 120g/l urea and 50 g/l ammonium ammonium polyphosphate

The mass loss as a function of the temperature was measured in air atmosphere within the range from 45 °C to 800 °C with a heating rate of 30°C/min.

Microscale Combustion Calorimeter (MCC) tests were done according to ASTM D 7309 on MCC-2, Govmark, USA. The 5 mg of test sample (three samples per each system) were placed within the sample cup and test is performed under the following conditions: pyrolysis operating temperature range of min. 25°C to 600°C at a heating rate of 1 K/s in an inert gas stream (nitrogen, 80 ml/min); detection sensitivity limit of min. 5 mW, repeatability of ± 2 %.

Breaking force were determined according to standard methods (EN ISO 13934-1:1999 - Textiles -Tensile properties of fabrics - Part 1: Determination of maximum force and elongation at maximum force using the strip method).

3. RESULTS AND DISCUSSION

Burning behaviour of untreated and urea/ammonium polyphosphate with/without TEOS treated cotton was researched through LOI tests according to ISO 4589 standard. These results are collected in Table 2. According to these results, it can be seen that untreated cotton burns rapidly when present 19% of O2, only. Application of present flame retardants improved its burning behaviour. Cotton fabric treated with full concentration of urea/ammonium polyphosphate show a high LOI 43 %. When concentration of ammonium polyphosphate is reduced by half LOI values fall on 28% which is to be expected, but still having good properties. TEOS added in the both bath improved LOI for one to two unit as silica makes thermal barrier to returning heat.

Table 2. LOI values of untreated and treated cotton fabrics

Samples	LOI	t 100 mm [s]
0	19	105
TEOS15	19	107
UREA120	21	121
UREA240	22	135
APP50	26	73
APP100	32	70
UREA120_APP50	28	65
UREA120_APP50_TEOS15	30	73
UREA240_APP100	43	72
UREA240_APP100_TEOS15	44	53

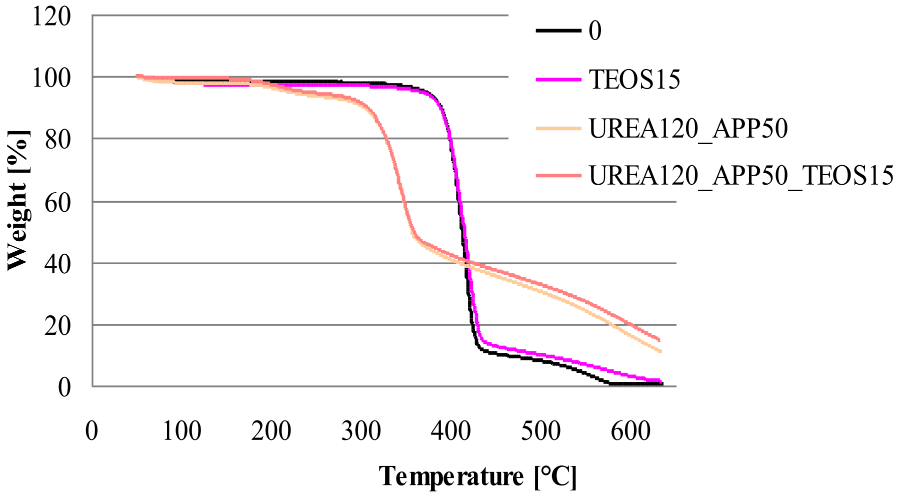
Urea and TEOS alone are not responsible for any significant LOI increase for cotton. Conversely, urea and ammonium polyphosphate in same bath increase cotton LOI from 19 to 28 and 43 (referring to the lowest and highest bath concentration, respectively); From Table 3 is shown synergistic effect (SE-UREA240_APP100=1,5) between urea and ammonium polyphosphate for highest bath concentration. When TEOS as synergist added in the bath with another flame retardant, urea/ammonium polyphosphate, SE calculated confirms the occurrence of synergism between TEOS and urea/ammonium polyphosphate in highest bath concentration (SE-UREA240_APP100_TEOS15=1,22)

Table 3. Synergistic effectiveness (SE) parameter based on LOI data

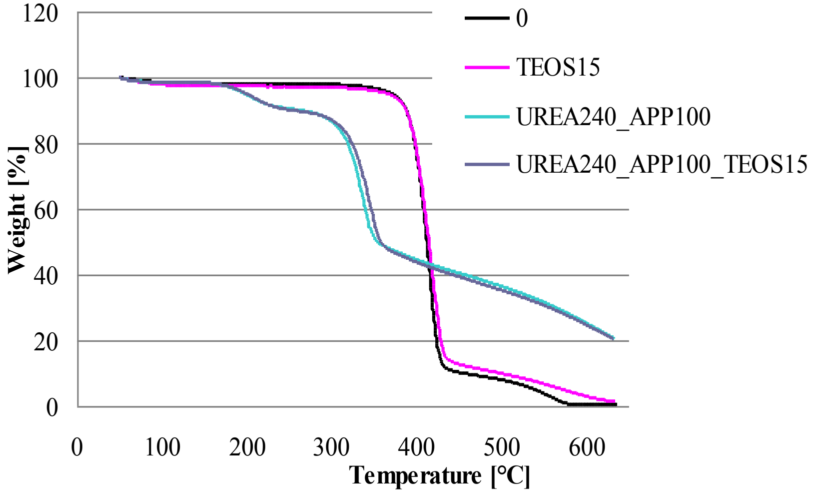
Samples	Synergistic effectiveness
SE-UREA120_APP50	1,02
SE- UREA240_APP100	1,5
SE-UREA120_APP50_ TEOS15	1,22
SE- UREA240_APP100_TEOS15	1,04

From Figure 1 and Table 4 it has be seen that the thermal degradation of cellulose takes place at 300–400 °C through two steps, namely by dehydration and depolymerisation processes. [3].

Cotton treated with urea/ammonium polyphosphate in full and half concentration starts with degradation at the lower temperature then untreated cotton ($T_{onset5\%}$ (UREA240_APP100) = 196 °C i $T_{onset5\%}$ (UREA120_APP50) = 226 °C, $T_{onset5\%}$(0)=312 °C). The temperature at the maximum mass loss for samples treated with urea/ammonium polyphosphate were also lower than untreated cotton (T_{max1} (UREA240_APP100) = 337 °C, T_{max1} (UREA120_APP50) = 346 °C, T_{max1}(0)=356 °C). A reason for this is the presence of phosphor and nitrogen in ammonium polyphosphate. Thermal degradation induced the char promotion from cotton and inhibited the production of volatile species. Phosphor based compounds generally acts in condensate phase in this process, depolymerisation reactions are stopped and the dominant reaction is the dehydration. This is evident form increasing char at the end of thermal decomposition. Char residue for samples treated with full concentration of urea/ammonium polyphosphate is 20,1% and for half concentration of same treatment is 11,2%.



a)



b)

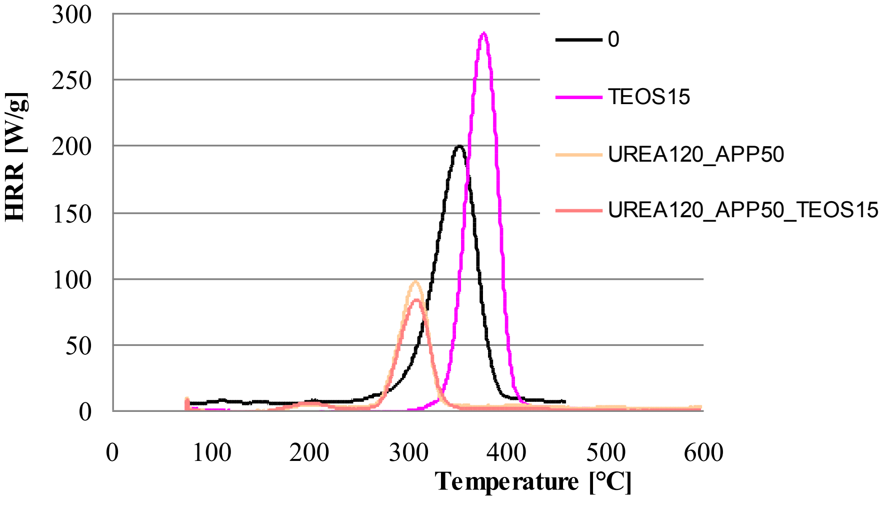
Figure 1. TGA curves of untreated and treated cotton fabric with urea/ammonium polyphosphate in half (a) and full (b) concentation with/without TEOS

When TEOS added in bath with full and half concentration of urea/ammonium polyphosphate thermal degradation of cotton fabric started at the similar temperature as cotton fabric treated with urea/ammonium polyphosphate.

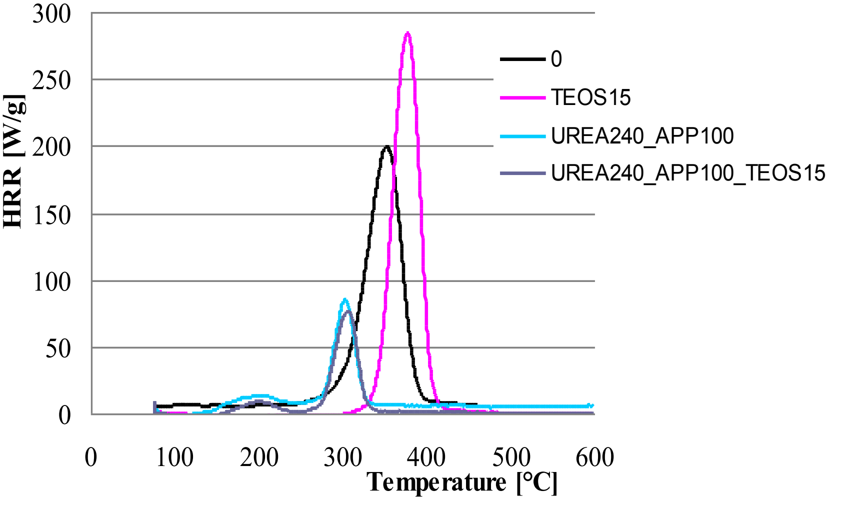
Table 4. TGA data of untreated and treated cotton fabric with urea/ammonium with/without TEOS

Samples	$T_{onset\ 5}$ [°C]	T_{max1} [°C]	Residue at T_{max1} [%]	T_{max2} [°C]	Residue at 650 °C [%]
0	312	356	48,8	481	0
TEOS15	364	419	41,6	577	1,7
UREA120_APP50	226	346	61,4	587	11,2
UREA120_APP50_TEOS15	238	346	32,6	591	14,7
UREA240_APP100	196	337	62,9	555	20,1
UREA240_APP100_TEOS15	207	345	61,5	538	20,0

The char residue was increased by the addition of TEOS but only for a half concentration. It can be explained that full concentration of urea/ammonium polyphosphate in combination of TEOS are to high amount of chemicals on cotton fabric.



a)



b)

Figure 2. MCC curves of untreated and treated cotton fabric with urea/ammonium polyphosphate in half (a) and full (b) concentation with/without TEOS

In order to confirm the results collected by TGA, MCC measurements were performed and the resulting info combined with them. Currently, Alongi et al. have demonstrated that this approach can be very useful in the case of cotton fabrics [6]. In particular, when a flame retardant promotes the char formation, revealed by TGA, in correspondence, a lower release of volatile species is detected by MCC. By this way, the collected results are complementary. In this case, the T_{max} values decreased in the presence of any flame retardant system applied and, in particular, the lowest values are achieved for UREA240_APP100_TEOS15 i UREA240_APP100_TEOS30 (T_{max} = 304,1 °C and T_{max} = 300,4°C). In correspondence, the lowest maximum specific heat release values have been found.

Table 5. MCCdata of untreated and treated cotton fabric with urea/ammonium with/without TEOS

Samples	Heat release temper ature Tmax (°C)	Maxim um specific heat release Qmax (W/g)	Specifi c Heat release hc (kJ/g)	Heat release capacit y ηc (J/g-K)	Yield of pyrolysi s residue Yp (g/g)	Spec. heat of fuel gases combu stion hc.gas (kJ/g)
0	199,66	222,8	318,1	10,2	0,09	11,22
TEOS15	279,0	284,9	384,0	11,4	0,03	11,80
UREA120_APP50	95,0	96,65	312,7	3,9	0,25	5,22
UREA120_APP50_TEOS15	82,0	83,27	306,7	3,4	0,27	4,65
UREA240_APP100	78,0	80,82	302,5	3,3	0,33	4,90
UREA240_APP100_TEOS15	76,0	76,39	304,1	3,0	0,27	4,10

From Figure 2 and Table 5, it is clear that cotton material treated with conventional flame retardants like urea/ammonium ployphosphate has much lower Heat Release Rate (HRR) and Specific Heat release (h_c). This confirms the lower total system energy and better thermal properties that are crucial for flame retardancy in general. Cotton material treated with TEOS and urea/ammonium polyphosphate has the lowest Heat Realise Rate and better flame retardant properties.

3. CONCLUSION

Tetraethoxysilane, TEOS significantly improves the flame retardancy of cotton when added in the bath with conventional flame retardants urea/ammonium polyphosphate increases the LOI values. Thermo gravimetric analysis shows increasing char residue by the addition of TEOS but only for a half concentration. The Heat Release Rate (HRR) value of cotton fabrics treated with conventional flame retardants are lower than the untreated material, which could be expected. By addition of TEOS in the bath with urea/ammonium polyphosphate HRR values are even lower resulting in even better flame retardant properties.

ACKNOWLEDGEMENTS

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TRENDS IN DEVELOPMENT OF FLAME RETARDANT FIBERS VIA PHOSPHORUS ADDITIVES

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Abstract: In this presentation we will summarize the latest development in phosphorus based additives for application in manufacturing of flame retardant fibers. Such additives can be incorporated in the manufacturing of manmade fibers by either incorporating them in the spinning process (solution spinning and melt extrusion). Opportunities and challenges of incorporating such additives in fibers will also be discussed. Flame retardant and physical properties of such fibers will be discussed.

Keywords: Phosphorus flame retardants, cellulose, viscose, polyester, nylon

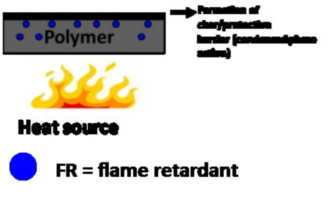
1. INTRODUCTION

In textile industry there are two main routes for manufacturing flame retardant textiles. They can be constructed from inherently flame retardant fibers (modification of polymer at molecular level) such as Nomex, Kevlar, Trevira CS, modacrylics, melamine fibers, polyvinyl chloride etc. Alternatively, flame retardant textiles can also be manufactured either by surface treatments with flame retardant compounds with various chemistries or by incorporating fire retardant additives in polymer bulk before fiber spinning. In this article we are going to focus on challenges and opportunities for development of inherently flame retardant fibers and new flame retardant fibers by incorporation of additives in the bulk. Flame retardant textiles developed from such kind of fibers (compared to surface treatments) may offer advantage in terms durability of the flame retardant effect and favorable comfort of the final product.

Manufacturing of flame retardant textiles via use of inherently flame retardant textile fibers provides textiles which have higher flame retardant efficacy. However such textiles demand premium price as compared to conventional fibers. Additionally textiles made from such fibers (e.g. Nomex® and Kevlar®) have poor comfort properties and may not be suitable (Trevira CS®) for technical application where mechanical properties are important. Fibers based on aromatic polymers such as polyimides, polybenzimidazole, polyphenylene sulfide, polyphenylene benzobisoxazole and fully aromatic polyesters are difficult to process. However are they characterized by high thermal and chemical stability and used in specialized technical applications. Inherently flame retardant fibers made from fully aromatic polymers have high thermal stability, have low heat release rates and usually produce significant amount of char (residue) on application of flame. Thus these fibers are suitable for areas where barrier effect of the textile material is quite important. Inherently flame retardant fibers can be manufactured by incorporating flame retardant monomers in conventional polymers like polyesters and acrylics. Trevira CS® (modified polyester) and Protex® (modacrylic) are some commercially available flame retardant modified fibers. There is certainly a need to develop cost effective new inherently flame retardant fibers. Any new attempt to develop special monomers which can be incorporated in the polymerization process of common polymers like polyesters, polyamide, acrylics face challenges, like process optimization (kinetics of polymerization), hydrolysis and thermal stability of the modified polymer, adequate mechanical performance, its coloration and final cost.

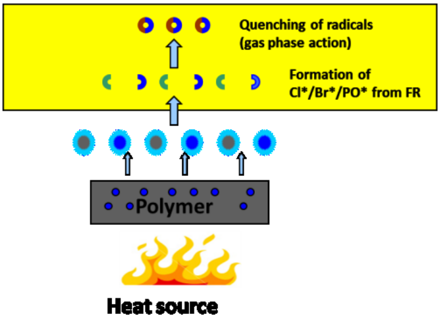
2. RESULTS AND DISCUSSION

Flame retardant textiles derived from fibers containing non-reactive flame retardant additives in the bulk offer great flexibility to textile producers. Addition of such additives in the bulk of fiber can be done via melt processing or via solution spinning. Flame retardant additives derived from elements like phosphorus, sulphur, silicone, nitrogen, antimony and halogens are available for fibers like cellulose (viscose), polyesters, acrylics and polyolefins. Depending on the polymer and flame retardant additive, the final flame retardant system could exhibit either condensed phase flame retardant action (scheme 1) or gas phase flame inhibition (scheme 2) or a combination of both. Conventional condensed phase flame retardant system (scheme 1) is characterized by formation of char (residue) during the burning process. Polymers like cellulose and protein together with a phosphorus based flame retardant additive primarily exhibit such flame retardant mechanism.



Scheme 1. Condensed flame retardant action

When subjected to fire, phosphorus additives and polymers react and form char by dehydration of water from the system. Water produced during the thermal decomposition process can cool down the system and dilute the fuel for burning process. The char thus formed act as a physical barrier for oxygen and volatile flammable gasses formed from decomposition of polymer.



(C) Gas phase active flame retardant system

We have recently developed new phosphorus based additive (aromatic bis-phosphoramidates) which can be incorporated in the viscose fiber manufacturing process to produce flame retardant viscose fibers[1]. These phosphoramidates are stable in pH rage 2-14 and insoluble in water. One of the technical challenge for viscose fiber manufacturing process is to disperse efficiently such pigments in a very small particle size of ≤ 1 µm to ensure good mechanical properties of final fiber.

R= CH_3, CH_2CH_3, $CH(CH_3)_2$

Scheme 3. Aromatic bis-Phosphormaidates

The limiting oxygen index (LOI) of viscose fibers and films containing 20% of such phosphoramidates are greater than 28%.

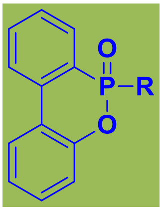
Unlike natural polymers, synthetic polymers (polyesters, polyolefins and polyamides) together with a flame retardant additive exhibit limited condensed phase activity in case of fire. Due to presence of very low amount or absence of hydroxyl functional group in the polymer, the dehydration reactions useful for condensed phase flame retardant activity are not possible. Such polymer systems exhibit only limited or very weak condensed phase activity in form of catalyzed (by the flame retardant additive) hydrolysis and chain scission reactions (depolymerization of the polymer). This leads to a complex physical/chemical flame retardant effect in which the polymer shrinks away from the flame rapidly and self-extinguishes. An excellent example of such system is the use of Flamestab® NOR 116 additive in polypropylene. Such kind of hindered amines are additionally useful in providing UV protection to the fibers. Some phosphorus flame retardant additive/ polyester systems exhibit similar flame retardant effect.

There is a need to develop thermoplastic synthetic fiber/ flame retardant additive system which could form appreciable amount of char for application where barrier protection is important. Especially char forming polyester and polyamide fibers are much required by the textile industry. To develop such kind of fibers, one has to choose suitable combination of additives. As thermoplastic fibers lack hydroxyl groups, additives with hydroxyl groups need to be additionally incorporated together with phosphorus based additive. These additives could interact with each other at high temperature to form char on surface of thermoplastic polymer. There are numerous technical challenges in developing such kind of char forming synthetic fibers. The amount of additive needed to form appreciable char for good barrier protection is in the range ~30-50%. It is quite challenging to spin thermoplastic fibers with additives higher than 5%. Thus future developments should focus on additives which can catalyze formation of high amount of char at low concentrations in the polymer (10% or lower in the fiber).

Most common flame retardant additive act as non-meltable pigments, thermally not stable and create clogging problems in the spinneret. Additionally the mechanical properties of fibers may be dramatically affected in presence of high concentration of such additives. A suitable solution would be to develop new meltable flame retardant additives for such synthetic polymers. Such additives can be evenly distributed in the fiber matrix. An ideal additive should melt in the melting temperature range of polymer, should be thermally stable under processing condition and also inert to the polymer during high temperature processing. By use of meltable additives, one can eliminate the need of using filter packs which are normally required for spinning thermoplastic fibers with additives. Thermally stable meltable additive for thermoplastic fibers could help in recycling and improved environmental profile of the final product.

More recently development of efficient and safe non-halogenated gas phase active systems have attracted much attention. Phosphorus based additives are considered as suitable alternative to halogenated flame retardant additives because of their versatile flame retardant action (effective on all kinds of polymers) and favorable environmental profile. It is important to note that phosphorus based flame retardants can act in condensed phase (scheme 1) by forming phosphoric acid (catalyzes dehydration reaction) or release low energy gas phase active species (PO_x*) which can interfere with the oxidation process of the fuel produced from thermal decomposition of polymer (scheme 2).

In the last few years DOPO (9,10-dihydro-9-oxa-10-phosphaphenanthrene 10-oxide) and its derivatives (scheme 4) are becoming very popular due to their efficient gas phase flame retardant activity. DOPO is commercially available (produced in Europe) and considered as environmentally safe (ENFIRO EU project) alternative to halogenated flame retardants. Being a reactive molecule, it can be modified into various derivatives. Several commercial DOPO derivatives like UKANOL ES ® (monomer), UKANOL FR 80 ® (oligomer) are available for application in polyester fiber production. More recently we have also developed DOPO based phosphonamidates[2] and phosphinates[2a] which can be incorporated in the polymer bulk and spun into fibers. The DOPO phosphonamidates can be tailored (depending on the chemical structure) for their solubility in solvents as well as thermal stability. Such DOPO derivatives can find application in solution and melt spinning of fibers.



Scheme 4. DOPO derivative

Development of new flame retardant additive for textile fiber application is a challenging task. It has to meet technical goals in fiber application, should be commercially feasible to produce and should be environment friendly. Such new additives have to be REACH registered which adds to the financial burden for a textile fiber producer. There are attempts to develop polymeric flame retardant additive like Nofia™ HM1100 (FRX Polymers) for application in polyester fibers. Such polymeric flame retardant additives offer flexibility to a fiber producer and are considered safer as they don't migrate out from fibers. However the monomers of such polymers also need REACH registration. New flame retardant fibers and their products thereof have to be tested and certified at every stage in the textile manufacturing process which could be quite challenging in a cost competitive textile market.

3. CONCLUSION

The need to develop flame retardant fibers which fulfils mechanical performance, health, safety and aesthetic requirements is increasing. A suitable way to achieve these objectives is to develop novel additives which are compatible with the manufacturing of fibers and environmentally acceptable. By varying the structure of organophosphorus compounds, one can design novel flame retardant additives which are not only compatible with the melt processing of fibers but also can meet the harsh conditions of viscose fiber manufacturing.

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CONDUCTIVE TEXTILES MODIFIED BY POLYPYRROLE

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Abstract: Method of in situ chemical oxidative polymerization of pyrrole on the textiles surface was used for conducting textiles preparation. To improve adhesion of the conducting layer to the polyamide and polypropylene textile, a pyrrole-functionalized silane (SP) was synthesized and bonded onto the surface before polypyrrole formation. The study of the influence of SP concentration on both, the fastness of the conducting layer after the washing process, and stability of the surface electrical conductivity of the prepared samples was investigated. Modifications of textile surfaces were examined by FTIR, elemental analysis and microscopy. X-ray photoelectron spectroscopy was used for a detailed study of the surface composition after silane treatment, after polymerization of polypyrrole layer, and also after washing of all prepared textiles. It was confirmed that the pre-treatment with Py-functionalised triethoxysilane significantly influenced the chemical composition of the modified textiles and the stability of modification by conducting polypyrrole layer.

Keywords: conductivity, polypyrrole, polyamide, polypropylene, surface treatment,

1. INTRODUCTION

The need of electrically conductive fibres and textiles has increased in recent years, because of applications as antistatic materials, materials for electromagnetic shielding and biomedical use. Electrically conducting polymers as polyaniline, polythiophene, and polypyrrole are often used for surface modification of various material. Deposition of conducting polymers on a textile surface is relatively simple and there are many publications dealing with this procedure [1, 2]. PPy-coated fabrics have good electrical conductivity, thermal properties and flexibility, and they are suitable for numerous applications [3]. In addition, the deposition of thin layers of conductive polymers on fabrics or yarns does not noticeably change and sometimes even improves the mechanical properties of the original material. However, an ideal method for the preparation of stable conductive textiles remains challenging.

2. MATERIALS AND METHODS

2.1. Materials

Polypropylene (PP, surface mass (ms) = 0.02 g/cm^2) and polyamide 6 (PA, surface mass (ms) = 0.025 g cm^{-2}) 0.01 g/cm^2) textiles were supplied by Chemitex Žilina (Slovakia). Pyrrole (Py > 97 %) monomer from Fluka (Germany), purified by distillation under reduced pressure and stored at 4°C, was polymerized by means of an oxidant, ferric chloride (FeCl3, Lachema, Czech Republic). The molar ratio [$FeCl_3$]/[pyrrole] was 2.3].

To improve the binding of polypyrrole layers to the surface, a pyrrole-functionalized silane, 1-(3-(triethoxysilyl)propylamino)-3-(1H-pyrrole-1-yl)propan-2-ol (SP), was used. SP was synthesized from pyrrole, epichlorhydrin, and 3-aminopropyltriethoxysilane, as reported earlier.

2.2. Preparation of pretreated PP (mPP)

PP textile was immersed in a solution of vinyltrimethoxysilane in n-propanol (5 vol.%) in order to obtain functional groups for covalent binding of SP to the polypropylene surface. After drying, it was treated for 2 minutes with radiofrequency plasma (13.56 MHz) in an argon atmosphere. Finally, the methoxy groups of VTMS were hydrolysed and condensed by immersing the material in a solution of 1 M NaOH for 1 hour to give mPP.

2.3. Polymerization of pyrrole on textile surface

The textiles were impregnated with 0.2, 0.6, and 1.0 wt.% of SP in $CHCl_3$ solution (based on the weight of textile) and after evaporation of $CHCl_3$, were left for 48 h in a 5 wt.% aqueous solution of NH_4OH to hydrolyse completely the alkoxy groups of the silane. After silanization textiles were immersed in an aqueous solution containing pyrrole monomer for 30 min. Then an aqueous solution of the oxidant ($FeCl_3$) was added for initiating of the polymerization.

3. RESULTS AND DISCUSSION

Conducting textiles of polypropylene (PP) and polyamide (PA) fabrics and polypyrrole (PPy) were prepared by in situ chemical oxidative polymerization of pyrrole (Py) on the textiles surface. To improve adhesion of the conducting PPy layer to the textile surface, a pyrrole-functionalized silane (SP) was synthesized and bound onto the surface before polypyrrole formation. For the PP modification first step was introducing hydroxyl groups on the surface by plasma pre-treatment and subsequent grafting of vinyltrimethoxysilane. The study of the influence of SP concentration on both the fastness of the conducting layer after the washing process and stability of the electrical sheet conductance of the prepared samples was done. The pyrrole monomer was added in four different concentrations from 10 to 25 wt. % into a solution containing PA or PP pre-treated with SP. Subsequently, the addition of the oxidant induced the chemical oxidative polymerization of pyrrole on the surface of the fabrics. An advantage of PA modification is that that no other treatment (plasma) is required prior to silanization [4].

Modified textile surfaces were examined by scanning electron microscopy. X-ray photoelectron spectroscopy was used for a detailed study of the surface composition. It was confirmed that the pre-treatment with Py-functionalised triethoxysilane significantly influenced the chemical composition of the PP and PA surface modified with PPy [5].

Sheet conductance of the samples treated and untreated by the sol–gel process of SP was measured both prior to and after washing of the prepared textiles. The conductance of the modified PA and PP is directly related to the PPy amount used for modification. In both cases, for polyamide as well as for polypropylene textiles, the presence of SP improved the modification with polypyrrole and consequently also the fastness of polypyrrole layers. Moreover, increasing the SP concentration in textile pre-treatment improved the fastness of the conductive PPy layer on textiles surface and the stability of the sheet conductance of modified materials. Thermooxidation stability and fire resistance of prepared conductive textiles was also investigated and results show positive effect of SP treatment on their overall stability. The highest sheet conductance 3×10^{-4} S after washing was obtained for PA pre-treated with 1.0 wt. % SP when 25 wt. % of Py was used in polymerization [5].

4. CONCLUSIONS

The polypropylene and polyamide textile surface was modified by polypyrrole layer. For better adhesion of conducting polypyrrole to the textile, a pyrrole-functionalized silane was bonded onto the surface before formation of PPy. The pyrrole monomer was added in four different concentrations into a solution containing PA or PP pre-treated textile with pyrrole-functionalized silane. The addition of the oxidizing agent, iron chloride induced the chemical oxidative polymerization of pyrrole on the surface of the fabrics. An advantage of the pyrrole-functionalized silane pre-treatment on the PA surface over other textiles is that prior to silanization no other treatment (plasma) is required. The sheet conductance of the modified PA is directly related to the PPy amount used for modification. In both cases the presence of pyrrole-functionalized silane applied to the surface improved the modification with conducting layer and also the fastness of polypyrrole layers. When pyrrole-functionalized silane concentration on textile surface reached 1.0 wt.%, the fastness of the conductive PPy layer on textiles surface and the stability of the sheet conductance of modified materials was the best.

This work conclusively stresses the importance of surface pre-treatment of textiles in order to obtain highly stable, and electrically conductive coatings.

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COST EFFECTIVE, EFFICIENT AND ENVIRONMENT FRIENDLY DURABLE FR AS PART OF PES HT DYEING

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Abstract: Flame retarded functional textiles are becoming more and more significant position on the technical and protective textiles market. Simultaneously the strict environmental and safety conditions restrict some of conventional FR substances – like halogen and antimony compound. Influenced by imperative pressure on the flexibility of production new efficient processing conditions need to be offered. Single step dyeing and FR finishing system for 100% PES (fibres, yarns, fabrics) and its advantages will be presented. Simplified processing using the existing dyehouse devices comply both – the protective and excellent colouristic requirements (for automotive, protective, home textiles etc.).

Keywords: PES-flameretardancy, durable FR, halogen and antimony free FR, efficient processing

1. INTRODUCTION

FR PES textiles are frequently required for number of technical and special textiles. Different end-uses are conditioned by range of existing international standards. Environmental and safety protections restrict the earlier frequently used halogenated and/or antimony based compounds. Additional FR post-impregnation systems often change the colour and touch of fabrics. Industry ask for an efficient, clean and reproducible process of FR treatment which can be used for broad range of coloured PES materials.

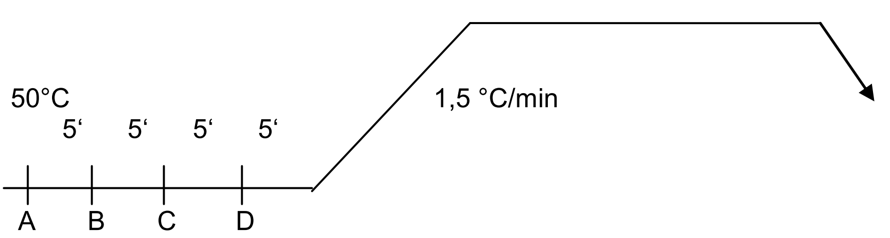
2. MATERIAL AND METHOD

In the textile industry commonly used 100% PES substrates in form of yarn, knitted and woven fabrics were used. Common HT dyeing devices (loose material, yarn dyeing device, JET) were used – single bath colouration (by disperse dyes) and halogen/antimony free P-based flame retardant were applied.

Example of process:

Permanent FR treatment of 100% PES loose material during dyeing:
Application by HT process (L.R. 1:10)
bath composition :

A 6,0-10,0% o.w.f. TEXAFLAM HT
B 1,5 g/l TEXAFLAM HX (booster)
C acetic or formic acid (pH=4-5)
D disperse dye



- rinsing
- reduction cleaning after HT process recommended

3. RESULTS AND DISCUSSION

Comparing to the commonly used two stage processing method (HT dyeing followed by FR treatment).

- The single stage exhaust procedure gives the fully reproducible results as well as in resulting colour shades as FR standards on 100% PES.
- Processing conditions and the time of complete treatment is shorter (of about 40%). It helps to utilize existing HT dyeing devices more flexibly.
- The FR system is halogen and Sb_2O_3 free – this is step forward in cleaner processing and eco-design of final PES textiles. Shorten process spare water and energy as an additional bonus.
- Very low fogging makes this FR system favourable for automotive PES textiles (reduction of initial value 6,7 to 2,45 mg/kg).

4. CONCLUSIONS

Based on range of bulk trials new single step dyeing and durable FR processing system for 100% PES technical and protective textiles (automotive, home, barrier and 3D) was introduced. Repeated applications confirm full harmonization with range of international FR standards (EN ISO 15025; EN 6940; FMVSS 302, ISO 3795; BS 5852; BS 5867). FR effect is durable in water, shampooing, dry-cleaning and washing.

Single treatment offer the efficient process which allow to offer the another subsequent functional effects of the PES substrate.

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FIRE RETARDANCY OF TEXTILES THROUGH SURFACE ENGINEERING METHODS: RECENT ADVANCES

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Abstract: This work is aimed at summarizing the recent attempts for conferring fire retardant features to both natural and synthetic fabrics (namely, cotton, polyester and their blends), trying to exploit environmentally friendly approaches at a lab scale.

More specifically, the use of Layer by Layer assemblies and sol-gel derived nanoparticles and nanocoatings will be discussed; in addition, some of the potentialities associated with the use of suitable biomacromolecules (i.e. proteins and nucleic acids) as novel low-environmental impact flame retardant additives will be presented. Finally, some possible solutions for overcoming the current limitations of the proposed surface engineering technologies will be proposed.

Keywords: fire retardancy, layer by layer technique, sol-gel processes, biomacromolecules.

1. INTRODUCTION

In the last decades, the field of flame retardant textiles has been continuously evolving mainly toward the design and large-scale exploitation of flame retardant additives, which could provide fibers and fabrics with flame retardant features, showing, at the same time, durability and comfort issues. In particular, different types of flame retardants synthesized on purposed have been developed and have already shown their great potential when applied to both natural and synthetic textiles. Among them, so far several different types of FRs, which are usually divided into classes including halogenated organic FRs (mainly brominated and chlorinated), phosphorous containing FRs, nitrogen-containing FRs and inorganic FRs, have been successfully exploited for conferring flame retardant features to textiles.

However, according to the very stringent directives recently promoted by EU community and USA, some of the halogenated compounds (like pentabromodiphenyl or decabromodiphenyl ethers and polychlorinated biphenyls) have been banned, since they have clearly demonstrated to be persistent, bioaccumulative, and/or possess environmentally toxic features for both humans and animals. The aforementioned drawbacks pushed the scientific community toward the design and development of phosphorus-based compounds, which seem less toxic and may represent a suitable alternative to their halogen-based counterparts. In particular, as far as cotton and cellulosic-rich substrates are considered, the current attention is focused either on the production of effective halogen-free substituents for coatings and back-coated textiles or on the use of hydroxymethylphosphonium salts (Proban®) or N-methylol phosphonopropionamide derivatives (Pyrovatex®).

Nowadays, the approach adopted by the scientific community is being slightly changed; indeed, although the durability of any new flame retardant is still mandatory, the novel processes and methods developed in last five years are quite far from this goal and are more focused on the design of environmentally-friendly systems. In doing so, the nanotechnology approach has clearly indicated high potentialities, which have been quite successfully exploited for assembling nano-objects on the fabric surface, thus creating a very thin layer able to slow down or even prevent the fire propagation. More specifically, different nanotechnology methods have been developed so far; in particular:

- The nanoparticle adsorption, which can be considered the first attempt for depositing nano-objects on fabric surfaces. It involves a simple impregnation of the fabric in a stable nanoparticle suspension, which leads to the formation of a nanoparticle assembly on the fabric substrate, acting as physical barrier (e.g. a thermal shield) able to protect the underlying fabric from a flame or a heat flux. This technique is a non-durable treatment, as it is based on the ionic interactions taking place between the fabric substrate and the nanoparticles, notwithstanding the possible use of a cross-linker between the fabric and the nanoparticles.
- *The sol-gel method,* which represents a bottom-up synthetic route based on a two-step reaction (hydrolysis and condensation), starting from (semi)metal alkoxides (usually tetraethoxysilane, tetramethoxysilane, titanium tetraisopropoxide, aluminium isopropoxide), leading to the formation of completely inorganic or hybrid organic–inorganic coatings at or near room temperature.
- *The Layer by Layer (LbL) assembly*, which can be considered as an evolution of the nanoparticle adsorption process, falling in the category of

self-assembled coatings: it simply consists in a step-by-step film build-up usually based on electrostatic interactions. The LbL assembly through electrostatic interactions requires the alternate immersion of the substrate into oppositely charged polyelectrolyte solutions or nanoparticle suspensions (the solvent is usually water and the concentrations of the solutions/suspensions are usually below 1 wt.%). Thus, it is possible to create an assembly of positively and negatively charged layers piled up on the fabric surface, exploiting a total surface charge reversal after each immersion step.

Quite recently, the seeking for environmentally friendly flame retardant systems for textiles has involved another possible approach that refers to the use of specific biomacromolecules (in particular some proteins – caseins, hydrophobins and whey proteins – as well as deoxyribonucleic acid, DNA): this is a quite novel strategy that goes far beyond the chemical approach behind the design and use of “traditional” flame retardants for textiles. Indeed, usually flame proofing is not directly associated with biomacromolecules: their application to textiles is considerably easy and can exploit the methods that are already designed and optimized for fabric finishing (like impregnation/exhaustion, spray) or even the layer-by-layer deposition.

2. MATERIAL AND METHOD

2.1 Fabrics and chemicals

Cotton, polyester and blends were kindly supplied as textile fabrics by Klopman International Srl (Frosinone-Italy) and used as received without any further treatment. The biomacromolecules and all the reagents employed for sol-gel processes and layer by layer treatments were purchased from Aldrich and used as received.

2.2 Surface treatments of the fabrics

The flame-retarded fabrics were obtained by using suitable methods according to the selected surface approach: sol-gel derived nanocoatings were prepared by dipping the fabrics in the preformed sol solution at room temperature; then, the sol–gel treatment was completed at 70°C for 24 h in an oven. Layer by layer treatments were performed by dipping the fabrics in water solutions/suspensions: after each immersion step, the fabrics were washed in bi-distilled water in order to avoid any contamination of the next dipping baths. Proteins or DNA aqueous solutions/suspensions were exploited for treating the fabrics in a climatic chamber (at 30°C and 30% R.H.): the excess was removed by gently pressing with a rotary drum; then the treated samples were dried to constant weight.

2.3 Characterization of the fire behavior

The resistance of the fabrics to a flame application was assessed through flammability tests performed in horizontal configuration; furthermore, LOI measurements with a FIRE oxygen index apparatus according to the standard ISO 4589-2. Cone calorimetry (Fire Testing Technology, FTT) was employed to investigate the combustion behavior of square samples (100 mm^2) under an irradiative heat flow of 35 kW/m^2, according to the standard ISO 5660.

3. CONCLUSION

The proposed surface engineering treatments have shown a significant potential for effectively improving the fire retardant properties of different natural and synthetic fibres/fabrics. Furthermore, they may represent a possible efficient alternative to the conventional flame retardant systems, some of which (like the halogenated products) are encountering limitations in use due to their suspected/assessed toxicity and poor eco-sustainability.

Indeed, the in situ assembly of nanostructured coatings on the fabric surface provided by layer by layer treatments or sol-gel processes has clearly demonstrated that nanotechnology is a valuable tool, also suitable for the textile field; finally, the unusual use of proteins and nucleic acids may overcome the current limitations of flame retardants toward the design and development of novel, sustainable and green products.

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ORAL PRESENTATIONS

3D TEXTILE STRUCTURES FOR LIGHTWEIGHT AND LOW COST PRODUCTION OF THERMOPLASTIC COMPOSITE SOLUTIONS

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Abstract: 3D thermoplastic composite structures have been designed and produced responding to different ground transportation sectors (automotive, railway and truck transportation). Depending on the capacity of textile processes of production, different shapes of knitted, braided and woven structures have been achieved and fast thermo-formed, providing lightweight and low cost thermoplastic composite solutions.

Keywords: textile composite, thermoplastic composite, lightweight material, 3D textiles, transportation applications

1. INTRODUCTION

Thermoplastic composites with fibrous reinforcement, using 3D shapes of textile structures made with comingled E-glass and Polypropylene yarns [HYPERLINK \l "Mäd08" *1*]*2*], can be rapidly produced in one step thermo-forming step [HYPERLINK \l "Duf13" *3*]. This paper presents the different proposed textile solutions to cope with the end-users requirements with respect to their criterion depending on the transportation application (Figure 1).

Figure 1. (1st column)(up) multiple woven cross stiffeners for railway application –(down)braided and 3D woven tubular cross for railway application – (2nd column) (up) 3D woven – (down) knitted seat frame for truck application – (3rd column) 3D woven automobile hood piece for automotive application.

2. RESULTS AND DISCUSSION

Different innovative solutions on process and products have been done to ensure low fibre degradation, thickness homogeneity of structure during forming process and joining of thermoplastic composite material on metallic frame. Comparison of textile technologies to obtain the final 3D preforms have been done, highlighting the pro and cons of these different complementary solutions.

ACKNOWLEDGEMENTS

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ELECTROMAGNETIC SHIELDING PERFORMANCE OF FLAT KNITTED SPACER FABRIC AND ITS COMPOSITE USING HYBRID YARN

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Abstract: In this study, it was aimed to investigate the EMSE(electromagneticshielding effectiveness) of weft-knitted spacer fabric and the composite form that reinforced with this fabric. Knitted spacer fabric produced in this study is composed of cotton yarn and copper wire while the composite form is composed of aramid yarn, polypropylene yarn and copper wire. 7G semi-automatic flat knitting machine was used to knit the fabric and a laboratory type hot press was used to form the composite. Electromagnetic shielding effectiveness (EMSE) of fabric and composite were tested by using ASTM D 4935 coaxial test fixture in 27-3000 MHz frequency band.As a result of the study, spacer fabric has 10 dB shielding performance but the composite form of the spacer fabric has a better shielding performance as 30-35 dB especially in the frequency range of 500-1500 dB.

Keywords: Spacer fabric, weft knitted, composite, electromagnetic shielding.

1.INTRODUCTION

In literature, spacer fabrics are known as energy absorbment structures. Spacer fabrics are complex three-dimensional (3D) constructions made of two separate fabric layers connected vertically with pile yarns or fabric layers. The conventional spacer fabrics composed of two surface layers bound with pile yarns are generally manufactured using weaving and knitting technologies. [1]

Traditional shields are based on the use of stiff metallic materials with well-known electromagnetic properties. Plastics with a metallic coat or with metal fibres injected during the molding stage are used also. But they are still not flexible. Recently attention has been paid to light weight and flexible materials, such as textiles covered with conductive layer. These materials, owing to their flexibility, durability, ease of manufacturing and application, are considered promising for shield of electro-magnetic radiation. [2,3]

EMI is becoming seriously an important health problem due to the increasing health hazards. So that it is an increasing need to produce EMI shielding materials.[4]

2.EXPERIMENTAL APPROACH

2.1.Material

For this study, Ne 20/2 cotton / 0.15 mm copper wire were used to form the conductivehybrid yarn for the spacer fabric.Conductive yarn was formed into spacerknitted structure using a 7gauge flat knitting machine. For spacer knitted fabric reinforced composites; Aramid/PP/ 0.15 mm copper wire were used as conductive hybrid yarn. The course density of fabric was 8 loop/cm and wale density was 6 loop/cm. The ply number of the composite was 2 with the lamination angle of 0º/90º (Figure 1).

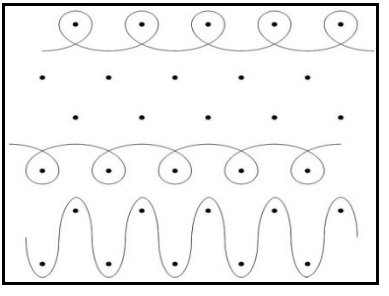

Figure 1. Stitch notations of spacer fabric

2.2.Method

Spacer knitted fabric reinforced composites were achieved by compression molding technique using a laboratory hot pres. The composites' surface are all covered with polypropylene and the composites had an elastic character as seen on Figure 2. A flanged coaxial test fixture referring to ASTM D 4935 was used for determining the electromagnetic shielding effectiveness (EMSE) of test samples.

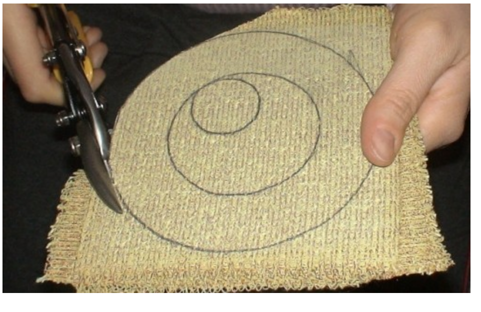

Figure 2. Appearance of the composite

3.RESULTS AND DISCUSSION

The spacer fabric has a poor shielding performance as 10 dB especially in high frequencies. But the composite form has a better shielding performance than its fabric as a shielding value of 30 dB especially in the frequency range of 750-2000 MHz. Inthe frequency range of 2500-3000 MHz, the composite form has a shielding performance of 30-40 dB (Figure 3).

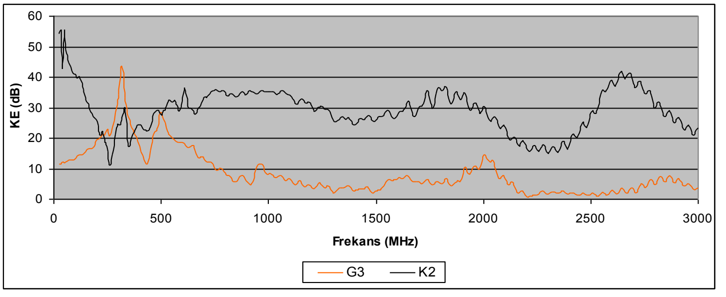

Figure 3. EMSE values of spacer fabric and composite form

4.CONCLUSIONS

Important difference between the spacer fabric and its composite for the electromagnetic shielding performance has been observed in this study.

The composite form of spacer fabric is more effective than its fabric form especially in high frequencies. The composite form has a shielding performance of 30-40 dB in the frequency range of 500-2000 MHz. So that, composite form reinforced with weft knitted spacer fabric can be used for many electromagnetic shielding applications in the frequency range of 500-2000 MHz.In future, composites reinforced with spacer fabrics or combinations of any other structures can be improved as shielding panels for civil engineering applications.

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PERFORMANCE UTILITY OF NOVEL BASALT WOVEN HYBRID FABRICS

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Abstract: This paper presents a study conducted on the thermal and mechanical properties of Basalt hybrid and non hybrid structures. For designing apparel as well as for other uses, the knowledge about the tensile properties of woven fabrics is important. Strength and elongation are the most important performance properties of fabrics governing the fabric performance in use.The thermal properties of the fabrics, i.e thermal resistance, thermal conductivity etc. were also studied vis-a-vis physiological behavior. In this paper ALAMBETA , PERMETEST and Air permeability tester are described, which provide reliable non-destructive measurement of thermal conductivity, thermal resistance , water vapor permeability and air permeability of fabric The effect of structure and composition on the above-mentioned properties of these fabrics has been investigated as well. The results of the testing shown that effect of weave geometrical parameters on thermal and mechanical properties is significant.

Keywords: Basalt, hybrid fabrics, elastic modulus, thermal conductivity, electrical properties

1. INTRODUCTION

Basalt is a newly worked upon raw material, it is natural material from the origin of volcanic rocks. Basalt rock can be used to make not only basalt bars but also basalt fabrics, chopped basalt fiber strands, continuous basalt filament wires and basalt mesh. The basalt fibers, in its method of production are similar to the process of glass fibers .Basalt is quarried, crushed and washed and then melted at 1500°C [1]. The molten rock of basalt is then extruded through small holes of tiny nozzles to produce continuous filaments of basalt fiber. The production procedure of basalt fibers is free from any additives; its production in a single production cycle makes it cost effective. The tensile strength of basalt fibers is known to be better than E- glass fibers. its nature of good resistance against chemical attacks, flammability with less poisonous flames, impact load and greater failure strain than carbon fibers [2]. It has good hardness and thermal properties, and has many other properties like good mechanical strength, excellent sound and thermal insulator, non flammable, biologically stable, etc.

2. MATERIAL AND METHODS

2.1. Materials

The research was focused on the mechanical and thermo physiological properties of fabrics with Basalt in warp and Basalt, Polypropylene and Jute yarns in weft. The raw materials to be tested were Plain weave hybrid Basalt-PP &Basalt-Jute, rib Basalt-PP and Basalt Jute, 1/3 Twill Basalt-PP and Basalt-Jute and Plain non hybrid Basalt-Basalt,rib Basalt-Basalt and 1/3 Twill Basalt-Basalt fabrics. Pure basalt fabrics were made for the comparison with other fabrics. Fabrics were made in most commonly used weaves (i.e. Plain, rib and twill 1/3). All fabrics were made on the CCI sample loom with the same density for all fabrics, 12 threads/cm in warp and 8 threads/cm in weft.

2.2 Methods

Mechanical properties were characterized with respect to tensile and shear mode using standard procedure. Measurement of the thermal insulation properties of the fabrics was done by means of an Alambeta, which is a computer controlled instrument for measuring the basic static and dynamic thermal characteristics of textiles. This method belongs to the so-called ‘plate methods’, the acting principle of which relies on the convection of heat emitted by the hot upper plate in one direction through the sample being examined to the cold bottom plate adjoined to the sample. The instrument directly measures the stationary heat flow density (by measuring the electric power at the known area of the plates), the temperature difference between the upper and bottom fabric surface, and the fabric thickness. Electical conductivity and resistivity was studied on the surface as well as through the thyickness.

3. RESULTS AND DISCUSSION

Mechanical properties describe the resistance of material against external forces. The response of the textile material depends upon the material properties, type of loading and direction of loading .There are many factors which will affect the mechanical properties of a woven fabric. Firstly, there are fiber properties, and their molecular properties and structure.The raw material involved in the fabric formation is the yarn and thread per inch of a fabric, the yarn properties are influenced by fiber properties and type of spinning whereas threads per inch i.e warp and weft density along with weave defines the fabric properties, machine speed and conditions in weaving may be the other factors. The knowledge of tensile properties is very important for development of a fabric for specific end use; strength and elongation are two of most important properties that are required for the performance as per end use. Their study involves many difficulties due to a great degree of bulkiness in the fabric structure and strain variation during deformation. Every woven fabric is made of large number of thread, each thread having even a larger number of fibers; any slight deformation of the fabric will subsequently give rise to a chain of complex movements of the latter .This is very complicated ,since both fibers and yarns behave in a non-Hookean way during deformation. At the beginning of loading, extension occurs in amorphous parts, where primary and secondary bonds are extending and are shear loaded. During this stage if there is stoppage of application of external force, most of the extension and elongation will return back to normal and the material shows elastic properties. If further load is applied, long chains of molecules are re arranged as a result of disconnection of secondary bonds resulting in plastic deformation. The re-arrangements of the reciprocal position of molecules give material better possibility to resist additional loading. If the loading continuous, a final break will occur.

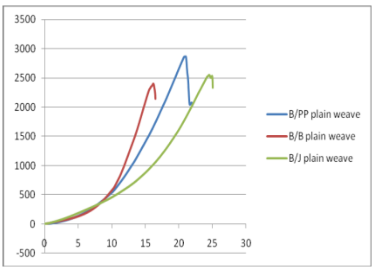

Figure 1. Load –elongation curves in warp direction

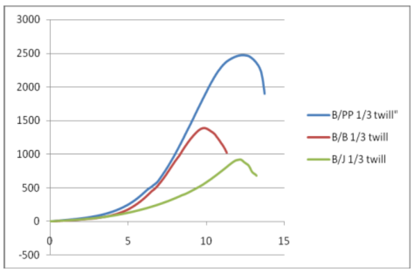

Figure 2. Load –elongation curves in weft direction

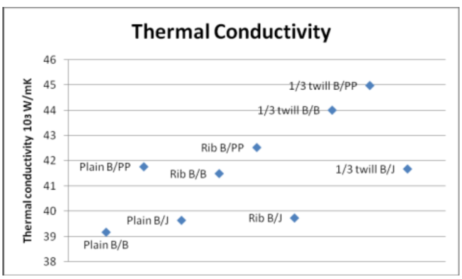

Figure 3. Thermal conductivity of basalt hybrid weaves

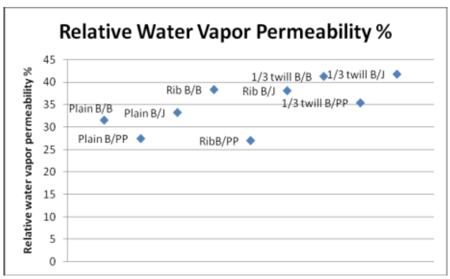

Figure 4. RWVP% of basalt hybrid weaves

4. CONCLUSION

It is concluded from above results that the weave of woven fabrics influences their mechanical and thermal insulation properties. Plain weave fabric has higher tensile strength for all woven fabrics and highest thermal insulation values. It can be seen that 1/3 twill fabric have higher air permeability and relative water vapor permeability but low thermal resistance. Use of PP in weft direction increase fabric tensile strength for all weaves except1/ 3 twill and increase of thermal conductivity for all weaves .Use of jute in weft direction increase Air permeability, Relative water vapor permeability for all weaves and better thermal resistance values except for plain weave.

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INFLUENCE OF FIBRE HYBRIDISATION ON POST-IMPACT BEHAVIOUR OF THERMOSET COMPOSITES

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Abstract: This work studies impact and damage tolerance behaviour of S-glass-Polypropylene/Epoxy composite laminates in non-crimp forms. Polypropylene (PP) and S-glass fibres were successfully mixed through commingling and core-wrapping methods with 37 % of polypropylene fibres. Test results indicated that core-wrapped composite laminates had better impact and damage tolerance performance than the commingled composite laminates due to the smaller impact induced damage areas and better PP fibre distribution. Glass laminate retained approximately 43-33% of its compressive strength while core-wrapped and commingled laminates retained their compressive strength approximately 60-43% and 60-39%, respectively at 15-50J impact energies.

Keywords: hybrid yarns, impact tolerance, damage tolerance, compression after impact

1. INTRODUCTION

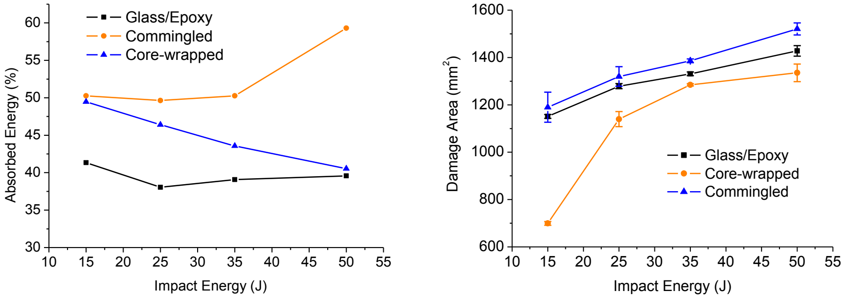
Fibre reinforced laminates have started to be very attractive in aerospace industry and have replaced metallic structures since late 1960s due to their high specific strength and modulus [1]. However, their low impact damage resistance and tolerance [2], easy delamination [3] and poor interlaminar fracture toughness properties [4] are the main drawbacks. It is known that low velocity impact damage causes large reduction in compressive strength and service life of the structure [5]. Different approaches have been proposed in the literature for improving impact resistance and residual strength of the composite laminates, such as modifying the resin system[6], using thermoplastic matrices [7], using 3D textile preforms or introducing through-thickness reinforcement (stitching or tufting) [8]. It was also reported that introducing of thermoplastic fibres as part of the preform system improved the impact tolerance of thermoset composite laminates. [9].

2. MATERIAL AND METHOD

For this study, three non-crimp fabrics with different types of hybrid fibres manufactured. The first non-crimp preform (control) was made from S-glass whilst the other two non-crimp preforms were made from S-glass/PP commingled and S-glass/PP core-wrapped yarns. S-glass and the hybrid yarns were converted into non-crimp $[0, 90]_7$ preforms using a tow placement machine developed in the University of Manchester. Once the preforms were made, they were infused with Araldite LY 564 epoxy resin (75% wt) and Aradur 3486 (25% wt) hardener using the vacuum bagging method and cured at the required temperature and time (80°C degrees for 8 hours). Low velocity impact tests were conducted at different energy levels (20-50J) using drop-weight impact test machine. The CAI tests were performed using an INSTRON 5989 testing machine fitted with a load cell of 300 kN at a constant displacement of 0.5 mm/min. A scanning electron microscope (SEM) and ultrasonic C-Scan was used to evaluate the fibre distribution and damage mechanism of composite samples.

3. RESULTS AND DISCUSSION

Figure 1.a presents the energy absorption percentages for each type of composite laminates after the low velocity impact tests. It can be seen that the energy absorption percentage of the hybrid samples is higher than the glass laminate, and their higher energy absorption comes from the extensive plastic deformation of the PP fibres and good stress transfer between the phases by the addition of PP fibres. This might also be due to the lower interfacial bonding and low elastic properties in the hybrid laminates compared to the glass/epoxy laminate. It can be seen from Figure 1.b that impact damage areas increases with increasing impact energy levels for the all laminates. However, the core-wrapped laminate showed smaller impact-induced damage areas than the other two laminates at all energy levels. This was due to PP fibres provided a protection to glass fibres from impact damages and fewer damages occurred. Test results showed that addition of PP fibres in form of commingling and core-wrapping decreased compression and CAI values of composite laminates. However, their residual strength values were higher than the glass laminate as shown in Table 1. The residual strength was calculated by normalising the CAI strength with compression strength values as a function of impact energies. It appeared that the PP fibres protected the glass fibres and less glass fibres were broken, hence higher residual strength values were achieved in hybrid composites.



(a) **(b)**

Figure 1. Energy absorption **(a)** and damage areas **(b)** of composite laminates after low velocity impact tests

Table 1. Residual strength of composite laminates after different impact energy levels

Impact Energy (J)	Residual Strength (%)		
	Glass laminate	Core-wrapped	Commingled
15	42,98	59,45	59,93
25	39,87	52,11	51,04
35	36,45	47,17	45,02
50	33,30	43,45	39,07

4. CONCLUSION

The inclusion of polypropylene fibres through the commingling or core wrapping techniques reduced the overall density (and hence weight) of the composites produced, by up to 20 % when compared to the glass/epoxy laminate; due to the lower cost of PP fibres, some cost reduction was also achieved through hybridisation. Compression tests results showed that addition of PP fibres into a thermoset system decreased the compressive strength and modulus of the laminates due to the low modulus PP fibres and the lower glass fibre volume fraction since strength and modulus of laminates is dominated by the strong stiff glass fibres. However, the compressive strength reduction of the glass/epoxy laminate was more than the hybrid laminates. This was due to there being fewer glass fibre breakages in the hybrid laminates because of the PP protection and a weaker fibre-resin bonding during impact loading, which led to higher compressive strength retention in the hybrid laminates. This revealed that strength reduction in impacted composite laminates is mainly controlled by the amount of broken glass fibres.

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SMART GEOSYNTHETICS FOR STRUCTURAL HEALTH MONITORING USING FULLY DISTRIBUTED BRILLOUIN-BASED FIBER OPTIC SENSORS

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Abstract: We report on the development of a complete system for structural health monitoring of large-scale geotechnical structures. The system uses Brillouin frequency domain analysis (BOFDA) for distributed measurement of strain and temperature along glass optical fibers (GOFs) by determining the so-called Brillouin frequency shift (BFS). In a number of research activities we managed to optimize the BOFDA measurement setup regarding the spatial resolution and the accuracy of the measured quantities. Moreover, we realized a simultaneous measurement of strain and temperature by using nonzero dispersion-shifted fibers (NZDSFs) with several multiple Brillouin scattering resonances. In cooperation with our German and Italian industry partners we finally succeeded in fabricating low-attenuation smart geosynthetics as a sensor component of a fully distributed Brillouin-based fiber optic monitoring system.

Keywords: Brillouin scattering, distributed sensor, fiber optic sensor, optical fiber, structural health monitoring

1. INTRODUCTION

Geosynthetics are commonly used within several industrial sectors ranging from medical, healthcare, earthworks, construction, civil engineering, transport, to name a few. The retrofitting of existing masonry walls and soil structures by geosynthetics [1] gains more and more importance especially in connection with earthquake protection of historic buildings and protection of roads and railway embankments against landslides. The integration of optical fibers into gesynthetics materials leads to additional measurement functionalities of the geogrids and geotextiles, respectively [2]. In this way, the monitoring of local mechanical deformations and temperature distribution along sensor fibers could be realized by developing a cost-effective measuring method called Brillouin frequency domain analysis (BOFDA).

2. BRILLOUIN-BASED FIBER OPTIC SENSOR SYSTEM

Generally, every Brillouin-based fiber optic sensor system can be divided into two functional blocks:

- measurement device / measurement setup for coupling the laser signals into the sensor fibers and for evaluating the backscattered optical signals with information about the strain and temperature distribution in the same time
- standard glass optical fiber (GOF) as a distributed sensor embedded into monitored structures.

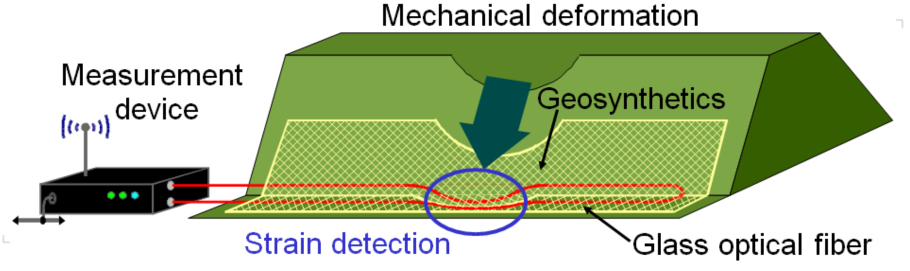

Figure 1. Components of the Brillouin-based fiber optic sensor system

2.1. Measuring principle

The use of all Brillouin-based distributed measurement systems is predicated on the determination of the spatially distributed Brillouin gain spectra (BGS) along the sensor fiber. Furthermore, the BGS is measured by coupling a pump lightwave into the sensor fiber and by observing the amplification of a weak counterpropagated probe signal coupled into the other end of the fiber. In the narrow-band method of BOFDA, the modulated pump beam and the backscattered signal are fed to a vector network analyzer, which calculates the so-called complex transfer function which converted by the inverse fast Fourier transform gives the distribution of strain and temperature along the GOF, providing high dynamic range and cost efficiency.

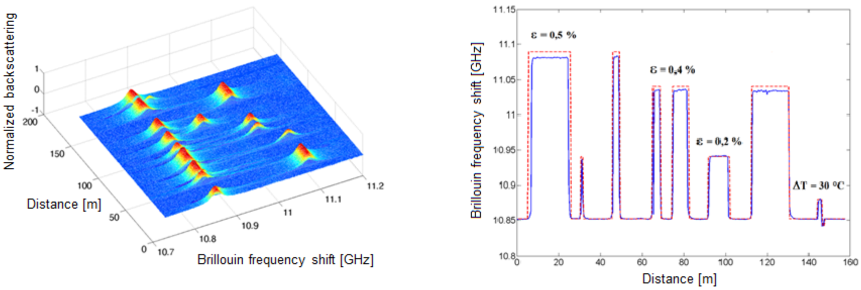

Figure 2. Left: Measurement of Brillouin gain spectrum distribution along a glass optical fiber using BOFDA. Right: Distributed strain and temperature profile measured on a glass optical fiber using BOFDA

2.2 Geosynthetics for detection of mechanical deformation and temperature gradients

The feasibility of the novel optical fiber cables based on GOFs and geosynthetics materials has been proven in several laboratory and field tests. Due to the achieved low optical attenuation of 1.5 dB/km along sensor cables integrated into geogrids the measurement range could be increased up to a few kilometers.

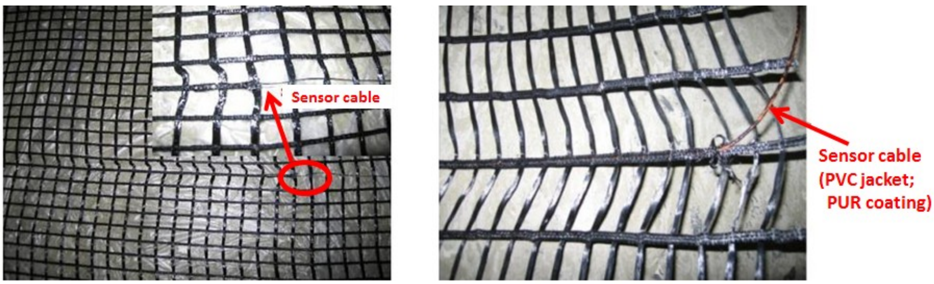

Figure 3. Sensitive geogrids for distributed temperature and strain measurements

3. RESULTS AND CONCLUSIONS

Due to the transfer of the latest integration technologies of fiber optic cables in geosynthetic reinforcement materials, new innovative geosynthetic mats as sensory final products can be fabricated for large-scale monitoring. Furthermore, the sensory use of the nonzero dispersion-shifted fibers (NZDSFs) led to realization of simultaneous measurement of strain and temperature based on BOFDA.

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UV CURING EFFECT ON FIXATING OF CAPSULE BASED SUBSTANCES ONTO TEXTILE MATERIALS

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Abstract: Capsulation technology is one of the methods that have been utilized for gaining various functional properties to textile materials. With the technology, in recent years, textile materials have made to exhibit functions such as vitamins, fragrances, moistening effect, insect repellent and anti-cellulite. To establish permanent bonding between capsule based materials and textile materials which also provides efficiency against washing make use of cross-linking agents. Commercial capsules are applied to a fabric by using acrylics or polyurethanes as the cross-linker at a drying temperature of around 100°C and thermofixation conditions between 110°C. The capsules used for fragrance and aromatherapy applications, which contain volatile oil, can be affected in high temperature conditions that cause evaporation, degradation of active ingredient. In this study, besides thermal curing, UV curing process will also be utilized for fixation of capsules onto textile material. Thus, active ingredient of beta carotene was capsulated with ethyl cellulose via spray drying first and then applied to textile materials in order to maintain tanning effect of cosmetic textiles. UV curing technique will be used as an alternative to thermal fixing of conventional cross-linkers. After application of the capsules onto textile materials, characterization and various efficiency tests such as antioxidant efficiency, color measurement) were performed.

Keywords: microcapsule, uv curing, acrylic binder, beta carotene, ethyl cellulose

1. INTRODUCTION

Encapsulation is an effective method to protect core agents from reactions caused by moisture, light, and oxygen. If functional agents were encapsulated, higher durability of functionality could be expected from the fabric. Capsules can contain various chemicals, including colorants, enzymes, softeners, fragrances, flame retardants, insect repellents, antimicrobials, and deodorants. Functional finishing with encapsulated technology will be conveniently achieved by using various functional capsules, and fixing them onto textiles. Traditionally, the fixation is achieved by applying a binder with capsules on fabric passing through a thermal curing process. The fabric will be exposed at relatively high temperature (130–170°C) for a certain period of time, in which the components in the binder are converted to a tough polymer and form a network on the fabric to hold the capsules. The thermal curing process can fix capsules to a good fastness whereas the difficult conditions may cause the core component in the capsule to volatilize and/or swell to release the contents and possibly break the capsule. In both cases functionality and durability of the finished fabric will diminish. In addition to the negative effects on the capsules, high temperature curing process consumes large amounts of energy, changes physical and mechanical properties, appearance of the fabric, and causes air pollution. UV curing is an alternative process to eliminate the disadvantage of the thermal process. UV curing process is the application of a UV-curable resin, which contains oligomers, monomers, and photo-initiators, with functional capsules onto the fabric. The fabric is then exposed to UV light for a few seconds to polymerize the resin components into a continuous film that strictly fix the capsules. The advantages of UV curing involve; low energy consumption, pollution prevention, yield increase and rapid process at low temperature. UV curing can be applied in many areas in textile wet processes, such as textile coloration (Li *et al.*, 2004b), durable press finish (Jang *et al.*, 2001, 1999), fabric printing (Fouassier *et al.*, 1995), pilling reduction (Millington, 1998), and shrink resistance for wool (Dodd *et al.*, 1998). Furthermore, undesired capsule fracture caused conventional appliqué techniques can be avoided via UV curing process.

2. MATERIAL AND METHOD

2.1 Preparation of β-carotene Capsules and Fixation on Textile Material

In order to obtain ethyl cellulose (EC) capsules containing β-carotene, spray drying method is employed. B-carotene and EC is solved homogenously at a specific ratio in ethyl acetate. The cosmetic capsules are prepared at different shell: core (w:w) ratios (2:1, 4:1, 8:1, 16:1). The operational conditions of the spray drying are given as follows: inlet temperature, 135°C; outlet temperature, 85°C; feeding rate, 10 mL/min. For thermal fixation the sample is impregnated in a solution bath containing cosmetic capsules and linking agent, squeezed between rollers to 90% wet pick-up. Then it is dried at 90°C and fixed for 5 minutes at 110°C. For UV fixation first impregnated samples dried for 5 min at 90°C and then were exposed to UV lamp for 5 minutes per each side.

2.2 Characterization of β-carotene Capsules

The optimum ratio of EC:β-carotene capsules which turns out to be 4:1(shell:core) is chosen according to SEM, XRD, FT-IR and particle size distribution analyses. Capsule applied fabrics are washed repetitively. In order to evaluate washing resistances of the capsules and the active agent; SEM, active agent ingredient and antioxidant capacity analysis are performed.

3. RESULT AND DISCUSSION

According to surface morphology examinations (Fig 1), EC:β-carotene capsules which were exposed to both thermal fixation and UV curing process are existed on cotton fabrics. Moreover, the capsules were still present on cotton fabrics after 10 washing cycles.

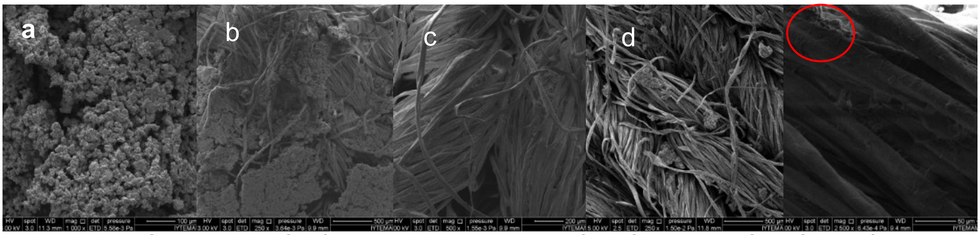

Figure 1. SEM images of **a.** β-carotene capsules **b.** UV fixed fabric **c.** UV fixed fabric after 10 washing cycles
d. thermally fixed fabric **e.** thermally fixed fabric after 10 washing cycles

FT-IR analyses (Fig 2) showed the presence of β-carotene peak which is at 1740 cm^{-1} and this peak proves the existence of the capsules cotton fabrics. FT-IR analyses demonstrated that β-carotene existed even after 10 washing cycles on both thermally fixed and UV cured fabrics.

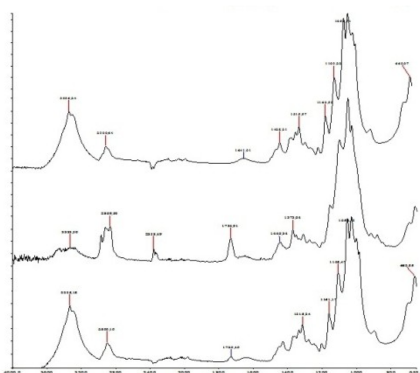

Figure 2. FT-IR diagrams of **a.** untreated fabric **b.** UV fixed fabric **c.** thermally fixed fabric

4. CONCLUSION

In this study, UV curing effect on fixating of capsule based substances onto textile materials was investigated Surface morphology and FT-IR analyses addressed that UV cured fabrics contained more β-carotene capsules than thermally fixed fabrics in terms of linking capacity. For future studies, It is anticipated to keep on investigations on the effects of different parameters in UV curing process such as; raw materials, photoinitiators, shell materials, active ingredients, distance between the fabric surface and UV lamb.

ACKNOWLEDGEMENTS

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A TEXTILE-BASED HEAT FLUX SENSOR

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Abstract: With the emergence of smart textiles, the research into textile-based sensors has increased as well. These sensors have the advantage of being flexible, and compatible with clothing thus more unobtrusively integratable and more comfortable to wear. On the other hand, one of the purposes of clothing is to enhance the thermal comfort of the wearer. Therefore, a textile-based sensor that can measure the heat flux between the body and its surrounding micro environment has been developed and manufactured on an industrial scale. The sensor is a woven structure and the sensing component is a thermoelectric wire inserted during the weaving process. In this way a flexible and breathable heat flux sensor is obtained.

Keywords: Smart textiles, textile sensor, heat flux, thermo-electric wire

1. INTRODUCTION

Increasing the thermal comfort of the wearer is one of the major objectives of our clothing. This sense of comfort is determined by the temperature and the humidity in the micro-environment surrounding our body. Clothing plays an important role in this since it modifies the heat loss and moisture loss from the skin surface [1]. The monitoring of this process during everyday life can give input on improved clothing design or on actively changing the thermal properties of the garment system, thus creating a smart garment. A heat flux sensor can provide data on the temperature gradient between skin and clothing, or environment. Furthermore, a textile-based sensor should be easily and unobtrusively integratable into our garments. Heat flux measurements for use in physiological and clothing research allow to look at body heat exchange with the environment.

2. MATERIAL AND METHOD

2.1. Sensor principle

The proposed sensor is based on the Seebeck (thermoelectric) effect which states that a temperature difference at the junction of two different conductive materials generates an electric voltage proportional to the temperature change. This is the basis for thermocouples. The presented sensor is formed on a thermoelectric wire made up of two different metals, constantan and copper. Each junction of the two metals is a thermocouple. The textile heat flux sensor has a textile substrate in which the thermoelectric wire is woven in such a way that the junctions between the metals are alternately facing both sides of the substrate, as shown in Fig.1. As such, a temperature difference between both faces of the substrate will generate a voltage. The more junctions present, the higher the voltage difference ΔV will be and the higher the sensitivity of the sensor.

$$\Delta V = N \cdot \alpha \cdot \Delta T = N \cdot \alpha \cdot R_{th} \cdot \emptyset$$

with N the amount of junctions on one side, α the Seebeck coefficient [µV/K], ΔT the temperature difference between the thermo-junctions [K], R_{th} the thermal resistance of the whole sensor [K/W] and $\emptyset$ the heat flow [W].

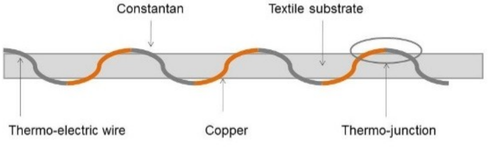

Figure 1. Cross section of a textile-based heat flux sensor and woven heat flux sensor

2.2. Sensor development

A thermo-electric (TE) wire is inserted into the woven structure to obtain a textile-based heat flux sensor. Yarns of polyester (PES) and polyester/cotton (PES/Co) are used for the textile substrate with the structure of plain, twill 4/1Z and satin 5. TE wire is prepared by an electrochemical deposition of copper (Cu), with a thickness of ~20-30 micron, to a wire of constantan (Cn) with a diameter of 76 micron. The weaving process is followed by a post-treatment to transform the textile structure to a sensor (thermopile) by obtaining the Cn-Cu junctions on each surface of the sample. The sensor is made by local etching of the copper deposit [2].

2.3. Characterization: calibration by Skin Model

Heat flux measurements for use in physiological and clothing research allow to look at body heat exchanges with the environment. However, the performance given by manufacturer of conventional heat flux meters has to be chosen according to the intended purpose of use [3]. We propose to observe the behavior of textile heat flux sensors and a reference conventional heat flux sensor (Captec Enterprise, Lille, France) on the sweating guarded hot plate (Skin Model, ISO 11092).

3. RESULTS AND DISCUSSION

The sensitivity of sensors in the closed conditions of wearing can be observed in Fig.2: The greater the gradient of the curve, the greater the sensitivity of the sensor. It is clearly shown that the satin structure with PES/Co yarn gives a closer performance to the reference heat flux sensor than the others.

Fig.3. indicates the behavior of the sensors in regards to the diffusion of water at the interface of the wet fabric and the heat flux sensor (both textile and reference) and for textile heat flux sensors the diffusion of humidity through the sensors.

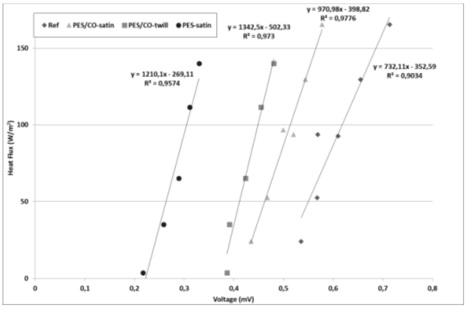

Figure 2. Heat flux generated by modification of Skin Model temperature function of the voltage given by sensors. The environment was fixed at 20°C, 50%H.R.

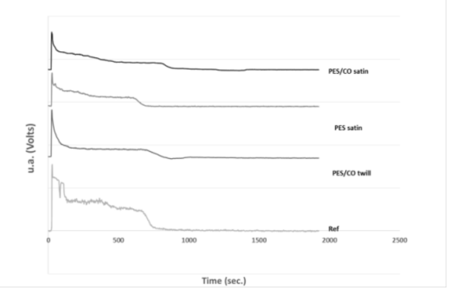

Figure 3. Evolution of the voltage during drying time of 0.1 ml distilled water impregnated fabric on the upper side of the sensor. The sensors were placed on the skin model (35°C, 0%H.R., 1 m.s^{-1})), and the entire system was placed in a climatic chamber (20°C, 50%H.R.)

4. CONCLUSION

Manufacturing a textile-based heat flux sensor requires the integration of a thermoelectric wire into a textile substrate. The thermoelectric wire is built up of two metals, creating junctions on both sides of the textile. The more junctions present the higher the measurable voltage. A non-elastic narrow woven fabric with integrated thermo-electric wire is presented here as sensor. The metal junctions on both sides of the sensor are obtained by selectively removing the copper coating of the constantan wire. The textile sensor is flexible, breathable and can easily be integrated in different parts of a garment where heat flux measurements are required.

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DETERMINATION OF CONDUCTIVE COMPOSITE YARN DEFECTS OF KNITTED FABRICS VIA REVERSE ABRASION TEST

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Abstract: There is a lot of academic and even commercial research going on for the production of conductive textile materials such as electronic textiles and electromagnetic shielding textiles. In the literature it is seen that mostly conductive composite yarns with metal wires are preferred as conductive components for electromagnetic shielding knitted fabrics. Producing knitted fabrics without defects (overcoming the yarn and/or knitting problems) is possible with the usage of appropriate composite yarn on an appropriate knitting machine with appropriate machine settings. However, it is also required to determine the possible metal wire defects of the fabrics to overcome the possible prickliness and itchiness problems. The aim of this study is to investigate a test method to determine the conductive composite yarn defects of knitted fabrics.

Keywords: Knitted Fabric, Conductive Composite Yarn, Metal Wire, Reverse Abrasion Test

1. INTRODUCTION

There is a lot of academic and even commercial research going on for the production of conductive textile materials such as electronic textiles and electromagnetic shielding textiles. Conductive textile materials are generally produced from woven fabrics, knitted fabrics, nonwovens and composites involving conductive polymers, metallic fibers, metal wires, metallic coated yarns or composite yarns.

In the literature it is seen that mostly conductive composite yarns with metal wires are preferred as conductive components for electromagnetic shielding knitted fabrics [1-5]. Producing knitted fabrics without defects (overcoming the yarn and/or knitting problems) is possible with the usage of appropriate composite yarn on an appropriate knitting machine with appropriate machine settings [5]. However, it is also required to determine the possible metal wire defects of the fabrics to overcome the possible prickliness and itchiness problems.

The aim of this study is to investigate a test method to determine the conductive composite yarn defects of knitted fabrics.

2. MATERIAL AND METHOD

AISI 316 L type conductive stainless steel (SS) wires with a diameter of 35 µm and 50 µm are used as conductive component of the textile material in the study. Conductive composite yarns are produced using a hollow spindle twisting machine with the same machine settings. Raw and dyed Ne 60/2 count cotton (Co) yarns are used to produce SS/Co composite yarns. Conductive composite yarn characteristics are presented in Table 1.

Table 1. Characteristics of the conductive composite yarns

Yarn Composition	Linear Density (Ne, Nm)	Breaking Force		Elongation	
		F (cN)	%CV	%	%CV
35 µm SS + Ne 60/2 Co (raw)	Ne 21.52 = Nm 36.45	387.333	6.068	5.332	7.984
50 µm SS + Ne 60/2 Co (raw)	Ne 16.25 = Nm 27.51	437.333	2.112	5.433	6.314
35 µm SS + Ne 60/2 Co (dyed)	Ne 20.73 = Nm 35.11	446.000	3.033	5.893	13.448
50 µm SS + Ne 60/2 Co (dyed)	Ne 16.85 = Nm 28.53	477.000	1.089	6.907	0.016

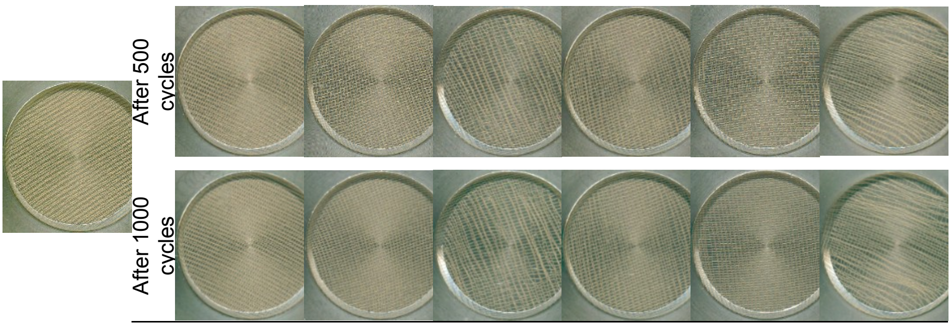
Single jersey fabric samples are knitted with the same machine settings on a Harry Lucas circular knitting machine with a gauge of 20, a diameter of 3½, and 220 needles. 100% cotton fabrics are also knitted in order to determine the effects of metal composite yarns. Following the knitting process, while fabrics with dyed cotton yarns are subjected to a finishing process, fabrics with raw cotton yarns are subjected to a dyeing and finishing process. Drying is made by laying the fabric samples on a smooth and flat surface in atmospheric conditions (20±2°C and 65±5% relative humidity).

A reverse abrasion test is made on a James H. Heal Nu-Martindale abrasion machine, in order to observe the effects of dyeing, the finishing processes, and the metal wire diameter on the conductive composite yarn defects in the knitted fabrics. First, standard felts and knitted fabrics are prepared with a diameter of 140 mm, using the press cutter and by placing them on the sample holder. Then, 60 mm x 60 mm sized 15 Denier stocking fabric samples are prepared and placed on the abradant holder and stretched as much as possible. In this stage no polyurethane foam is placed on the abradant holder. Finally, 9 kPa head weights are exerted on the abradant holders and the machine is powered up. The test equipment is stopped after 500 and 1000 cycles and the deformation of the 15 Denier stocking fabric samples is scanned and saved digitally using an Hp Scanjet 2300c model scanner.

3. RESULTS AND DISCUSSION

Images of the 15 Denier stocking fabric samples that are scanned before and after the reverse abrasion test are presented in Figure 1.

15 Denier stocking fabric before the reverse abrasion test	Deformation caused by the fabrics with raw cotton yarns that are subjected to dyeing and finishing processes	Deformation caused by the fabrics with dyed cotton yarns that are subjected to a finishing process



Deformation caused by the fabrics with Ne60/2 Co yarns	Deformation caused by the fabrics with 35µm SS+Ne60/2 Co yarns	Deformation caused by the fabrics with 50µm SS+Ne60/2 Co yarns	Deformation caused by the fabrics with Ne60/2 Co yarns	Deformation caused by the fabrics with 35µm SS+Ne60/2 Co yarns	Deformation caused by the fabrics with 50µm SS+Ne60/2 Co yarns

Figure 1. Images of the 15 Denier stocking fabrics after 0, 500 and 1000 cycles of reverse abrasion testing.

Images of the 15 Denier stocking fabric samples after 500 and 1000 cycles of reverse abrasion test show that both the fabrics with 35 µm SS wires and raw cotton yarns that are subjected to dyeing and finishing processes and the fabrics with 35 µm SS wires and dyed cotton yarns that are subjected to finishing process do not make any deformation on the stocking fabrics.

Images of the stocking fabric samples after the reverse abrasion test also show that while fabrics with 50 µm SS wires do not deform the stocking fabric like ladder, loop forms of the stocking fabrics become misshapen.

4. CONCLUSION

Producing knitted fabrics without defects (overcoming the yarn and/or knitting problems) is possible with the usage of appropriate composite yarn on an appropriate knitting machine with appropriate machine settings. However, it is also required to determine the possible metal wire defects of the fabrics to overcome the possible prickliness and itchiness problems. Therefore, the aim of this study was to investigate a test method to determine the conductive composite yarn defects of knitted fabrics.

A reverse abrasion test is made on a James H. Heal Nu-Martindale abrasion machine using ultra-thin stocking fabric samples. Reverse abrasion test results reveal that none of the fabrics that are investigated in this study have broken metal wire content.

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DEVELOPMENT OF SILVER BASED ANTIBACTERIAL MASTERBATCH FOR POLYESTER FILAMENT YARNS

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Abstract: The aim of this work is to synthesize an antimicrobial composite material containing silver ions, then use it in masterbatch formation to obtain antibacterial polyester yarns. Firstly silver embedded antibacterial material was developed by wet chemical method then milled to sub-micron size. Antibacterial performance of the composite powders was tested by Halo test method. Characterization tests were carried out by SEM, EDX, XRD and particle size analyses. Afterwards composite material, carrier polymer and other auxiliaries were fed in extruder and antibacterial masterbatch in granular form was produced. Characterization and chemical tests showed that developed masterbatch is convenient to be doped into polyester yarn by spinning process.

Keywords: silver, composite material, masterbatch, antibacterial polyester

1. INTRODUCTION

Microorganisms can cause functional, hygienic and aesthetic problems on textile products. Therefore, antibacterial materials have been developed to protect the textiles from the harmful effects of microorganisms [1]. For centuries silver has been in use for the treatment of burns and chronic wounds [2]. Silver has been described as being 'oligodynamic' because of its ability to exert a bactericidal effect on products containing silver, principally due to its antimicrobial activities and low toxicity to human cells [3]. Masterbatch approach was used to functionalize polyester. In this work, a silver containing material was developed and used in masterbatch which can be used in order to give antimicrobial property to polyester filament yarns.

2. MATERIAL AND METHOD

2.1 Polybutylene Terephthalate

In this work polybutylene terephthalate polymer was selected as a carrier. Main properties of PBT is shown in Table 1.

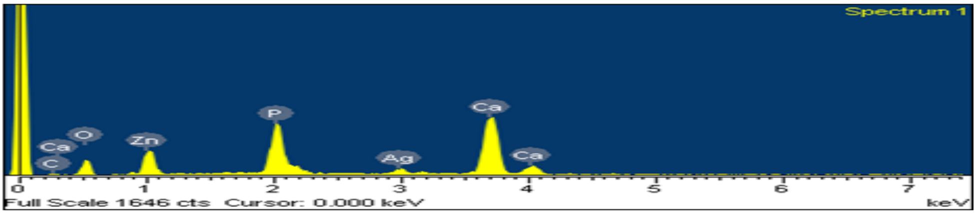
Table 1. Main properties of PBT.

Property	Results
Degradation Temperature	> 300 °C
İgnition Temperature	> 420 °C
Density	1,3 - 1,4 gr/cm³
Moisture	40 ppm (% 0,004)
Melt Flow Index (g/10 min) at 235°C	42-55

3. RESULTS AND DISCUSSION

3.1 Preparation of composite material and characterisation tests

Hydroxylapatites $(Ca_{10}(PO_4)_6(OH)_2$ are biocompatible and are not harmful to human skin. They enable cation transfer of metal ions at higher rates. For this reason in this work silver ions were reacted in solution with calcium phosphate and embedded in it. The active substance was the silver and the carrier material was calcium phosphate. The silver ions released from the material attacked to the bacteria and provided the inhibition of the growth of bacteria. The antibacterial material synthesized was then grinded in mills to nano size. EDX analysis results given in Figure 1 confirm the elemental composition of antibacterial material.



Element	Weight%	Atomic%	Compd%	Formula
P K	14.70	13.11	33.67	P2O5
Ca K	24.08	16.60	33.70	CaO
Zn K	23.08	9.76	28.73	ZnO
Ag L	3.63	0.93	3.90	Ag2O
O	34.51	59.60		
Totals	100.00			

Figure 1. EDX analyses of antibacterial material

3.2 Preparation and characterisation of masterbatch samples

Composite material was mixed with carrier polymer (PBT in grinded powder form), dispersant agents and other chemical auxiliaries in high shear mixer then dried at 120 °C for 3 hours in oven. After drying, the mixture was fed into a twin screw extruder. The melt mixture was prepared by heating under regulated pressure, it was then cooled in water and pelletized. Figure 2 shows the DSC thermograms of the masterbatch samples. It can be concluded that antibacterial powders didn't change the melting temperature of the polymer. However integral areas of the each sample were different from each other

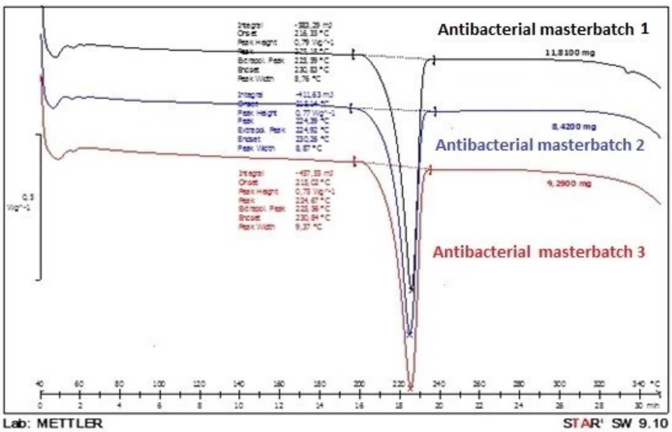


Figure 2. DSC thermograms of the antibacterial masterbatch samples.

4. CONCLUSION

Silver containing antibacterial powder was successfully developed and milled to sub-micron scales (250 nm) to be used in polyester filament yarns having 5-10 microns diameter. XRD and EDX analyses confirm the crystal structure and elemental composition of antibacterial material. The antibacterial material was mixed with carrier polymer and other auxiliaries during extrusion process and antibacterial PBT masterbatch was prepared. SEM images of masterbatch samples show that there is no agglomeration of active composite material. DSC graphics of masterbatch confirmed the stability of the polymer and viscosity values are convenient for doping it in extrusion of polyester yarn spinning easily.

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INVESTIGATING THE SURFACE CHARACTERISTICS OF WOVEN AUTOMOTIVE UPHOLSTERY FABRICS

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Abstract: Automobile seat covers are one of the most important product groups in technical textiles. Seat covers must meet the aesthetic, comfort and physical requirements. This study was carried out to investigate effect of yarn type, fabric density and mechanical finishing process on the surface characteristics of woven fabric. In this context, impact of warp yarn hairiness, fabric density and calendering process on the static friction behavior of fabrics were investigated. And also the relationship between static friction behavior and abrasion resistance of woven fabrics was analyzed.

Keywords: seat cover, woven fabric, yarn type, fabric density, mechanical finishing

1. INTRODUCTION

Automotive upholstery fabric is a complicated material which is produced to respond various demands. These demands are simulated with a variety of test methods in laboratory conditions. One of them is static friction behavior. Coefficient of static friction is evaluated to simulate sliding on seat of occupant. To be within a certain range of static friction value is important for the optimum comfort.

The aim of this study is to investigate effect of yarn type, fabric density and mechanical finishing process on the surface characteristics of woven fabric. And also the relationship between static friction behavior and abrasion resistance of woven fabrics was analyzed. For this purpose; impact of warp yarn hairiness, fabric density and the calendering process on static friction behavior were investigated. Furthermore relationship between static friction behavior and abrasion resistance of woven fabrics was analyzed.

2. MATERIALS AND METHODS

2.1Material and Methods

In this study woven fabrics were produced with same pattern. Warp and weft yarns were produced from polyester fibers in the air jet texturized machine. Warp yarn thickness was 1150 decitex (dtex) for all fabrics. But the hairiness of the warp yarn was changed. Hairy yarn is named as normal and the less hairy one is as compact. Two different weft yarns were used in order to change the weft density. Weaving machine has worked with maximum density for each weft yarn on this structure. The fabrics having 20 density and 17 density were produced with 890 and 1050 dtex yarn respectively. And each fabric that was produced divided into two group. Calendering process was applied onto the one of the groups. Detailed study plan is shown in Table 1.

Table 1: Experimental study plan

Fabric Code	Warp Yarn Type	Weft Yarn Thickness (dtex)-Weft Density(pick/cm)	Mechanical Process
N17	normal	1050-17	-
N20	normal	890-20	-
C17	compact	1050-17	-
C20	compact	890-20	-
N17C	normal	1050-17	calendering
N20C	normal	890-20	calendering
C17C	compact	1050-17	calendering
C20C	compact	890-20	calendering

All fabrics were laminated with foam and scrim fabric on the flame lamination machine. The foam used in this study was based on polyester polyurethane. Scrim fabric was produced from polyester yarn. Laminated fabrics were tested.

2.2Tests

Coefficient of static friction was measured and taber test was done. Tests were realized according to the different OEMs specifications in MARTUR R&D Labs.

3. RESULTS AND DISCUSSION

Test results are shown in Table 2.

Table 2. Test Results

	N17	C17	N20	C20	N17C	C17C	N20C	C20C
Coefficient of Static Friction (Θ)	0,51	0,51	0,52	0,53	0,51	0,51	0,71	0,73
Taber Test	NOK	NOK	NOK	OK	NOK	OK	NOK	OK

According to the all test results it was seen that some parameters investigated in the study have influences on coefficient of static friction. And also it was determined that there is a relationship between static friction behavior and abrasion resistance of woven fabrics. Coefficient of static friction must be above a certain value in order to pass taber test. Compact yarns must be used in order to be able to use this type of fabric in automotive. Fabric produced with compact yarns must be either subjected to the calendering process or produced in high weft density.

4. CONCLUSION

This study was carried out to investigate effect of yarn type, fabric density and calendering process on the surface characteristics of woven fabric. In this context, coefficient of static behavior and Taber test was investigated. As a result of the study, yarn hairiness, weft density and the calendering process have different influences on fabric properties investigated in the study. It was determined that there is a relationship between static friction behavior and abrasion resistance of woven fabrics.

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IN-SITU COATED OF Ag, ZnO, Ag/ZnO COMPOSITE NANO PARTICLES TO THE TECHNICAL FIBER AND YARN BY HYDROTERMAL METHOD

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Abstract: Nowadays, the usage of antibacterial textiles is very popular for different type of textiles. The silver (Ag) and zinc oxide (ZnO) are the most popular materials in order to improve antibacterial properties of textiles.In this experimental study, it was investigated whetherit was possible to produce AgNp, ZnONp, Ag/ZnO Npcomposite materials by hydrothermal method which wasknown as in-situ approach. In addition, the colloidal silver (Ag^+) was produced by electrolysis method, and applied to the polyester fiber by exhaust method. After whole applications, the samples were characterized by SEM, XRD, EDX analyses and the antibacterial/fungal activity of specimens was tested according to the ASTM E2149-1 (gram negative Escherichia coli, gram-positive Staphylococcus aureus). In addition, the resistance to the repeated washes of these antibacterial samples was investigated. The results showed that polyester based samples had sufficient antibacterial activity and this activity did not reduce depending on repeated washing treatments.

Keywords: Antibacterial, antifungal, hydrothermal, fiber, yarn, electrolysis, silver, ZnO

1. INTRODUCTION

Emergence of the antibiotic resistance pathogens has become a serious health issue and thus, numerous studies have been reported to improve the current antimicrobial therapies. It is known that over 70% of bacterial infections are resistant to one or more of the antibiotics that are generally used to eradicate the infection. Development ofnew and effective antimicrobial agents seems to be of paramount importance. The antimicrobial activity of metals such as silver (Ag), copper (Cu), gold (Au), titanium(Ti), and zinc (Zn), each having various properties, potencies and spectra of activity, has been known and applied for centuries [1]. Recent advances in the field ofnanotechnology, particularly the ability to prepare highly ordered nanoparticulates of any size and shape, have led to the development of new biocidalagents [2].In this case, NPs have been demonstrated to be interesting in the context of combating bacteria [3].In the study, the technical antibacterial/fungal polyester fibre were tried to be produced by hydrothermal method. The hydrothermal method refers to any heterogeneous reaction in the presence of aqueous solvents or mineralizes under high pressure and temperature conditions in order to dissolve and recrystallize materials which are relatively insoluble under ordinary conditions [4, 5].

2. MATERIAL AND METHOD

2.1. Material

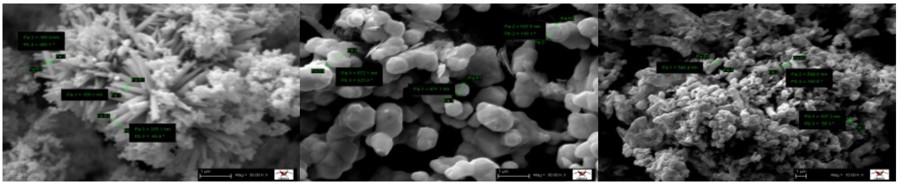
In this experimental study, the zinc nitrate hexa -hydrate ($Zn(NO_3)_2 .6H_2O$, Sigma), zinc acetatedehydrate ($Zn(NO_3)_2 . 2H_2O$, Sigma), silver nitrate (AgNO3) and hexamethylen-etetramine (HMTA, C6H12N4 , Sigma) were used for synthesis of ZnO, Ag and Ag/ZnO nanocompositeparticles according to in-situ hydrothermal method.In the study, 100% polyester fibre were used for in-situ coating method. These samples also were used for exhaust application of colloidal silver. In order to produce colloidal silver solutions, %99,9pure silver wire was used by a special equipment.

2.2. Method

In order to produce ZnO nano particle on the fiber/yarn with in-situ method, the precursor solution was prepared by dissolving 0.01 M of zinc nitrate hexahydrate or 0.01 M of zinc acetatedehydrate and 0.01 M of hexa - methylenetetramine in 200 ml deionizer water- 200 ml ethanol. When the composite material was tried to produce, 0.01 M of silver nitrate was added the zinc precursor solutions. Here, HMTA was used as complexion agent. The pH of prepared starting solution was measured and fixed to 6.5 value.The polyester fiber added to this precursor solution. The hydrothermal growth in the solutions and on the textile materialwas carried out at 120 and 90°C in HT dying machine during 1 and 2 hours. In order to obtain colloidal silver, the pure silver wire was used. The wire was dipped into distilled water during 3 hours. The electric produced from 9V batteries was passed through wire, then Ag+ ion was passed to the water, and colloid solution was formed. We obtained colloidal silver solutions at 40 ppm. We also stirred the solutions while producing colloidal silver. After producing of colloidal silver, the solutions were applied to the fibre in the tubes at 120 and 90°C by exhaust method, and the fibre was modified. The samples were characterized by SEM, XRD, EDX analyses and the antibacterial activity of specimens was tested according to the ASTM E 2149-1 for unwashed and washed samples.

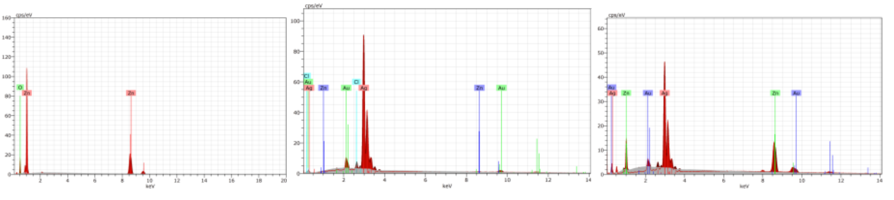
3. RESULTS AND DISCUSSION

The synthesized particles were characterized by SEM,XRD,EDX and the antibacterial activity of specimens was tested according to the ASTM E2149-1 (gram negative Escherichia coli, gram-positive Staphylococcus aureus). In Figure 1, the SEM images, EDX graphics and XRD pattern of the particles can be seen in Figure 1-2-3, respectively.



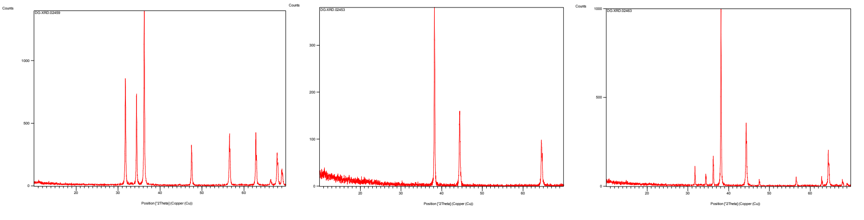
(a) **(b)** **(c)**

Figure1. SEM images of filtered nano powders (a) ZnO (b) Ag (c) ZnO/Ag [5]



(a) **(b)** **(c)**

Figure 2.EDX graphics of filtered nanopowders(a) ZnO (b) Ag (c) ZnO/Ag [5]



(a) **(b)** **(c)**

Figure 3. XRD pattern of filtered nanopowders (a) ZnO (b)Ag (c) ZnO/Ag [5]

4. CONCLUSION

In the study, the nano Ag, ZnONp, Ag/ZnO composite Np were obtained by hydrothermal method and coated to the fibre via in-situ method, therefore technical fibre can be produced with this selected approach. Either nano particles or coated samples were characterized, and it was found out that these particles were stabile even after repeated washing applications. In addition, the antibacterial activity of whole coated and colloidal silver applied samples had antibacterial activity between percent of 100 level.

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HEAT TRANSPORT PHENOMENA IN ADVANCED INSULATION MATERIALS

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Abstract: The heat transport properties observed in nanostructured materials like aerogel treated nonwoven fabrics are promoting revolutionary breakthroughs as thermal insulators. This paper is focused on the thermal transport characteristics of nonwoven fabrics treated with aerogel which are nanostructured materials for potential uses in thermal protective applications. Highly efficient aerogel thermal blankets are now considered a viable option in applications such as clothing, building, pipelines etc. A variety of fiber and fabric structures or finishing parameters influence the functional properties of nonwoven materials. In order to assess the thermal properties of aerogel treated nonwoven fabrics the KES Thermolabo-II & NT-H1 (plate/fabric/plate method for thermal conductivity, qmax cool/warm feeling and thermal insulation) was used. Fabrics of higher thicknesses show lower heat conductance and therefore higher thermal insulation properties. It has been found that the thermal insulation is also related to the weight and compressional properties of fabric. To make an insulating material effective it should have low compression-set/high-resiliency to make the still air entrapped into the material.

Key Words: Thermal insulation, advanced materials, aerogel, KES, thermal conductivity, compressional resilience

1. INTRODUCTION

Different kinds of fibrous materials are used as the middle thermal insulating layer of multilayer clothing, such as traditional nonwovens. Nonwoven fabrics are important components for good thermal insulation of the body from the surroundings, and have both space and weight savings [1]. The important constructive parameters are thickness, weight per unit area and packing fraction p.f., which is the ratio between the bulk density of fibrous structure samples and of the same sample if it was made up wholly from the same polymer [2]. Thermal insulation properties are determined by the physical parameters of fibrous structures as well as the structural parameters [3]. Aerogel is one of the highly advanced thermal insulating materials used to treat nonwoven fibrous structures. Aerogel have a very low solid material density ~0.02 to 0.4 g/cm^3 and a very high internal surface area ~900 to 1000 m^2/g. Based on the combination of its solid microstructure, low density, and silica composition, aerogel show great promise as an insulation medium [4].

2. MATERIAL AND METHODS

2.1. Materials

50:50 ratio compositions of six polyester/polyethylene non-woven fabrics treated with aerogel were used. Six aerogel treated nonwoven fabrics shown in table 1 were used in the study. The type of aerogel incorporated in the fabric was hydrophobic amorphous silica aerogel which is most suitable for application in textile material which provides the superinsulating properties in a flexible form. It is excellent for ambient and sub-ambient insulating applications. The aerogel particles were added during thermal bonding of the non-woven web. The samples were chosen in different thicknesses widely used in most textile insulating applications.

Table 1. Sample description

Samples No.	Description	Thickness (mm)	Weight (g/m^2)	Density (kg/m^3)
S1	Aerogel treated nonwoven fabrics	3.424	272.56	79.66
S2		6.212	499.46	80.42
S3		6.608	440.7	66.73
S4		8.06	535.1	66.39
S5		11.12	733.7	65.99
S6		13.8	942.7	68.33

2.2 Methods

The thermal properties were measured for each fabric with the KES-FB7 instrument and NT-H1 (where, N stands for NISHIMATSU and TOYONORI) in accordance with the standard procedure ASTM 1518 (surface: 10cm^2, temperature difference between the two sides: 10^{o}C), except for the pressure applied to the sample, in order to examine the influence of thickness. A fixed contact temperature of 30^{o}C for the hot plate was used to reproduce the temperature of the skin surface. An assessment of thermal insulation was also carried out for all fabrics. Using Kawabata's Thermolabo device, a heat flux versus time curve is generated when a preheated hot plate (as a simulator of human skin) is placed on a fabric sample. A KES compression tester was used to measure the thickness and compressional properties of the samples. All the experiments were carried out under standard conditions, BS1051, at 20 °C and 65% relative humidity.

3. RESULTS AND DISCUSSION

The influence of wind speed on the thermal insulation properties of the fabrics has been studied. It is expressed as a percentage which represents the reduction in the rate of heat loss due to the insulation, relative to the heat loss from the surface. It was observed that heat retention properties is always more important for fabrics in colder environments; besides there is a linear relationship with the air flow velocity. The fabrics or fabrics with high porosity will prevent air passage and then reduce convection heat loss. It is observed from Figure 1 that with the increase in aerogel content, the thermal insulation rate increases with increase in wind velocity. This may be attributed to higher thickness of the fabric having higher aerogel content.

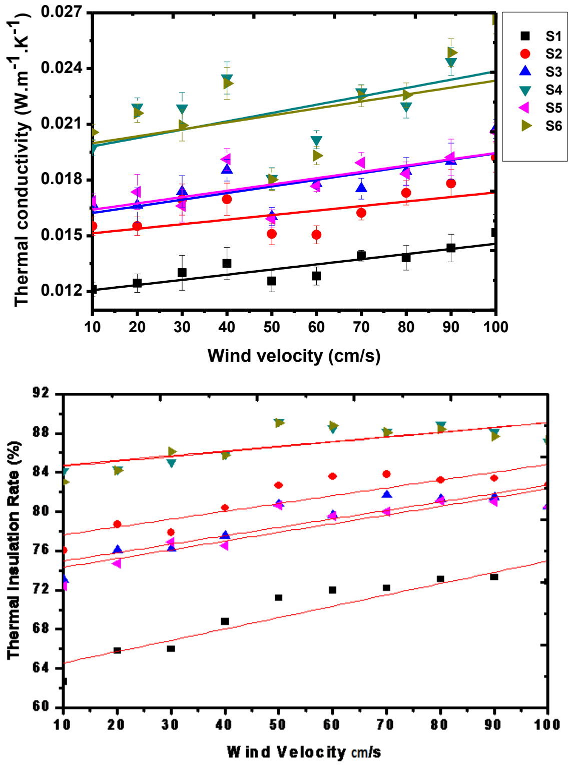

Figure 1. Thermal Insulation (Left: KES Thermolabo II, Right: NT-H1)

4. CONCLUSION

Nanostructured materials (aerogel treated nonwoven fabrics) are becoming the materials of choice for textile applications mostly due to the reduction of the thermal conductivity. However, a large number of applications could presently benefit from nanostructured materials. A lot of fiber and fabric structures or finishing parameters influence the functional properties of fabrics. The measurements are useful for providing objective thermal parameters and therefore wear comfort evaluation. In this study, three aerogel treated nonwoven fabrics were compared. From the results, we conclude that the thickness, density and the aerogel present in the fabrics are three chief factors which determine the insulation property. The thickness of fabric strongly affects amount of heat insulation. In general the greater the fabric thickness, greater the thermal insulation. It has also been found that the thermal insulation is also related to the weight and compressional properties of fabric. To make an insulating material effective it should have low compression set/high resiliency to make the still air entrapped into the material.

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COMPARISON OF METHODS FOR EVALUATING THE SHIELDING EFFECTIVENESS OF CLOTHING WOVEN FABRICS

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Abstract: Textured steel yarns have soft feeling and flexibility, which are required properties for clothing fabrics. Therefore, in this research, textured steel yarn was selected as a conductive yarn to produce conductive clothing fabrics. The electromagnetic shielding effectiveness (EMSE) of herringbone, whipcord, barathea, and crêpe woven fabrics, which are twill and sateen derivatives, woven with textured steel yarns have been measured by both open area free space measurement technique and free space measurement technique in a RF chamber. The EMSE of these clothing fabrics woven with textured steel yarns have not been investigated by free space measurement technique in a RF chamber so far.

It is clear that RF chamber measurement technique is more convenient comparing with open area measurements. The reflections of environment, interference of other sources and multi path effects should be decreased as much as possible.

In this study, the EMSE characteristics of different weaves were investigated and it is seen that when the yarn floats arrangement is changed the EMSE characteristic changes. And also, it was observed that all conductive clothing woven fabric samples shielded well in medium and high frequency bands, which contain 900 MHz GSM, 1800 MHz GSM, 2100 MHz 3G, and 2400 MHz Wi-Fi bands.

Keywords: Clothing woven fabrics, twill derivatives, sateen derivatives, electromagnetic shielding effectiveness, textured steel yarns

1. INTRODUCTION

Wireless communication links have been used worldwide for many years as solutions for connectivity in point to-point and point-to-multipoint applications. Especially higher generation cell phone structures (3G, 4G, 5G etc.), Wi-Fi, radiophones and baby monitors have been commonly used in recent years. These devices occupy industrial, scientific and medical (ISM) bands from 50 MHz up to 15GHz. As they operate, these devices emit low power electromagnetic fields. Even though we face with many sources of natural electromagnetic fields, artificial electromagnetic sources raise awareness in public due to their unknown affects to human health. An important issue to be addressed with electromagnetic (EM) waves is their possible health effects on humans [1–2]. The World Health Organization (WHO) suggests that a wide range of environmental EM influences cause biological effects [3]. Thus, preventing unwanted electromagnetic signals become an important topic.

Więckowski and Janukiewicz [4] suggested the scope of application of the measurement methods based on MIL-STD 285 & IEEE-STD-299 for comparison to ASTM D4935 of EMSE of textiles and gave their limitations and the possibilities for comparisons of the results. Özdemir and Özkurt [5–6] measured the EMSE of some cellular and diced woven conductive fabrics woven with stainless steel core yarns at different weft densities by open area free space measurement technique at horizontal polarization of the antenna. In other research [7], they investigated the EMSE of 2/2 twill, 3/1 twill, herringbone, whipcord, barathea, and crêpe woven clothing fabrics, woven with textured steel yarns, in large band width by open area free space measurement technique.

The aim of the study is to compare the open area free space measurement technique with RF chamber measurement technique in order to explain environmental effects on measurements. The shielding curves for both measurements conditions are given together and compared with the effects on shielding properties of woven fabrics interested. Furthermore, the effect of weave on the EMSE characteristics of the some common clothing woven fabrics was investigated.

2. MATERIAL AND METHOD

2.1. Production of woven fabric samples

In this research, 6 types of clothing woven fabric samples, whose weaves are 2/2 twill, 3/1 twill, herringbone, whipcord, barathea, and crêpe, (42×42 cm) were produced in weaving workshop of in-house by CCI automatic sample rapier loom (Evergreen 8900, Taiwan). The 100% PET yarns and textured stainless steel yarns, which have soft feeling and flexibility, required properties for clothing fabrics, were used. The optical image of the textured steel yarn was taken by using Olympus BX 43 Microscopy as shown in Figure 1. The specifications of yarns are given in Table 1. Weave patterns are shown in Figure 2.

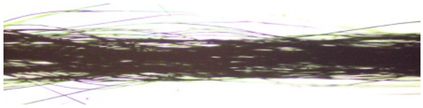


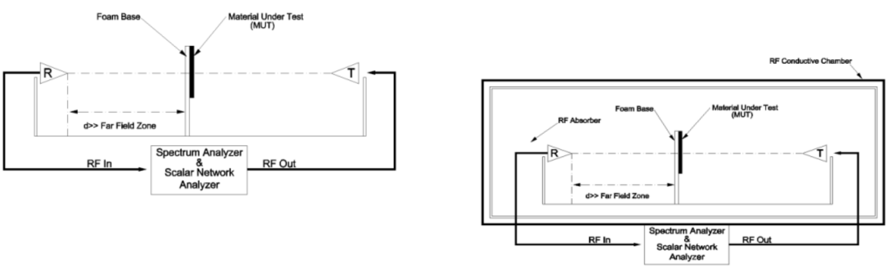
Figure 1. Optical image of textured steel yarn

Table 1. The specifications of yarns

Material	**Yarn count (dtex)**	**Diameter of wire (mm)**	**Conductor resistance (Ωmm2/m)**
Polyester yarn	600	–	–
Textured steel yarn	695	0.037	0.013

2.2. Open Area Free Space and RF chamber Measurement Techniques

Fundamental measurement method was based on the signal attenuation on two sides of woven fabric material located on far field zones of transmitter and receiver antennas for both vertical and horizontal polarization. The ratio of total amount of transmitted signal strength over total incident signal strength determined the SE term related to material properties. The sample is mounted between two antennas connected to a spectrum analyzer in which has a RF source. The measurements are realized in open area and in RF chamber which is shielded and covered by RF absorber insider walls. The measurement set-ups are shown in Figure 2.



a **b**

Figure 4. The measurement set-ups: (a) Open area free space measurement technique, (b) RF chamber measurement technique

3. RESULTS AND DISCUSSION

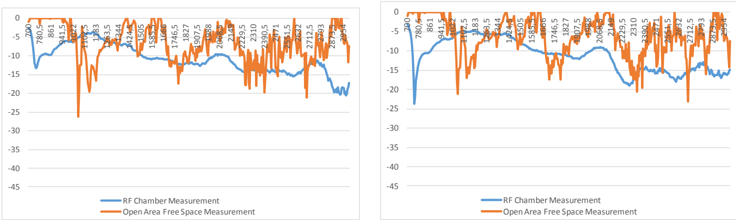
From the measurements, which will be given as graphs, it is seen that open area measurements can be affected by environmental conditions. More spikes and level raises resulted by reflections are observed and frequency band changed. Average shielding levels are low comparing to chamber measurements. In chamber measurements, there are less reflection effects and frequency responses of shielding are more realistic.

There are differences between the vertical and horizontal measurements of EMSE results because of material properties. The material characteristics are the weave, construction of fabrics, direction of conductive yarns woven both vertically and horizontally. The weave directly affects the EMSE; because of the weave pattern change to antenna polarization. In some fabrics vertical measurements, in some fabrics horizontal measurements show better EMSE performance or frequency response of high, medium, low frequencies are major to other type of polarization.

From the measurement results of herringbone woven fabric that are promising results, which are by means of both symmetrical arrangement of the conductive warp yarn floats and following conductive weft yarn floats at successive conductive weft yarns, given in Figure 3, it is observed that open area measurement is significantly more variant and less EMSE performance comparing with RF chamber measurement.

The herringbone woven fabric results of horizontal conditions are better EMSE performance than that of vertical conditions. This is probably due to the fact that the interaction of successive conductive weft yarn floats, within the next conductive weft yarn, is stronger than that of symmetrically arranged conductive wrap yarns. When GSM 900, GSM 1800, 3G (2100 MHz) and ISM band (2400 MHz) frequency bands are investigated, in vertical conditions 10 dB average values, in horizontal conditions 15 dB average values are observed. At medium frequency band of interested frequency band, both samples show similar EMSE characteristics, but low and high frequency bands horizontal measurements give best EMSE performance up to 20 dB in limited bandwidths. Also, high frequency bandwidth performance is better comparing to low frequency band.

Other five samples’ results will be given in the paper in detail.



a b

Figure 3. The EMSE of herringbone weave a) Vertical measurements, b) Horizontal measurements

4. CONCLUSION

In this study, the RF EMSE measurements of woven fabrics has been investigated and compared in both open area and RF chamber conditions. Also, vertical and horizontal behaviors of the materials depending on the change of weave patterns are evaluated. Six different woven fabric samples are measured and EMSE results are given.

It is seen that RF chamber usage improves the EMSE measurement efficiency by decreasing environmental effects like reflections and interferences. RF chamber structures have good isolation and attenuation to external EMI sources. At the same time, internal wall absorber/attenuator construction omits reflections of conductive walls and multi-path distorting effects.

It is observed that the symmetrical and sequential arrangement of yarn floats, which constitute weave and so; determine the fabric structures and properties, have significant positive effects on the EMSE performance of clothing fabric samples depending on wavelength of the signal suitable to distances between conductive yarns.

The given herringbone woven fabric samples have promising results in frequency band of interest, 800-2500 MHz band which is covers GSM, 3G and ISM public bands. In average, 10-20 dB attenuations can be observed.

Consequently, the conductive clothing fabrics produced with textured steel yarns within the scope of this study have good EMSE values in medium and high frequency bands, so these can be used as EM shielding material for 900 and 1800 GSM, 3G, Wi-Fi and radiophones.

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ENHANCEMENTS OF A CAPACITOR - BASED MEASUREMENT OF THE TENSILE PROPERTIES OF TEXTILES

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Abstract: Lately, there is an increasing tendency to use textile products for technical applications, such as medical textiles (i.e., implants) and geotextiles (i.e., reinforcments). In this respect, the accurate investigation of the tensile properties of the textile fabrics becomes essential. In the present paper the coupling of capacitive – based tensile testing prototype device for textiles with a reconfigurable capacitive sensor array interface is presented and discussed. The preliminary results show that the coupling of these two subsystems leads to measurements of high accuracy providing also further processing possibilities of the experimental data.

Keywords: capacitive sensor array, textile fabrics, tensile properties

1. INTRODUCTION

The textile fabrics are structures produced by the characteristic interlacing of the yarns which provides them with a usually non-isotropic mechanical behavior. The typical tensile test of textiles determines their breaking strength and lacks information regarding their directional mechanical behavior. Furthermore, although breaking strength provided by such tests is a valuable information, low-stress testing could provide useful data necessary for the implementation of the textile fabrics in technical applications. This is especially true if measurement in more than one or two axis can be obtained. In the related literature the importance of the multiaxial testing measurements of the technical textile fabrics is stressed out [1-4].

Lately a multiaxial tensile testing equipment has been proposed by the authors [5] utilizing capacitive based sensors. Capacitive sensor interfacing is an open subject in the literature, since more sensors of this type are being developed because of the advantages they offer in terms of sensitivity, reliability, low temperature dependence and low power consumption [6, 7]. To this end a great number of techniques have been developed to translate the minute changes of capacitance of these sensors into an electric signal [7-10] based on analogue signal conditioning and processing principles. These solutions, though offering high accuracy, precision or high sampling rate, do not offer processing power.

In the present paper a previously presented prototype device designed and developed for the measurement of the tensile properties of textile fabrics is coupled with an a reconfigurable capacitive sensor array interface used for the readout and processing of the capacitive sensor array in a digital way.

2. MATERIAL AND METHOD

The prototype tensile testing device is based on the measurement of deformation using capacitive sensor array. In more details the fabric under test is laid over the testing level which consists of a ring of 20 cm diameter, divided in eight sectors, as presented in Fig. 1. Below that ring, an identical one is placed forming eight capacitive sensors.

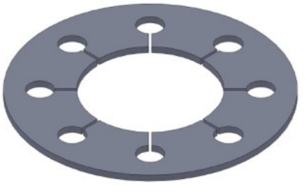

Figure 1. Geometry of the upper and lower ring shaped plate

A ball, in dimensions smaller than the inner diameter of the ring, enters in the ring drifting the fabric. By the application of the load, each sector of the upper ring plate is bent i.e. the distance between the plates of the capacitors (upper and lower ring) is reduced, leading to the increase of the capacitance of the capacitors. The eight sectors form a capacitive sensor array. The readings of the eight sensors give a deformation profile of the fabric over eight directions.

In the present work the monitoring of the capacitance of the sensor array is performed via a reconfigurable interface for the measurement of the capacitance. This interface is comprised of a subsystem able to read the array of capacitive-type sensors and an embedded processor. Each sector of the circular area is connected to a ring oscillator (Fig. 2), which translates capacitive changes into a variable-frequency pulse train.

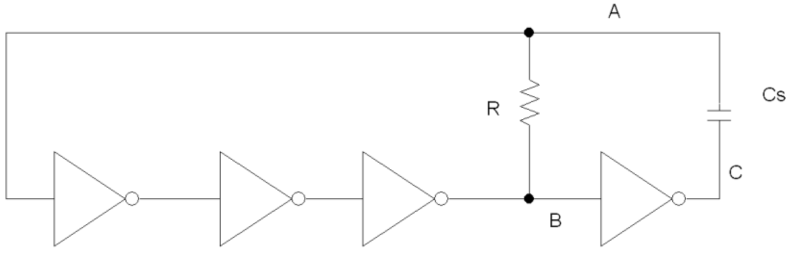

Figure 2. Typical ring oscillator for the measurent of a capacitive sensing element

The oscillator presented in Fig. 2 is an astable oscillator with frequency output dependent on the capacitance. The oscillation period depends mainly on the RC time constant since it is assumed to be considerably higher than the delay of the inverter chain. Furthermore, a Schmitt trigger is introduced at the oscillator input in order to assure oscillation for capacitance values ranging from 1 to 1500 pF, which is compatible to the range of the tensile testing equipment.

3. RESULTS AND DISCUSSION

Measurements of the tensile properties of a fabric have been performed with and without the proposed coupling in order to explore the proposed enhancement.

4. CONCLUSION

The proposed coupling of the two subsystems led to measurements of high accuracy providing also further processing possibilities of the experimental data making the electronics part of the device more compact and lowering further its cost.

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COST MP1105-WORKSOP ORAL PRESENTATIONS

A NOVEL FLAME RETARDANT AGENT WITH DMDHEU FOR FINISHING CO/PES BLENDS

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Abstract: In our study, a novel polymeric flame retardant with phosphorous-nitrogen synergism was synthesized by polyvinyl alcohol (PVA), hydrophilic polyester resin (PR), phosphoric acid and dicyandiamide (DCDA). Polyester/Cotton (PES/CO) blended fabrics were treated via pad-dry-cure process with this synthesized chemical. PVA (PR)-P-DCDA has shown that it is an effective flame retardant on the PES/CO fabrics. In order to improve durable flame retardancy for cotton part of the blend, we have added dimethyloldihydroxyethyleneurea (DMDHEU) and ammonium chloride (NH_4Cl) auxiliaries in FR finishing bath. Flammability characteristics samples were tested according to ISO 6940 standard. Also, durability of treated fabrics against domestic laundering were evaluated using by ISO 6330:4G procedures. The obtained results demonstrated that this new finishing formulation is a good char-forming and durable agent for the PES/CO blends with high efficiency and DMDHEU could be used for cellulosic blends with PVA (PR)-P-DCDA.

Keywords: Flame retardancy, PES/CO blends, flammability, P-N synergism, DMDHEU.

1. INTRODUCTION

PES/CO blends has a high usage in home textiles, clothing and knitwear. However, due to their high flammability, fire retardancy is one of the essential properties for these blends [1-3]. Flame retardancy of PES/CO blends is not predictable according to each fiber property individually so there should be a precision study for a suitable chemical [4]. The chemicals that are used to get the flame retardancy of PES/CO blends are not sufficient to comply with the European standards and they have difficulties during applications such as requiring extra equipment for binding. Usage of halogenated flame retardant chemicals is limited due to environmental problems [5]. Therefore there is a need of a fire retardant chemical in the market which will be complying with the international standards, and will not have negative impact on human life [6-7]. Thus, current researches in the literature intensified on developing of an effective, phosphorus-based, halogen and/or formaldehyde-free, greener stable fire retardants [8-9]. However, durability of these FR systems against multiple home laundering still needs to be improved. Using crosslinkers in FR finish receipes is an option to lead better bonding properties of FR agents on textile fibers. N-methylol reagents, such as DMDHEU, have long been used in the textile industry as the crosslinking agents for cotton to produce wrinkle- resistant cotton fabrics and garments [10]. Few studies have indicated that it was also suitable as a crosslinker for flame retardancy on cellulosic fabrics [11-12].

In our previous research, we developed a formaldehyde-free flame retarding system (PVA (PR)-P-DCDA) called Fire-off for PES/CO blended fabrics. In this research, we used dimethyloldihydroxyethyleneurea as the binding agent between Fire-off and cotton, in addition ammonium chloride (NH_4Cl) has been used as auxiliaries in FR finishing bath. Lastly, we compared the reactivity of DMDHEU in the flame retarding systems based on Fire-off, evaluated the flame retarding performance as well as durability performance against multiple laundering.

2. MATERIAL AND METHOD

2.1. Materials

Scoured 50/50% PES-CO (185 g/m^2), twill fabric was supplied by BJ Textile for use in the study. PVA (PR)-P-DCDA (as synthesized in our previous study), DMDHEU and NH_4Cl were used for chemical FR treatment.

2.2. Fabric Treatment and Home Laundering Procedures

The fabric was firstly immersed in a finish solution containing Fire-off, and Fire-off /DMDHEU, then passed through a laboratory padder with two dips and two nips. For Fire-off treatments, samples were dried at 100°C for 3 min, and cured in an oven at 180°C for 3 min. For Fire-off/DMDHEU treatments, additionally NH_4Cl was used as a catalyst for DMDHEU. After impregnation, samples were dried at 90°C for 3 min, and finally cured in a curing oven at 165°C for 2.5 min. The wet pick-up of the PES/CO fabrics was approximately 100±3%. After curing, the treated fabrics were subjected to a different number of home laundering/drying cycles according to ISO 6330 Test Method -2012 (‘‘Textiles - Domestic washing and drying procedures for textile testing’’).

2.3. Fabric Performance Evaluation

The vertical flammability of treated PES/CO fabrics was measured according to ISO 6940:2006 entitled "Textile fabrics - Burning behaviour - Determination of ease of ignition of vertically oriented specimens.

3. RESULTS AND DISCUSSION

Treated fabric samples after vertical flammability test are shown in Figure 1. After 20 s of flame exposure to the specimens, both of the specimen were not ignited.

(a) Fire-off (b) Fire-off/DMDHEU

Figure 1. Treated fabric samples after vertical flammability test

After the test, char length and width were measured. Flammability of the fabrics after laundering cycles are also exhibited in Table 1. As seen from the table, Fire-off/DMDHEU treatment leads better results in terms of FR efficiency and the durability against washing.

Table 1. Comparison of flammability results of fabric samples

Recipe No	Recipe	Flame subjection time	Char length/width	Ignition time after 5 washing	Ignition time after 10 washing	Ignition time after 15 washing
1	Fire-off 350 g/L	20 s	11.8 / 2.4 cm	11s	10 s	8 s
2	Fire-off 350 g/L DMDHEU 100 g/L NH_4Cl 4,8 g/L	20 s	12.7 / 2.3 cm	19 s	16 s	11 s

4. CONCLUSION

In previous part of this study, a novel formaldehyde-free FR agent was developed by polymerization of polyvinyl alcohol (PVA) phosphate, dicyandiamide (DCDA) together with hydrophilic polyester resin (PR). By phosphorous-nitrogen (P-N) synergism, the characteristic of flame retardancy obtained for PES/CO blended fabrics. In this part, in order to improve the durability of FR chemical to the cotton part of blend, DMDHEU has been added to the previous finishing recipes for obtaining durability to multiple laundering cycles. Flammability performance test were performed for treated fabrics. Besides, domestic washing procedures were applied to the fabrics to examine the durability of finishing treatments. Results indicated that Fire-off /DMDHEU chemical treatment imparts better flame retardancy properties than Fire-off treatment on PES/CO blends. Durability of FR performance has also been improved by addition of DMDHEU as a bonding agent in Fire-off finishing bath. Consequently, DMDHEU could be used for cellulosic blends with PVA (PR)-P-DCDA in finishing formulation.

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MODIFIED MAGNESIUM HYDROXIDE FOR HYBRID ORGANIC COMPOUNDS ABLE TO CO-POLYMERIZE WITH POLYCARBONATE

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Abstract: The main objectives of this experimental research are to obtain Magnesium Hydroxide (MH)-based compounds able to co-polymerize with polycarbonate (PC). Samples, obtained with a fixed molar stoichiometry ratio MH:3-Trimethoxysylil Propyl Methacrylate (3-TPM), are characterized by differential scanning calorimetry (DSC), which has shown a good thermal stability as well as a good chemical interaction with PC. We propose to extend and functionalize the chemical structure of the MH with 3-TPM and its derivative able to co-polymerize with PC, in order to obtain new compounds which have different flame retardant properties with an improved stability to the thermal effects and with an effective chemical affinity in a hybrid magnesium-organic co-polymer system. Infrared Spectroscopy (FTIR) technique is used to a further characterization and definition of the two chemical steps of MH structural change and functionalization.

Keywords: Magnesium hydroxide, flame retardant, differential scanning calorimetry, core-shell, hybrid material, thermic gravimetric analysis, polycarbonate

1. INTRODUCTION

In the last years, nano-sized magnesium hydroxide (MH) particles have attracted a considerable attention in the field of flame retardant materials as an alternative to inorganic minerals, organo-phosphates, and free from halogen derivatives, in that they are characterized by low production costs, reduced toxicity and corrosiveness, improved performance and high availability in the global markets [1-4]. MH naked particles with reduced size dimension have a higher specific surface area but poor polymer compatibility due to simplifying hydrophilic structure. The heating effects above 150°C into polycarbonate (PC) nano-composite induce a viscosity decrease with preferential pathways where particles lose the surfactant cover to give an irreversible and visible irregular aggregations [5]. The last consideration is justified by the change of rheological properties but also by a poor intrinsic affinity with apolar functional group such as aromatic rings in PC polymer, which do not result into a more permanent anchoring. We here report the structural characterization of the functionalized chains on MH with 3-TPM derivatives able to polymerize with PC.

2. MATERIAL AND METHOD

MH with average particle size of 80 nm was purchased from Sigma Aldrich. PC pellets were supplied for Quipilon (China) and 3-(trimethoxysilyl) (3-TPM) propyl methacrylate from Sigma Aldrich; the last one were distilled under reduced pressure in order to remove the inhibitor. Potassium persulfate (KPS), sodium dodecyl sulphate (SDS) and aniline were used as received. PC was heated before the use on a stove at 120°C for one night to reduce the humidity and to degas the material from trace of Bisphenol A.

3. RESULTS AND DISCUSSION

The ion pair of hydroxyl groups on the MH surface react with the silanol groups generated by hydrolysis of alkyloxyl group of 3-TPM through dehydration and condensation to form Si–O–Si bonds, thereby the vinyl groups are covalently attached on MH surface. Then the vinylated-MH was further modified by in situ copolymerization with PC.

Fig. 1 (a) shows FTIR spectra of pristine MH, vinylated MH and MH/3-TPM hybrid nanoparticles co polymerize with PC. The obvious stretching vibration peaks of CH_3, C=O and C=C groups located at 2960, 1722, and 1639 cm^{-1} in vinylated MH indicate that the vinyl groups are grafted on MH surface. After that the vinylated MH was modified by in situ copolymerization with PC, the characteristic peaks of benzene ring located at 702, 755, 1494 and 1603 cm^{-1} appear in MH/3-TPM hybrid nanoparticles co polymerize with polycarbonate.

Fig. 1(b) displays the TGA curves of pristine MH, extracted and not extracted MH/3-TPM hybrid nanoparticles, showing 37%, 41% and 47% weight loss at 800 °C, respectively. The pristine MH started to decompose at 310 °C, associated with dehydration of MH. The thermal weight loss of extracted MH/3-TPM hybrid nanoparticles shifted to a lower temperature when compared with that of pristine MH due to the 3-TPM covered on MH, but the thermal stability of extracted MH/3-TPM hybrid nanoparticles was better than that of not extracted MH/3-TPM hybrid nanoparticles. This finding suggests that the covalent interaction between 3-TPM and MH improves the thermal stability of 3-TPM. This shift of peak is an unexpected result that we were able to justify only in part. We can speculate that traces of MH are present in the sample but do not have reacted.

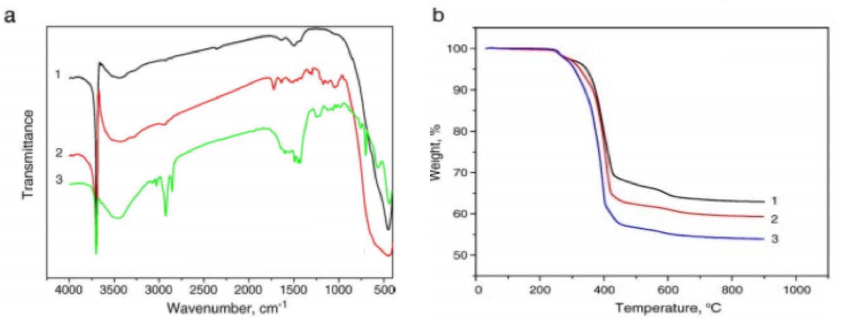

Figure 1 (a,b). (a) FTIR analysis of 1 pristine MH, 2) vinylated particles, 3) vinylated particles with PC (b) DSC profile of 1) pristine MH, 2) hybrid nanoparticles and 3) hybrid nanoparticles with PC.

4. CONCLUSION

The MH hybrid/PC nanoparticles were successfully prepared by ultrasonic wave-assisted in situ copolymerization from vinylated MH nanosheets and polycarbonate. Difference from the previous aggregated multiple-core structure of MH/3-TPM hybrid nanoparticles are in evidence, the uniformly-dispersed core-shell structure of hybrid nanoparticles was proved and can be attributed to the fact that the ultrasonic irradiation enhances the dispersion of MH nanosheets in the formed emulsion particles.

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STRUCTURAL AND MECHANICAL PROPERTIES OF MEDICAL GRADE POLYURETHANE ELECTROSPUN FROM MIXED SOLVENTS

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Abstract: Polymer-fiber-based meshes, matrices, or scaffolds have been applied in various engineering fields such as textile and biomedical engineering. The control of the structural features (e.g., fiber diameter, porosity, surface to-volume ratio, surface roughness) and mechanical properties (e.g., elasticity, mechanical durability) of fiber-based matrices and scaffolds is an essential issue in engineering applications. Therefore, in this study we focused on morphology analyses of electrospun fibers from a medical grade polymer of polyurethane (Tecoflex EG 72D), a family of hydrophilic polyether-based thermoplastic aliphatic polyurethanes (PU), and mechanical properties of collected nanofibers at different structures. The result showed that a minimum concentration (10%w/v) for polymer solution with volume ratios of 70:30 (DMF: THF) was required to yield fibers without beads with average diameter less than 200 nm.

Keywords: electrospinning, polyurethane, mixed solvent, stress-strain behavior, aligned nanofiber

1. INTRODUCTION

Polyurethanes are a broad family of polymers that have been used in a large number of medical applications such as in medical prostheses, wound dressing, and tissue scaffolds. Electrospun elastomeric polyurethanes may represent an ideal class of materials for soft tissues replacement [1]. The future use of electrospun materials in practical applications will require a thorough understanding of their mechanical behaviour, so that they has to exhibit significant mechanical strength to keep their physical and behavioral integrity as long as possible. However, the mechanical properties of nanofibers depend on their morphology that are mainly influenced by the electrospinning parameters and processing conditions [2, 3].

2. MATERIAL AND METHOD

2.1. Materials

A medical grade of polyurethane (Tecoflex EG 72D), an ether-based thermoplastic polyurethane, was obtained from Lubrizol Corporation. N, N-Dimethyl formamide (DMF) and tetrahydrofuran (THF) were purchased from the Sigma-Aldrich and used as solvents for electrospinning.

2.2. Sample preparation

Polymeric solutions were prepared by dissolving polyurethane in DMF and THF with volume ratios of 70:30, 50:50 ,and 30:70 to obtain concentrations of 10%-14% (w/v), followed by 12 h stirring at room temperature. Each solution was loaded into a 1 ml syringe capped with a 21 G blunted stainless steel needle, connected to the positive terminal of a high voltage power supply (16- 25kV), and a grounded collector wrapped in aluminum foil was placed at a distance of 25 cm from the needle tip to collect fibers. The flow rate was set on 0.5-0.75 ml/h using a programmable syringe pump.

2.3. Morphological Characterization

Scanning electron microscopy (SEM) was used to study the morphological features of electrospun mats, operated at an accelerating voltage of 15 kV.

2.4. Mechanical Properties

The tensile behavior of the random and aligned electrospun polyurethane mats was tested using a uniaxial testing system (Instron 5566) with a 50 N load cell and an extension rate of 10 mm/min.

3. RESULTS AND DISCUSSION

The SEM results of PU nanofibers prepared at three different volume ratios of DMF/THF solvents (70/30, 50/50, 30/70) at concentration of 10% w/v showed the decreasing nanofiber diameter and amount of bead in nanofibrous structure with increase at DMF content. As expected, the increase in concentration from 10% w/v to 14% w/v was lead to the growth of the diameter of nanofibers prepared at solvent type of DMF/THF (70/30). The investigation of stress-strain behavior of PU nanofibrous layers picked at three angles of 0^o, 45^o and 90^o indicates the randomly collected nanofibers is nearly isotropic, while the aligned structure exhibits anisotropic property. The maximum stress undergone with aligned nanofibrous structure was acquired at angle of 90^o i. e. in the direction of nanofiber aligning. The stress and strain of both nanofibrous structure (random and oriented) in fully hydrated state were increased and decreased, respectively.

4. CONCLUSION

In this atticle, morphological features and the stress–strain behavior of random and aligned electrospun thermoplastic polyurethane fibers were studied. The results showed that the diameters of fibers in electrospun polyurethane mats were significantly changed with the use of the different mixing ratios of THF and DMF in solvent system. An isotropic fiber mat can also be produced from solution of thermoplastic polyurethane so that nano fibers were randomly collected.

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DEVELOPING FLAME RETARDANT TEXTILE COATINGS MATERIALS WITH SOL-GEL METHOD

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In this study, flame retardancy properties of cotton fabrics treated with phosphorus-containing silane based nanosols were developed by sol-gel technique. As to this aim, silane based nanosols added tetraethoxysilane or (3-aminopropyl)triethoxysilane as precursor, (3-glycidyloxypropyl)trimethoxysilane as crosslinking agent and guanidine phosphate monobasic as flame retarding agent were impregnated on cotton fabrics. Coating durability to washing process has been evaluated as well. Functional properties of the coatings were characterized by using Fourier transform infrared spectroscopy, X-ray photoelectron spectroscopy and scanning electron microscope. Also flame retardancy and thermal properties of the fabrics were determined by limited flame spread, limited oxygen index (LOI) tests and thermogravimetric analysis. Limited flame spread test results showed that coated fabrics were achieved flame retardancy, whereas they lost this feature after washing. The phosphorus–silica synergistic effect on the LOI value was observed as 46% of LOI. Moreover, ecological process was provided thanks to using halogen-free flame retardant.

Keywords: Cotton fabric, flame retardant, phosphorus–silica, sol-gel technique.

1. INTRODUCTION

Conventional flame retardant finishing for cellulosic materials are based on treatment with halogen-containing compounds such as bromine and chlorine. Also, formaldehyde is used for enhancement the washing durable [1]. However, it is limited or forbidden these chemicals [2 - 7] in consequence of their negative effect on environment and human health [8, 9]. For this reason, sol-gel process that is free-halogen and free-formaldehyde can use for the flame retardant finishing of cellulosic materials as an alternative to conventional methods.

2. MATERIAL AND METHOD

2.1. Materials

Scoured, bleached and treated with optical brightener 100% plain-weave cotton fabric (weight: 120 g/m^2, 26 picks/cm, 36 ends/cm) was used in this research. Ethanol (C_2H_5OH) (Merck) and water (H_2O) as solvent, tetraethoxysilane (TEOS, $Si(OC_2H_5)_4$) (98%, Sigma-Aldrich) or (3-aminopropyl)triethoxysilane (APTES, $H_2N(CH_2)_3Si(OC_2H_5)_3$) (98%, Sigma-Aldrich) as precursor, (3-glycidyloxypropyl)trimethoxysilane (GPTMS, $C_9H_{20}O_5Si$) (98%, Sigma-Aldrich) as crosslinking agent, phosphoric acid (H_3PO_4) (85%, Merck) as acidic catalyst, guanidine phosphate monobasic (GP, $NH_2C(=NH)NH_2{\cdot}H_3PO_4$) as flame retarding agent, urea (NH_2CONH_2) (Merck) and sodium chloride (NaCl) (Emir Kimya) were used.

2.2. Preparation Nanosol

The solution was prepared by mixing TEOS or APTES, and GPTMS with ethanol and water. Then, the obtained solution was stirred. After H_3PO_4 were added to the solution drop by drop until pH 4.5 - 5. Following GP, urea and NaCl was added to the solution, respectively. After these solutions were stirred at 60°C for 90 min in air to obtain transparent sols.

2.3. Coating Process

The cotton fabrics was impregnated the prepared solution by dip coating method. Then the fabrics were squeezed using a fulard for 90% AF (take up). The drying processes were done using oven at 100°C for 10 min. and using a stenter at 140°C for 3 min., respectively.

3. RESULTS AND DISCUSSION

3.1. Flame Retardancy Properties

Untreated and coated fabrics were tested by ASTM D 2863 limited oxygen index (LOI) and TS EN ISO 15025 limited flame spread tests. LOI values were raised from 18.2% (untreated cotton) to 35-46%. It was determined that the best LOI value was 46% for fabric samples treated with nanosol containing APTES with GP. Their LOI values decreased from 46% to 41% when TEOS together with GP was used instead of APTES. This result was based on the Si-P synergism and the effect of phosphorous amount. Limited flame spread test result showed that treated fabric samples didn’t burn.

3.2. Coating Characterization

Coating on the fabric surface was investigated by FTIR, XPS, TGA analyses and SEM pictures.

3.3. Washing Process

Treated fabric samples were washed by TS ISO EN 12138 standard. Limited flame spread test was repeated and SEM pictures were investigated after washing process. All fabrics burned to form the char. Film layer on the fabric surface was removed partially.

4. CONCLUSIONS

In the study, TEOS or APTES together with GP in nanosol recipes were used to evaluate the effect of phosphorus–silica synergism and phosphorous amount on flame retardancy properties of fabric samples treated with these nanosols. GPTMS was preferred as crosslinking agent for supporting P-Si effect. As a result, it was observed that this effect provided flame retardancy property for cotton fabrics. Also, higher phosphorus amount in nanosol caused increasing flame retardancy effect. Flame retardancy was achieved by halogen-free compounds, thus the process has been become eco-friendly. Treated fabric samples were washed to evaluate the washing durability. Treated fabric samples did not exhibit durability to washing. In the future study, it was intended to develop durability of the flame retardancy efficiency on the fabric against multi-washing.

ACKNOWLEDGEMENT

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EVALUATION OF FIRE BEHAVIOUR OF FLAX FABRICS TREATED WITH EXPANDABLE GRAPHITE BASED COATINGS

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Abstract: Improvement of the fire behaviour of flax fabrics treated with silica coatings containing expandable graphite prepared through sol–gel treatment has been studied. Results show that silica coating containing expandable graphite enhances the flax fabric fire behaviour.

Keywords: Flax fabric, flame retardant, expandable graphite, sol-gel, sonication.

1. INTRODUCTION

Fire safety is an important requirement in many textiles. Different approaches can be used to improve the flame retardant properties of textile materials, including basically the use of inherently fire-resistant fibres, the incorporation of flame retardant additives in fibre spinning and the application of flame retardant formulations during the finishing processes on the yarns of fabrics. In the case of textile materials made of natural fibres the only possibility is the last one. This finishing can be performed directly using chemical grafting of additives on the fibre surface or by means of linkers like thermoset resin-coatings which allow a more durable finishing. Nonetheless, these treatments usually imply the use of toxic formaldehyde-urea resins or other synthetic polymers, which alter the comfort, and the visual and tactile properties of natural fibres based fabrics.

The sol-gel technology has emerged in the last years as a promising way to functionalize fabric surfaces [1]. Sols based on modified silica form well adhering transparent oxide layers on textiles which can act as carrier for embedded functional additives such as organic or biological compounds, inorganic particles and polymers since it is easy to control layer porosity and the degree of immobilization of the embedded compounds [2]. The sol-gel technique allows the deposition of nanoparticles on the fabric, minimizing the thickness of the coating. Moreover, these silica nanocoatings are effectively suitable for enhancing the flame retardant properties of fabrics based on natural fibres [3].

Expandable graphite (EG) is an intumescent flame retardant that when it is exposed to a heat source expands and generates a voluminous insulating layer. The use of EG particles combined with a sol-gel coating can offer a successful alternative to obtain fire flexible barriers for flame retardant textile materials [4]. The final properties of the finished textile will depend, aside from the composition of the coating, on the good dispersion of the particles on the surface and their good adhesion to the textile surface.

This study is focused on the evaluation of fire-retardant coatings for woven fabrics made of flax fibres. It has been studied the flame retardant combination of silica coating (SG) acting as binder and the intumescent EG particles. The following processing parameters have been taken into account: the content of silica precursor, the influence of a previous surface treatment with vinyltriethoxysilane (VTES) on EG particles on the bonding adherence to silica and flax fibres, and the effect of using a conventional bath exhaustion (BE) or sonication (SO) during the finishing process.

2. MATERIALS AND METHODS

Table 1 summarizes the formulations analysed. The silica precursor content was varied between 5 and 10%. The influence of the coating procedure, the presence of EG and the surface treatment of EG have been also studied. The textile samples had a size of 15.5 x 7.5 cm. The coating was done using a bath ratio of 1/15 with sonication (SO) or bath exhaustion (BE).

Fire behaviour was tested by means of the horizontal burning test and a pyrolysis combustion flow calorimeter (PCFC) standardized according to ASTM D7309.

3. RESULTS AND DISCUSSION

As can be seen in table 1 increasing the silica content increases the amount of added coating. As expected, samples coated with EG have a slightly higher weight than samples without EG. Also, samples coated with VTES-g-EG have a slightly higher weight than samples coated with EG and this effect is more significant for the samples coated with sonication. On the other hand, higher homogeneity of the samples was found with higher silica content and using sonication. Moreover, these samples showed the best results of washing fastness demonstrating the effectiveness of the combination of the sol-gel treatment; VTES surface modification of EG particles and the sonication process to obtain well dispersed and more durable coatings.

Figure 1 shows the aspect of an untreated sample and the sample SG5-VTES-EG_SO after the horizontal burning test. As it can be seen the sample without treatment is almost totally consumed, while the presence of sol-gel treatment with expandable graphite particles causes higher amount of charred residue, probably due to the intumescent effect.

The curves of heat release rate (HRR) in front temperature obtained in the PCFC are shown in figure 2. It can be observed that the peak of HRR (PHRR) is reduced for the treated samples, especially for the sample that contains 10% of silica binder and EG treated with VTES. On the other hand, treated samples decrease the temperature of the PHRR.

Table 1. Reference, process used, composition, total dry solids add-on and washing fastness of the flax fiber treated fabrics

Sample reference	Silica precursor (wt %)	Coating	Intumescent	Added coating (wt %) Average	s.d.	Weight loss after 3 washes
SG5_BE	5	Bath exhaustion	No	4.42	3.21	94.0
SG5_SO	5	Sonication	No	3.04	1.65	88.2
SG5-EG_BE	5	Bath exhaustion	EG	6.10	4.28	92.7
SG5-EG_SO	5	Sonication	EG	6.42	2.69	77,2
SG5-VTES-EG_BE	5	Bath exhaustion	VTES-g-EG	5.06	0.27	86.0
SG5-VTES-EG_SO	5	Sonication	VTES-g-EG	7.25	0.71	71.0
SG10_BE	10	Bath exhaustion	No	8.18	0.42	71.1
SG10_SO	10	Sonication	No	8.17	0.41	63.1
SG10-EG_BE	10	Bath exhaustion	EG	9.43	1.25	80.0
SG10-EG_SO	10	Sonication	EG	11.02	0.42	75.1
SG10-VTES-EG_BE	10	Bath exhaustion	VTES-g-EG	9.08	0.93	68.0
SG10-VTES-EG_SO	10	Sonication	VTES-g-EG	11.55	0.23	52.3

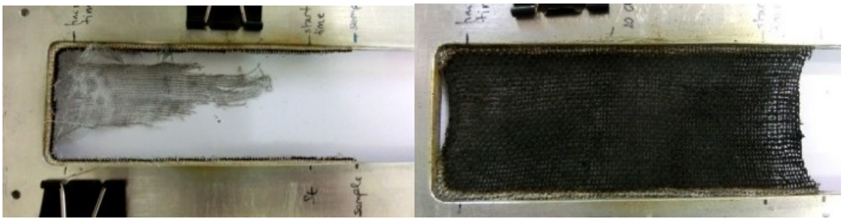

Figure 1. Images of the untreated fabric (left) and the fabric sample SG5-VTES-EG_SO (right) after the horizontal burning test.

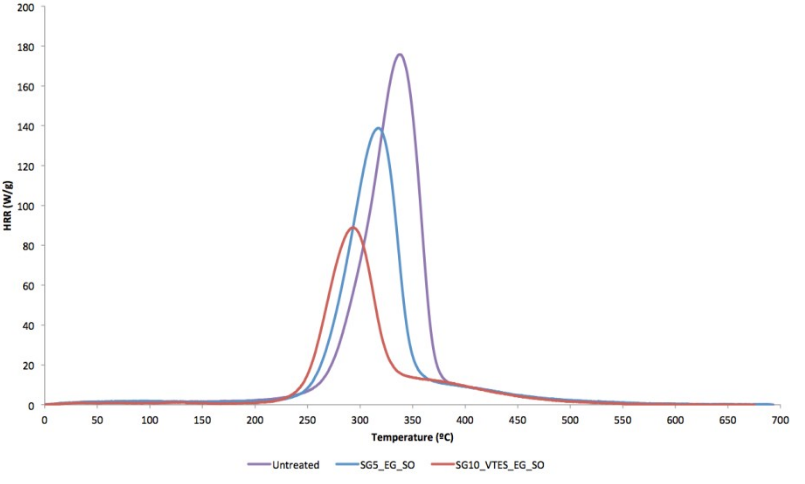

Figure 2. Heating release rate curves in front of temperature for three of the samples tested.

4. CONCLUSION

Flax fabrics have been successfully coated with sol-gel and expandable graphite particles. Coatings with higher silica precursor content containing modified VTES-g-EG prepared with sonication lead to most effective coatings, with higher weight content and washing fastness. Samples containing expandable graphite exhibit a better fire behaviour. Samples with EG produce higher amounts of residue in the horizontal burning test and show a significant decrease in the peak of heat release rate.

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IDENTIFICATION OF VOLATILE ORGANIC COMPOUNDS IN EARLY STAGES OF FIRE FROM INSULATION PRODUCTS

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Abstract: The composition and yield of collected soot depends primarily on ventilation condition and combusted material. There has been comparatively little research done in identifying volatiles that are released in the early stages of fire. Several materials which are commonly used as insulation in homes and workplaces were investigated. Expanded polystyrene, polyisocyanurate, phenolic and polyurethane foams were thermally degraded using pyrolysis gas chromatography/mass spectroscopy (pyGC/MS) across a range of different temperatures. Several compounds classified by IARC as carcinogenic or possibly carcinogenic to humans were identified from combustion of insulation materials which may pose a potential risk to human health.

Keywords: NFX 70-100, cancer, chronic toxicants, polycyclic aromatic hydrocarbons, PAHs, benzene, insulation materials.

INTRODUCTION

Smoke has variable composition depending on the chemical structure of the burning material, oxygen supply, temperature and heating rate[1-3]. It is important to determine fire effluents which have the potential to produce both a toxic hazard and a detrimental impact on the environment. Benzene, toluene, polycyclic aromatic hydrocarbons (PAHs), chlorinated hydrocarbons, dioxins, dibenzofurans, polychlorinated biphenyls, etc. may also pose a risk to human health. In some studies, it is shown that they are released in much higher quantities from fire retarded samples, however, their release under different fire scenarios is still not very well studied and needs to be further developed[4].

Pyrolysis is the non-flaming thermal degradation of a molecule, and can involve several different pyrolytic reactions that occur subsequently or simultaneously[1].

The products formed during this process depend on both the materials involved and the conditions in which pyrolysis takes place. The temperature, the atmosphere and whether it takes place in the gas or solid phase all affect the products formed[2]. In the laboratory these parameters can be controlled so the outcome is as expected, unlike in a real world fire scenario.

There has been comparatively little research done in identifying volatiles from insulation materials that are released in the early stages of fire. Pyrolysis-Gas Chromatography-Mass Spectroscopy (py GC/MS) has been widely recognised as one of the most promising and practical method used in product analysis of thermal decomposition of polymer materials. Predominant uses for GC/MS is identification and quantification of volatile and semi volatile organic compounds in complex mixtures, determination of molecular weights and structural determination of unknown organic compounds.[3]

Several materials which are commonly used as insulation in homes and workplaces are investigated using pyGCMS, across a range of different temperatures.

RESULTS

Semi-volatile and volatile organic compounds, including PAHs, were investigated under different temperatures from different insulation materials: glass wool (GW), stone wool (SW), phenolic foam (PhF), polyurethane foam (PUR), polyisocyanurate foam (PIR), expanded polystyrene (EPS).

Soot samples for analysis were generated, using the NF X 70-100 standard test method[4], under 400, 600 and 800°C. The sampling of the fire effluents was conducted for 10 minutes (complete burn was observed within 2-3 first minutes) with the exception of the mineral and stone wool samples. These samples did not ignite and 30 minute sampling time was taken. Samples then were analysed using the GC/MS ultrasonication (hexane/acetone (3:1) solvents) and GC/MS headspace method respectively. All GC/MS peaks were analysed towards semi-volatile and volatile substances, with the particular focus on PAHs. An example of chromatograms and data analysis is presented in Figure 1 and Table 1.

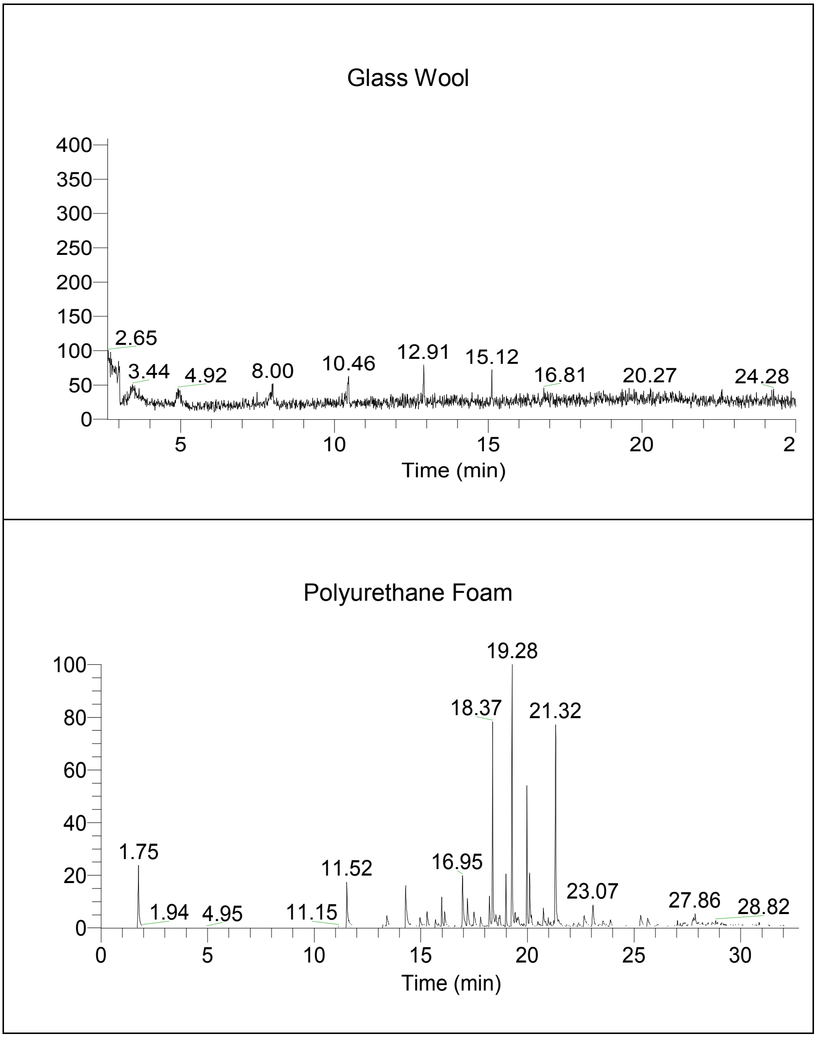

Figure 1. Insulation materials chromatograms using GC/MS solvent extraction method.

Table 1. GC/MS solvent extraction (●) and headspace (○) results at 800°C- selected volatiles.

○ Headspace ● GC/MS Compound	**SW/ MW** 800°C	**PIR** 800°C	**PUR** 800°C	**PhF** 800°C	**EPS** 800°C
Benzene			○	○	
Aniline		○ ●	○	○	
Styrene					○
Naphthalene		○ ●	○		○ ●
1-methylnaphthalene		○			○ ●
2-cyanobenzoic acid		●		●	
1-ethyl-4-isocyanoto-benzene		●	●		
Acenaphthylene		○ ●	○ ●	○ ●	●
Biphenylene			○ ●	●	
1-naphthyl isocyanide		●	●	●	
Biphenyl		○ ●	○ ●	○	○ ●
2-vinylnaphtalene			○	○	
Fluorene		○ ●	○ ●	○ ●	○ ●
Carbazole		●	●		
Dibenzofuran				○ ●	
Diphenylmethane			●		●
4-Phenyltoluene			○ ●	○	○ ●
Phenanthrene		●	○ ●	○ ●	●
Anthracene				○ ●	
Fluoranthene		●	●	●	●
Pyrene		●	●	●	●
2-phenylnaphtalene			●	●	●
Cyclopenta[cd]pyrene			●	●	
Benz[a]anthracene		●	●	●	●
Triphenylene				●	
Tetracene			●	●	
Tris(2-chloro-1-methylethyl)ester phosphoric acid			●		

CONCLUSIONS

A combination of the headspace technique and conventional sample preparation methods coupled with GC/MS enables comprehensive analysis of substances collected on the soot filter using the same material and combustion conditions.

Products from PIR, PUR and phenolic foam combustion contain nitrogen. There were not any reliable peaks observed for glass wool and stone wool. These materials do not produce smoke or soot even at high temperatures (800°C).

Several compounds classified by IARC as carcinogenic or possibly carcinogenic to humans (group 2B) were found in soot collected from combustion of the analysed materials. These may pose a potential risk for people exposed to the products in a fire. The rest are either not classifiable as to their carcinogenicity to humans (group 3) or not classified at all, however it is worth noting that they could still pose a possible toxicity risk.

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POSTER PRESENTATIONS

A STUDY ON THE EFFECT OF METALLIC WIRE/CORE SPUN YARN COUNTS ON ELECTROMAGNETIC SHIELDING PROPERTIES OF KNITTED FABRICS

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Abstract: This work reports the development of copper filament-reinforced core spun yarns containing cotton fibers as sheath. Metallic wire based knitted fabrics were produced with different yarn counts to study the electromagnetic shielding characteristics. Four different yarn counts (Ne8, Ne12, Ne15, and Ne18) were produced by ring spinning and the core yarns were converted to the knitted fabrics by sock knitting system. Two different knitted fabrics were manufactured which were single and double layers. The knitting structures were tested and analysed in different course and wale lines with one and two plies. All fabrics exhibited Electromagnetic Shielding Effectiveness (EMSE) at some extend. In this study, the most interesting finding was that the EMSE values of the structures depends on the yarn counts and the fabric layers. The yarn counts had the major influence on the EMSE of the fabrics as compared to fabric layers.

Keywords: Core yarns, Electromagnetic shielding, knitting fabrics, cotton, steal wire

1. INTRODUCTION

The main aim of the electromagnetic shielding textiles is to decrease the possible effects of the electromagnetic waves emitted by the mostly used devices such as mobile communication systems, electronic devices, etc. The developed textile structures are expected to minimise the negative effect of electromagnetic waves to human. Various electrical, electromechanical and electronics apparatus emit electromagnetic energy in their normal operation. Practical examples of systems that emit strong electromagnetic signals during their operation are the radars, communication equipment, television and radio broadcast transmitters and transmitters used for navigational aids [1]. The operation of man-made engineering devices makes an increasingly larger contribution to the electromagnetic environment. This may be regarded as a form of pollution and it is expected that increasingly closer attention will be paid to reducing and controlling electromagnetic emissions [2].

2. MATERIALS AND METHODS

Before using the copper filament as reinforcement, the physical properties of the copper filament were determined. It is important to identify the physical properties of the copper filament because of the yarn processing settings. The conventional ring spinning system has been modified for the production of the core yarns. Four different yarn counts (Ne8, Ne12, Ne15, and Ne18) were produced during the study with and without copper filament. The copper which was used as core element was 60-micron diameter. The yarn production was made by using SUESSEN lab type yarn machine with 6 spindles. The spindle speed was selected to 5500 rpm. The core yarns were successfully produced and the properties of the developed yarns were tested and analysed in accordance with the standard test methods. The knitting fabric structures were made from the produced yarns by Komet socks knitting machine. The settings of the knitting machine were 4 pus diameter and the thinness of E14. The physical and the electromagnetic properties of these novel structures are studied. The results are discussed in terms of the effect of the copper filament reinforcement. The electromagnetic characteristics of the developed structures were determined in accordance with MIL-STD-285 standard.

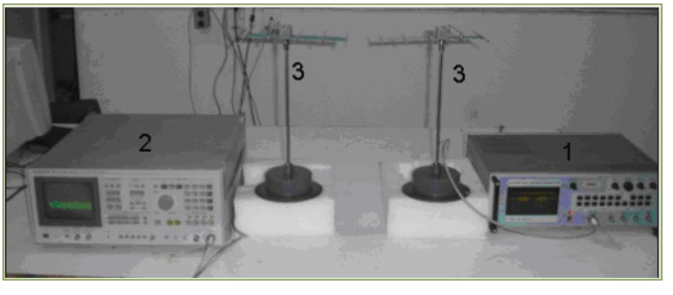

Figure 1. Electromagnetic waves test equipment (1. Radio Frequency Signal Generator; 2. Spectrum Analyser; 3. Yagi Antenna

3. RESULTS AND DISCUSSION

In the current study, comparing the unreinforced (control) and the copper reinforced (core) 100% cotton yarns showed that the resistance, the elongation and the twisting values of the core yarns were found to be higher than the control yarns. Another important finding was that the core yarns had higher hairiness as compared the control yarns. The knitting structures were tested and analysed in different course and wale lines with one and two plies. In this test, the most interesting finding was that the EMSE characteristics of the structures depends on the yarn counts. In general, therefore, it seems that the EMSE of the fabrics increases when the yarn count decreases. It is also interesting to note that in the fabric form, the single ply fabric structure has better shielding effect as compared to the double ply fabric structure.

Table 1. Yarn properties

Properties	Ne 8	Ne 12	Ne 15	Ne 18
Yarn Count (Ne)	8.8	12.3	15.6	18.8
Twist (T/m)	427	636	758	916
Strength (cN)	686	431	247	178
Elongation (%)	3.1	4.9	4.2	3.6
Hairiness (H/m)	142	97	92	67

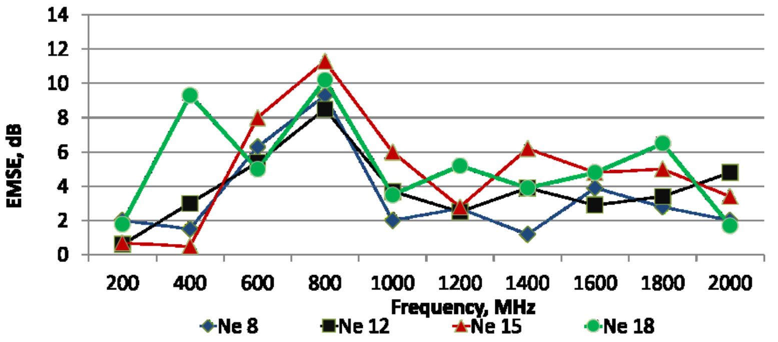

Figure 2. EMSE values of single-layer knitting fabrics

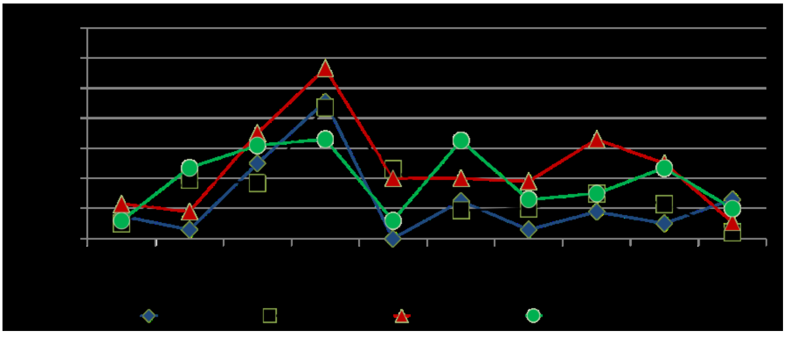

Figure 3. EMSE values of double-layer knitting fabrics

4. CONCLUSION

- ❖ In this study, the copper filament reinforced yarns have been successfully produced and the developed yarns have been converted into the knitting textile structures.
- ❖ The copper filament reinforcement enhances the tested properties of the cotton yarns.
- ❖ The EMSE values of the structures depend on the yarn counts and the number of fabric layers.
- ❖ It was clearly seen that the yarn counts had the major influence on the EMSE characteristics of the fabrics as compared to the knitting fabric layers.

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AN ALTERNATIVE GREENER PROCESSES FOR TEXTILE PRE-TREATMENTS

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Abstract: In this present research conventional and enzymatic process which consist of wet pre-treatment process were done. In the conventional treatment desizing, scouring and bleaching processes were done separately in different baths. Except from desizing, chemicals were used in the scouring and bleaching process in the conventional process. Difference the enzymatic process from conventional process was to do desizing and scouring process in the same bath with enzymes. Bleaching conditions were same for two processes. To evaluate effects of processes on the raw cotton fabric whiteness, hidrophilicity and tear strength properties some tests were done. The test results were very promising and showed that conventional process replace with enzymatic process. The whiteness, hidrophilicity and desizing values which obtained from enzymatic treatment were as high as conventional process. Moreover, enzymatic process gave better tear strength values than conventional process.

Keywords: Environmental friendly production, cleaner production, amylase, pectinase, bleaching, peroxide

1. INTRODUCTION

The raw cotton pre-treatment processes are made to improve its performance in further finishing processes. These pre-treatment processes consist of desizing, scouring and bleaching, in general. Desizing needs long process times and its washing effluents have lots of ecological loads. Scouring of cotton process aims to improve the absorbency of fabric with removing non-cellulosic natural matters, i.e. fats, waxes, proteins, pectines. They are responsible for the hydrophobic properties of raw cotton. Scouring process success directly affects subsequent wet process operations and it is performed in alkaline medium at boiling temperature. Scouring processes have same ecological problems with desizing. Furthermore, cotton is sensitive to oxidation under alkaline conditions with high temperatures. This conditions lead to some changes in fabric strength, shrinkage and handle [1-5]. Peroxide bleaching process also performed in alkaline conditions and it is preferred more frequently than hypo and natrium chloride because of it's some good properties, e.g. minimum redox potential, partially non-toxic reaction products, scouring effect. On the other hand, peroxide very susceptible to degradation with metals and it cause oxidation of cotton. As a result environmental friendly technologies should be used in textile process. Enzymes have been the best solution from 19th century. At first enzymes were used in desizing. From this time, enzymatic processes have been developed for wet processing of textile goods in widespread operations, e.g. scouring, bio-polishing, serisin removing, fading.

Objective of present research to show replace the conventional desizing, scouring and belaching processes with enzymatic combine processes working at milder conditions.

2. MATERIAL AND METHOD

2.1. Conventional processes and materials

The raw cotton fabric conventionally treated with amylase to desize. After desizing process alkaline scouring was done at boiling temperature. In the bleaching process H_2O_2 was used with different ratios. In the neutralization process caustic soda applied with detergent. The conventional process was completed with washings.

2.2 Enzymatic process and materials

Enzymatic process was consisted of combine desizing and scouring processes in the same bath before peroxide bleaching process. The same amylase enzyme was used to desize and scouring process was done with pectinase enzyme. After the enzymatic treatment, peroxide bleaching and neutralization process was applied, respectively. The different peroxide ratios were used which were the same with conventional process in the bleaching process.

Table 1. Process conditions for conventional and enzymatic processes

	Desizing	**Scouring**	**Bleaching**	**Neutralization**
Conventional treatment	50^0C, 40 m	90-95^0C,100 m	90-95^0C,60 m	90-95^0C,60 m
Enzymatic treatment	50^0C, 40 m		90-95^0C,60 m	90-95^0C,60 m

3. RESULTS AND DISCUSSION

After these processes whiteness, hidrophilicity, tear strength and desizing tests were done to compare effects of processes on cotton fabric properties. The whiteness, hidrophilicity and desizing tests results of the enzymatic process which was done with the highest H_2O_2 ratio were the same as conventional treatment. Conventional process tear strength values were lower than the enzymatic process tear strength values.

4. CONCLUSION

The results are very promising. The enzymatic process should be used instead of conventional process because nearly the same whiteness and hidrophilicity results were obtained with enzymes besides higher tear strength values. These results also shows us long-time conventional process can be done at very short time, so it means saving money and energy.

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ANALYSIS OF THE SPINNABILITYOF POLYMERS WITH A HIGH-SPEED-RHEOMETER UNDER REAL CONDITIONS

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Abstract: Polymers usually employed for the production of thermoplastic filaments (melt spinning) are limited to a few due to the long time to develop polymers which have on the one hand beneficial turn to spin and provide on the other hand good mechanical, thermal and chemical properties of the final product. The aim of the research project is the evaluation, quantification and visualization of the melt-spinnability of polymers for high-performance industrial processes avoiding material waste and loss of production by filament breaks. Therefore a rheometer to study the spinnability of polymers under real spinning conditions is developed. These studies can be performed under a high-speed-haul-off, a sensitive force sensor and an optical measuring system for detecting the melt strand. In here the rheometer development including the versatile applications which this system offers as well as the actual test results which were obtained previously by using this new system are presented.

Keywords: rheometer, melt spinning, high velocity haul-off, spinnability, polymer fibres

1. INTRODUCTION

All thermoplastic manmade fibres are in consequence of the production process endless threads. The polymer is transferred into a liquid state by dissolving or melting, pressed through spinnerets, resolidified, taken up as thread, molecularly oriented by drawing and finished leading to filament yarns, which consist of thin individual filaments.[1]

2. MATERIAL AND METHOD

Polymers that are used for the production of thermoplastic filaments by melt spinning are restricted mainly to polyethylene terephthalate (PET), polyamide 6 (PA 6) and polyamide 6.6 (PA 6.6) and polypropylene (PP) [1]. In addition, there is only a limited number of high performance polymers for technical specialty applications. The development time of a polymer handled in the melt spinning process into a filament yarn often takes several years or even decades. The challenge in processing is to get simultaneously good mechanical, thermal and chemical properties of the fibres in the final product.

However the ability of a polymer to be extruded into a filament yarn depends on several material properties. The spinnability results from a complex relationship between polymer composition and structure, flow properties and viscoelasticity, molecular weight, molecular weight distribution, molecular topology, and thermal and chemical resistance. [2] Some of these relationships are known above all from semi-empirical investigations. Polymers with good spinning properties provide e.g. long polymer chains without, or with only small branches and a narrow molecular weight distribution. Moreover the spin desired flow properties at high shear rates of many spinning-polymers are known. [3] However, these findings are not sufficient to predict the spinnability or the quality of the thread formation of a new polymer.

Drawback of this approach is the time consuming and costly way needed to develop a polymer to a spinnable material which is suitable for large variation in textile applications diminishing significantly the interest of the polymer producers to develop new polymer grades for the melt spinning process. Furthermore the development costs for new spin polymers is higher in fibre applications than for other extrusion applications. In addition polymer fibres market is smaller in comparison to other plastic applications. Therefore most polymer manufacturers refrain from a polymer redevelopment. With shorter development times the interest for the development of new spin polymers can be greatly intensified.

3. AIM OF THE PROJECT

The aim of the here presented project is the assessment, quantification and visualization of the melt-spinnability of polymers for high-performance industrial processes avoiding material waste and loss of production by filament breaks. In this case the melt-spinnability of polymers is defined as the ability of a melted polymer to form stable liquid threads. Therefore a rheometer making studies of the spinnability of polymers under real spinning conditions possible is developed. This rheometer-system includes the development of a highly sensitive force sensor allowing for the first time the high resolution measurement of thread haul-off forces at high haul-off velocities. Thereby an optical sensor will enable the measurement of the extruded profile or swell in thread haul-off direction. Another approach consists in the development of a numerical model for the description of the extensional viscosity from linear and branched polymers under the consideration of thread haul-off velocity and molecular structure of the studied polymers. This rheometer-system will allow, next to conventional rheological characteristics, statements about the maximum force on the melt strand, its elastic limit and defects that occur at the melting line.

4. RESULTS AND DISSCUSSION

So far, a test environment was set up, which consists of an extruder with a spinneret, optical components to visualize the die swell, a force sensor (resolution <1 mN), a high-speed haul-off (up to 8000 m/min) and a filament aspirator. Currently trails are being conducted on that set-up to determine the effect of the nozzle number and nozzle geometry on spinning behavior. In addition, the influence of the cooling rate of the filaments is examined for the spinnability of filaments. To describe resulting quantities, a mathematical model is set up, describing the melt strand at high take-off speeds. By its 2-dimensionality the model considers the die swell below the nozzle and can be used universally and practically.

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APPLICATION OF WATER REPELLENT CHEMICALS IN DOMESTIC WASHING MACHINES FOR KNITTED COTTON SPORTSWEAR

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Abstract: Functional textiles generally are preferred for sportswear because of its advantages of comfort, weather guard properties and easy care. For both sports and daily clothing, it is seen that water repellency is one of the most popular and desired function of textiles. With this project, a new application method is developed that gives people a chance to make their textiles water repellent whenever they want. In this study, impregnation process adapted to domestic washing machines and dryers to give the consumers a chance to make their textiles water repellent and renew their garments which lose their water repellent functions. For this purpose, experimental works were designed to determine the critical washing and drying parameters that affect the targeted water repellency. After different impregnation processes that are arranged with statistical tools, water spray rate results were analyzed and by the optimization of suitable impregnation program parameters were determined.

Keywords: water repellency, knitted fabric, sport textile, washing machine

1. INTRODUCTION

Besides the basic expectations from textiles such as protection from external conditions like hot and cold weather and provide aesthetic appearance, functional properties are expected from them. These functional properties might be water repellency, easy drying property, antibacterial property and etc. [1-2]. Although there are many methods to make textiles functional, the impregnation technique is one of the most popular methods which is preferred frequently. Functional properties, like water repellency, are important especially for some part of customers who do outdoor sports [3]. Impregnation method is a well-known process in industrial applications. In this study, a method to apply the impregnation process in a domestic washing machine, which is a suitable medium for the interaction of textile and chemical, was developed.

2. MATERIAL AND METHOD

2.1. Primary Works

In the beginning of the study different types of textiles that include cotton and synthetic, knitted and woven fabrics were impregnated by the use of various washing algorithms that is designed for this special technique and then they were tested for their water repellency property. Results of the preliminary studies showed that it was easier for the synthetic fabrics to have water repellent properties independent of the washing parameters. If sufficient chemical was supplied, synthetic fabrics could be impregnated effectively. On the other hand, it was observed that the washing parameters were as important as the chemicals used for cotton fabrics, and thereof, this study focused on the work on cotton goods impregnation process.

2.2 Design of Experiment

In this study, design of experiment tools was adapted by using with Minitab 16.0 program. Six parameters were analyzed with ½ factorial design statistically. Parameters included four washing machine parameters that were temperature, mechanical action percentage, washing rotational speed and chemical amount. Besides the application of the chemicals, dryer and/or iron usages were other two variables for the system. Washing programs were designed on a simulation machine by using special software.

2.3. Materials and Testing Method

Properties of the knitted cotton fabric used for specifying suitable washing and drying parameters for domestic impregnation process are given in Table 1.The fabrics were produced under controlled conditions and all sweatshirt samples were sewn from same batch.

Table 1. Properties of knitted cotton fabric

Cotton Fabric								
Fiber type	**Weight**	**Yarn count**	**Yarn type**	**Fabric construction**	**Density**	**Dye Type**	**Finishing Proces**	**Water Spray Rate**
100 % Cotton	235 g/m²	Ne 30/30/20	Ring	3 thread fleece	10 wales/cm	Reactive	Enyzme Washing	0

The cotton fabric that is employed is a common type of knitted fabric that is used in the production of sweatshirts that widely used for outdoor sportswear.

In an attempt to attain water repellency to the samples, a special finishing chemical suitable for home conditions, Bionic Finish Eco from Rudolf Chemie, was used in a variety of concentration. This chemical is important because of its non-fluorocarbon structure and it is effective with its dendrimer components. Thus, the chemical is eco-friendly and safe for human health [4].

After the impregnation processes, fabrics' water repellency was measured in accordance with AATCC 22 Spray Test. To analyze the effects of the impregnation process on the samples' performance, bursting test, Martindale abrasion test, and pilling test were conducted in accordance with the standards TS EN ISO 13938-2, TS EN ISO 12947-2, and TS EN ISO 12945-2, respectively.

3. RESULTS AND DISCUSSION

Analysis of the water repellency test results showed that for % 100 knitted cotton fabrics the use of a domestic dryer is the most important factor for obtaining water repellency. Besides, increasing of the amount of the chemical has a positive effect on improving the water repellency and temperature levels that are examined for this study do not have an important effect on the desired water repellency performance. Results of the optimized analysis is given in Figure 1.

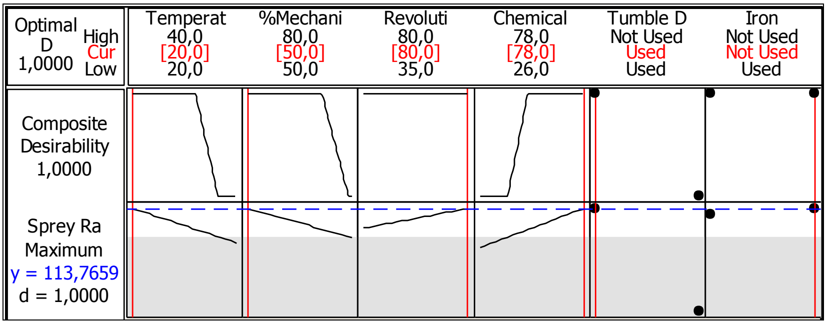

Figure 1. Optimization of impregnation process

With the method proposed for attaining water repellency properties to 100% cotton knitted goods in domestic washing and drying machines, it has been possible to make 100 % cotton knitted fabrics water repellent with a rating of "100" on the spray test which is the maximum value. Results of the textile performance tests showed that the impregnation process applied in household conditions had no obvious negative effect on the textile.

4. CONCLUSION

With this study, it has been possible to suggest a simple method to the consumers in domestic conditions in order to make their cotton textiles water repellent and renew their garments that had lost their water repellency properties after several washing cycles. Additionally, the chemical that was used in this study enabled the application of an environmentaly friendly and healthy water repellency agent on the textile due of its non-toxic and fluorocarbon free structure. Besides, no textile damage was observed because of the proposed home type impregnation process.

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CALCULATION OF KEY STRUCTURAL PARAMETERS OF WOVEN FABRICS PORES THROUGH IMAGE ANALYSIS

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Abstract: Porosity and air permeability are woven fabrics properties of crucial importance, which drastically affect the selection of key manufacturing parameters, such as warp and weft density. This study deals with the estimation of pores' diameters of woven fabrics with the use of image analysis. More specifically, this article focuses on the estimation of the minimum and maximum pore diameter, as well as the average pore diameter in woven fabrics. These pore characteristics are especially useful for the estimation of interesting properties of woven fabrics, like the air permeability and porosity, through sophisticated image analysis methods, such as fractal analysis.

Keywords: woven fabrics, fractal dimensions, pore's diameter, image analysis

1. INTRODUCTION

The comfort of a garment is characterized, as directly depended, by the structural parameters of the used woven fabric. The most important and fundamental properties of textile fabrics in terms of comfort and hygiene are the air permeability and porosity. It is often necessary that air passes through the fabric for the evaporation of sweat, while, on the other hand, the dangerous microorganisms are prevented by the fabric to reach the body, acting thus as a protective filter.

The structural elements of a woven fabric which determine whether it is capable of performing such functions are the yarn and the pores, the second ones being dependent on the weave and the construction parameters of the fabric. For long time, several studies have been dedicated to the determination of the relationship between the characteristics of fabric pores and the above mentioned properties [1-3].

These structural elements should be determined during the designing phase and realized during the weaving process [4-6]. Furthermore the permeability of fabrics is correlated with many other properties. The air permeability of woven fabrics has an inverse relationship with many mechanical properties, such as the bending rigidity, shear rigidity and strength [7].

The notion of pores provides a convenient way of describing fabric porosity. The total porosity, ε, is generally defined as a physical characteristic of woven fabrics which indicates the percent (%) portion of air volume in the total volume of a fabric [8], as given in by Eq. (1):

$$\varepsilon = \frac{V_{pores}}{V_{fabric}} \cdot 100 \qquad (1)$$

where ε is the total porosity (in %), V_{pores} is the volume of pores in woven fabrics (in cm^3), V_{fabric} is the volume of woven fabric (in cm^3). Once the volume of pores inside the fabric is determined, the porosity is straightforwardly resulting.

For these reasons, this work is an attempt to estimate the diameter of the pores of woven fabrics using image analysis techniques. This might be used in several ways in order to estimate pore volume and then porosity through Eq. (1), or through other more sophisticated methods, like fractal analysis, for alternative estimations of porosity or air permeability.

2. MATERIAL AND METHOD

The aim of this study is to estimate the diameter of pore of woven fabrics following an easy to apply procedure; these estimates can then be used in other significant research related to the estimation of porosity of the woven fabrics, for example through the use of a fractal analysis. In this work, a step by step procedure is proposed for the determination of pores' size, while an example of application is given on a woven fabric 100% made from cotton yarns.

In short the procedure consists of the following six steps:

(a) Four images are taken with the use of a digital camera from the fabric under test.

(b) Then, these colored images are converted into grey scale images.

(c) Following, the grey scale images are converted to black and white using an appropriate threshold, best revealing the pores of the fabric.

(d) Thereafter, from each image the corresponding pores are isolated.

(e) For each one of these pores, the number of white pixels, as corresponding to the open area of each pore, is counted; note that, the number of pixel is transformed into area units with the use of a unit conversion coefficient.

(f) Finally, the effective diameter of each one of the isolated pores is estimated from the abovementioned calculated open area, while the minimum and maximum diameter, as well as the average diameter of pores of the tested woven fabric, are statistically inferred.

3. CONCLUSION

In this study a six step procedure is proposed for the estimation of pores' diameters of woven fabrics using image analysis. The reliable and easy estimation of the effective diameter of pores of a textile is very important for the extraction of woven fabrics functional properties of crucial importance like porosity and air permeability, while facilitates the further application of sophisticated analysis methods, such as those based on fractal theory.

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ECOLOGICAL SURFACE MODIFICATION OF LIGNOCELLULOSIC FIBERS OBTAINED FROM ARUNDO DONAX L. PLANT

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Abstract: Ultrasonic energy method is an ecological and alternative method of the conventional surface processes and less chemicals, water and energy are consumed by using this method [1]. Microwave energy method is an also ecological method which reduce the process time, consume less energy and accelerate the chemical processes[2-4].

Surface modification processes are applied to the lignocellulosic fibers to improve the adhesion with matris due to their polarize hydroxyl groups[5]. Alkali process [6], acetic anhydride process [7,8], cellulase, pectinase, laccase applications [9] are some surface modification methods.

In this study, surface modification processes of Arundo donax L. fibers were performed by conventional, ultrasonic and microwave methods with sodium hydroxide. Tensile strength and elongation properties of the treated fibers were investigated.

Keywords: Arundo donax L., ecological methods, surface modification

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ELECTROCHROMIC FIBER FOR TECHNOLOGICAL TEXTILE

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Keywords: Electrochromic Textile, ITO (Indium Tin Oxide), Magnetron Sputtering

Electrochromism is a reversible change in a material's optical properties (transmittance, absorbance and reflectance) under an applied voltage [1-3]. The typical electrochromic device composition is a five-layer structure [4]. The one of the most important layers of this structure is transparent conducting oxide (TCO). Indium-tin-oxide (ITO) thin films have been widely used as transparent conductive electrodes in various optoelectronics applications such as liquid crystal displays, plasma displays, solar cells, and organic light emitting diodes. Because they possess high electrical conductivity and high optical transparency in the visible region [5, 6]. In this study, the magnetron sputtering method is being used to deposit ITO on surface of polyamide cylindrical fibers. Cylindrical magnetron sputtering system is seen in the Figure 1 and plasma generated during magnetron sputtering is represented in the Figure 2.

Figure 1: Cylindrical magnetron sputtering system.

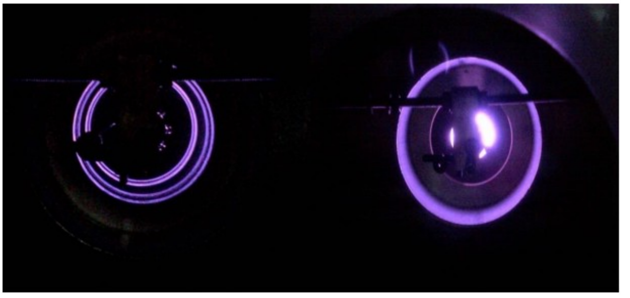


Figure 2: During deposition; polyamide fibers passing through the target plasma zone.

The coating parameters were studied for optimizing the ITO film properties (Table 1). Optical microscopy images of ITO coated fibers are seen in Figure 3.

Table 1: Deposition parameters of ITO coated fibers

Sample name	**a**	**b**	**c**
Gas flow (sccm)	100	100	100
Deposition Pressure (10^{-3} Torr)	4.7	4.7	4.7
Power (Watt)	80	90	100
Rotator velocity (cm/min)	119	119	119
Resistance (kΩ/cm)	~65	~50	~30

The results of electrical characterizations ITO coated polyamide fibers were indicated that the resistance of the thin film is reduced when the applied power is increased.

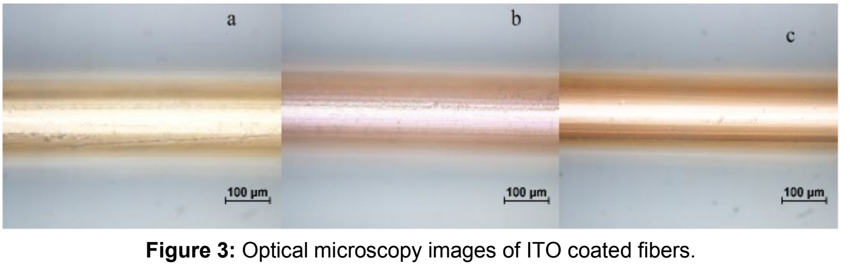
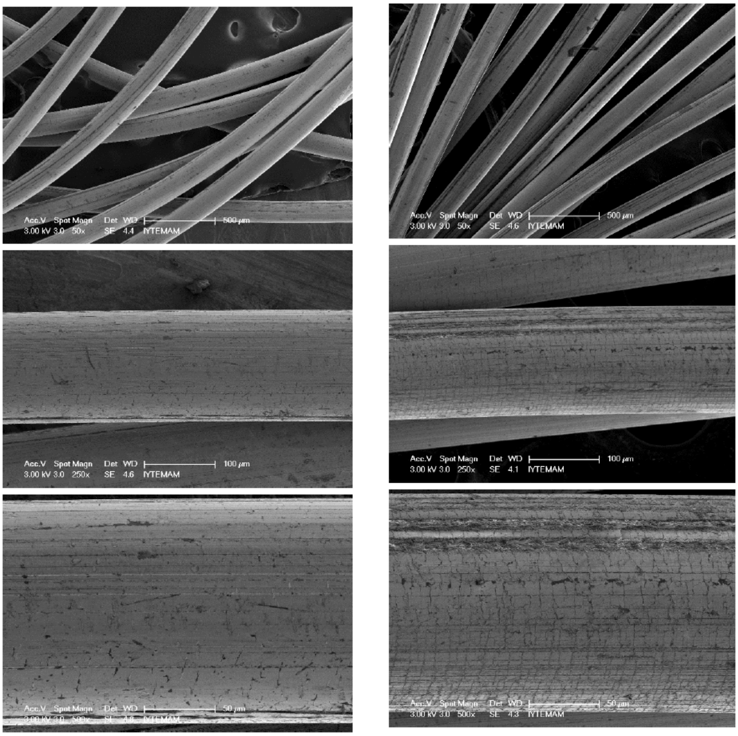


Figure 3: Optical microscopy images of ITO coated fibers.

The obtained ITO coatings on polyamide fibers were characterized by resistance per cm and ITO thickness. The surface imaging done by optical microscope and SEM for thickness studies.



ITO coated PA fiber (b) ITO coated PA fiber (c)

Figure 4: SEM images of ITO coated PA fibers

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EVALUATION OF THE EFFECT OF THROUGH-THE-THICKNESS YARNS AND THEIR DISTANCE ON THE FLEXURAL BEHAVIOR OF 3D COMPOSITES REINFORCED BY CARBON FABRIC

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Abstract: The effects of through-the-thickness yarns and their distance on the mechanical performance of 3D carbon-phenolic composites fabricated by vacuum pressure infiltration method were investigated. The composites with different tufting distances, ranging from 5.5 mm to 16.5 mm, were produced. Experimental results of the three point bending test confirmed that for all tufting composites, through-the-thickness yarns decrease the failure stress and change the failure mechanisms. In the case of UC composites (without tufting), the stress progressively increases until reaching the flexural strength, and then, decreases abruptly. Upon presence of through-the-thickness yarns, such behavior changed, and the tufted composites exhibited a slower stress decrease as well as higher levels of after-failure stresses. In UC composites, the specified crack grows quickly along the composites; however, the through-the-thickness yarn stops crack growth and branches cracks through the thickness of composite. Therefore, the delamination resistance is improved. The proportion of energy absorbed after the first drop in stress from the total absorbed energy for each specimen was calculated, which is 19.65% for UC composites while it reaches to 50% for some of its tufted counterparts. In other words, after the first failure in UC composites, the composite performance was greatly reduced, while in the tufted composites, through-the-thickness yarns impose more delamination resistance and reduce crack length, and finally, higher energy absorption is achieved.

Keywords: 3D composites, tufting, flexural strength, energy absorption, delamination

1. INTRODUCTION

Carbon composites are widely used in various industrial sectors such as transportation, aerospace and energy mainly due to their high strength-to-weight properties. However, traditional 2D laminated composite structures are more vulnerable to out-of-plane loading, resulting in the delamination failure [1, 2]. Significant efforts are being made to improve the interlaminar strength of laminated composites by various methods like 3-D reinforcements and improvements in the toughness of the matrix by additives [3].

Through-the-thickness reinforcements set up a mechanical connection between the plies of the composite laminate and bridge delamination cracks, and retain them closed; therefore, the laminate strength can be increased, and as a result, failure mechanism will be possibly changed [4].

Through-the-thickness fibers can be put in the plies using a variety of processes, including 3D weaving, stitching, knitting, tufting and braiding or z-pinning [3,4]. Stitching fundamentally includes inserting a tough thread through a stack of prepreg or fabric plies by sewing machine while the tufting is simpler than stitching; due to the absence of a second (bobbin) thread, and not locking the threads. A tufted fabric is a pile fabric, which is generated through inserting thread into a woven fabric made by needles, and the inserted through-the-thickness thread is not locked or woven into the fabric; however, they remained in place by friction resistance [5, 6].

2. EXPERIMENTAL PROCEDURES

2.1. Preform manufacturing

The dry lay-up of the laminates (preforms) were fabricated using 34 layers of unidirectional carbon fiber fabric (UD, 130 gr/m^2, Toray), with ply orientations of 0 and 90. Four types of tufted specimens with different tufting distance were prepared and listed in Table 1. For impregnation of the preforms; the vacuum pressure infiltration method was employed.

Table 1. Tufting parameters for ten kinds of preforms

Parameters	Tufting distance (mm)	Thread count (tex)	Thickness (mm)
UC	--	--	5
H6	5.5	396	5
M6	11	396	5
L6	16	396	5

2.2 Mechanical test

The bending strength and fracture behavior were studied using the three-point flexural strength test (STM-150, Santam Co., Iran) with a support distance of 86 mm and a loading speed of 0.5 mm/min according to ASTM D790 for five specimens of each composite.

3. RESULTS AND DISCUSSION

Through-the-thickness yarns decrease the failure stress and change the failure mechanisms. In the case of UC composite (without tufting), the stress progressively increases until reaching the flexural strength, and then, decreases abruptly. Upon presence of through-the-thickness yarns, such behavior changed, and the tufted composites exhibited a slower stress decrease as well as higher levels of after-failure stresses (figure 1).

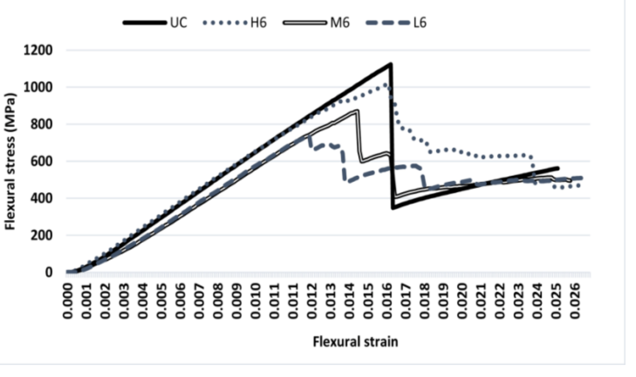

Figure. 1. Typical flexural stress–strain curves for the four kinds of composites.

Figure 2 shows the proportion of energy absorbed after the first drop in stress from the total absorbed energy, which is 19.65% for UC composites while it reaches to 50% for L6 composite. In other words, after the first failure in UC composites, the composite performance was greatly reduced, while in the tufted composites, through-the-thickness yarns impose more delamination resistance and reduce crack length, and finally, higher energy absorption is achieved.

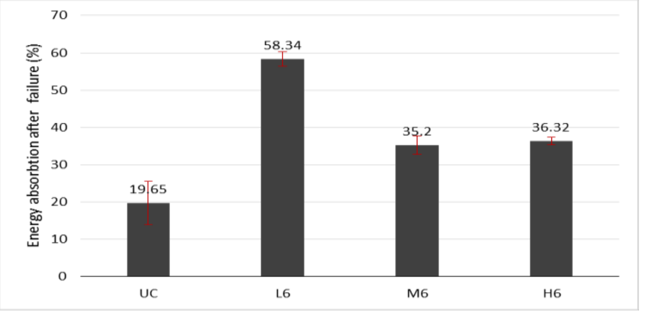

Figure. 2. Energy absorption after failure in all composite samples

4. CONCLUSION

- The tufted carbon/phenolic composites with different tufting distance ranging from 5.5 mm to 16.5 mm (sparse, moderate and high tufting density were manufactured. Upon the presence of through-the-thickness yarns, the damage behavior was changed and tufted composites exhibited a slower stress decrease.
- In untufted composites, specified crack growth occurred quickly along the composites, but the through-the-thickness yarn lowers the crack length and branches the cracks, so the delamination resistance is improved and the stress remains at a high level after the first failure and during the crack propagation in the case of tufted composites.

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ELECTROMAGNETIC SHIELDING EFFECTIVENESS OF KNITTED FABRICS WITH CONDUCTIVE YARNS

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Abstract: While electric fields have been a vital part of our daily life for over a century now, and have not shown clear evidence of ill effects on health, they are becoming more pervasive. A means to provide "protection" against electromagnetic radiation is the use of electromagnetic shielding. Typical materials used for electromagnetic shielding (EMSE) include sheet metals, metal screens, and metal foams. Textile shielding materials are generally produced from woven fabrics, knitted fabrics, nonwovens and composites involving conductive polymers, metallic fibers, metal wires, metallic coated yarns or composite yarns. Scientific literature about the EMSE properties of knitted fabrics indicates that the knitting structure and the type of the conductive material content affect the electromagnetic shielding properties of the fabrics. Therefore, the purpose of this study is to provide an overview on the effect of conductive yarn type, knitting structure and EMSE measurement technique on electromagnetic shielding effectiveness of knitted fabrics.

Keywords: Knitted Fabric, Conductive Yarn, Electromagnetic Shielding Effectiveness, Coaxial Transmission Line Equipment, Free Space Measurement Technique

1. INTRODUCTION

The 20th century witnessed an explosion of technological applications that rely on electricity and thus produce electromagnetic fields. There will be even more of these innovative technologies in the 21st century. However, while electric fields have been a vital part of our daily life for over a century now, and have not shown clear evidence of ill effects on health, they are becoming more pervasive [1]. A means to provide "protection" against electromagnetic radiation is the use of electromagnetic shielding.

Typical materials used for electromagnetic shielding include sheet metals, metal screens, and metal foams [2]. The development of electromagnetic wave resistant textiles originated in the military industry and moved gradually to civilian industries [3]. Textile shielding materials are generally produced from woven fabrics, knitted fabrics, nonwovens and composites involving conductive polymers, metallic fibers, metal wires, metallic coated yarns or composite yarns. Conductive material coated fabrics and conductive fabric reinforced composites can be also used as textile shielding materials.

2. MATERIAL AND METHOD

The purpose of this study is to provide an overview on the effect of conductive yarn type, knitting structure and EMSE measurement technique on electromagnetic shielding effectiveness of knitted fabrics.

3. RESULTS AND DISCUSSION

The electromagnetic shielding effectiveness (EMSE) of a shielding material is related to the residual traveling energy after applying the shield. The residual energy is the energy that is neither reflected nor absorbed by the shield but that emerges out of the shielding material [4].

There are several methods to measure EMSE, described by standards. In the literature it is seen that authors prefer to use the shielded box shielding efficiency measurement technique, the free space measurement technique, and the coaxial transmission line technique in order to determine the EMSE of knitted fabrics.

Due to the production technique, the textile yarns can be found only in the production direction (warp-knitted fabrics) or only normal to it (weft-knitted fabrics). Therefore the conducting yarns can only be incorporated in one direction and consequently shielding is achieved for electrical field components in just that direction [5]. In other words, knitted fabrics give different EMSE values when measured with different measurement techniques and/or different polarizations [6-8].

Scientific literature about the EMSE properties of knitted fabrics indicates that the knitting structure [5,9-15] and the type of the conductive material content [5,8-10,14-17] affect the electromagnetic shielding properties of the fabrics.

4. CONCLUSION

The purpose of this study was to provide an overview on electromagnetic shielding effectiveness of knitted fabrics with conductive yarns. It is seen that conductive yarn type, knitting structure and different measurement techniques and/or different polarizations affect electromagnetic shielding effectiveness of knitted fabrics.

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ENHANCING THE DYEABILITY OF COTTON FIBERS WITH HALOCHROMIC DYES IN ORDER TO USE IN SMART MEDICAL WOUNDS

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Abstract: In recent years smart textiles have become the subject of many studies all over the world. Within the group of smart textiles, interest in color change materials is growing. Among these groups, halochromic textiles, which can change color due to the change in pH, can be applied in the making of pH sensors. One of the potential application area of halochromic textiles is wound dressings which allow the monitoring of the wound healing process. In literature it was stated that cotton fabric can be dyed with some halochromic dyes with good efficiency. But with bromothymol blue, which changes color between pH 6-8 range, sufficient color could not be obtained. The aim of this study is to apply chemical modification to cotton fabric with cationization agents and hence to increase its dyeability with bromothymol blue dye. From the experimental results it was determined that the optimum conditions for cationization of cotton fabrics is 2.5% polyethylene polyamine compound based cationization agent, pH 7 and 60°C for 15 minutes. Optimal dyeing depth was found to be 0.6%.

Keywords: Halochromic, cotton, smart textiles, dyeing, cationization

1. INTRODUCTION

The original function of textiles was to shield man from cold and rain. Later on in history aesthetic aspects also came to play a role in clothing. Much more recently a new generation of textiles has arisen; smart or intelligent textiles. Smart textiles are active materials that have sensing and actuation properties [1]. In the last decade smart textiles have become the subject of many studies all over the world. Within the group of smart textiles, a growing interest in color change materials, or socalled chameleon textiles, is recognized. These materials can change their color due to a change of several external triggers [2]. Photochromism is a change in color, usually colorless to colored, brought about normally by UV light, electrochromism is a reversible color change upon oxidation or reduction brought about by an electrical current or potential, thermochromism is a color change brought about by heat, solvatochromism by solvents and ionochromism by ions, halochromism is a change in color occurring due to the change in pH, etc [3]. Halochromic dyes have been developed and used for textiles, and the resulting halochromic fibers or textiles can be applied in the making of pH sensors [4].

When a dressing for the treatment of burns **(**having an alkaline pH) which allows the monitoring of the wound healing process is taken into consideration, an indicator having the ability to change color at pH 5.5 will be necessary. Alike, it will be expected from a plaster used for a wound formed by cutting to give a signal via changing its color if an infection arises. In this case a halochromic dye having the ability to change color at pH 6.5-8.5 range will be necessary [5]. In the study carried out by **Van der Schueren and De Clerck** cotton fabric could be dyed with some indicators with good efficiency. But with bromothymol blue, which changes color between pH 6-8 range, sufficient color could not be obtained [2].

The aim of this study is to apply chemical modification to cotton fabric with cationization agents and hence to increase its dyeability with bromothymol blue dye.

2. MATERIAL AND METHOD

Bleached knitted fabric produced from Ne 30/1 100% cotton yarn was used in the study. As a cationization agent Albafix ECO (Hunstman) was used. It is a polyethylene polyamine compound based product. Bromothymol blue was used as a halochromic dye.

Cotton fabrics were treated with Albafix ECO at various conditions. Cationization process was carried out in laboratory scale dyeing machine (Termal HT) by using exhaust method. In order to determine the optimum conditions of cationization process, four factors potentially affecting this process were evaluated, namely cationizing agent concentration (2.5-5-10%), pH (5-7-9), treatment time (15-30-45 min.) and treatment temperature (40-60-80°C). At the end of the reaction, each sample was taken out and washed several times with cold water and dried at ambient conditions. In order to determine the optimum conditions of cationization treatment, fabrics treated at different conditions were dyed with bromothymol blue dye in a color depth of 1%. Then color yield values of samples were measured and compared. After determination of optimum conditions of cationization treatment, fabrics treated with cationization agent at optimum conditions were dyed with bromothymol blue dye in different dyeing depths; 0.2%-0.4%-0.6%-0.8%-1%. Color yield (K/S) values of samples were measured.

3. RESULTS AND DISCUSSION

In order to determine the optimum conditions of cationization process, cotton fabrics were treated with Albafix ECO at different concentrations (2.5-5-10%), pHs (5-7-9), times (15-30-45 min.) and temperatures (40-60-80°C). Then cationized fabrics were dyed with bromothymol blue dye. The results obtained are given in Figure 1.

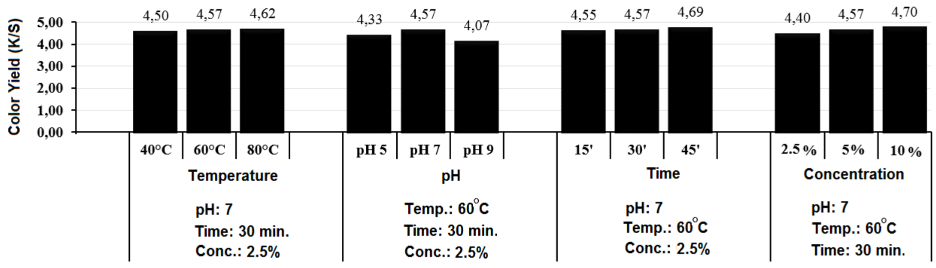

Figure 1: Results related to the optimization of cationization process

First of all, it is necessary to indicate that color yield of untreated cotton fabric dyed with bromothymol blue was 0.24 which means fabric was not dyed. So it is possible to say that cationization process is necessary in order to make cotton fabric dyeable with bromothymol blue. According to the results given in Figure 1, it can be said that the optimum conditions for cationization of cotton fabrics is found to be 2.5% cationization agent, pH 7 and 60°C for 15 minutes.

After determination of optimum conditions of cationization treatment, fabrics treated with cationization agent at optimum conditions were dyed with bromothymol blue dye in 5 different dyeing depths; 0.2%-0.4%-0.6%-0.8%-1% in order to determine the minimum dyeing depth in which level dyeing could be obtained on cotton fabric. During dyeing in 0.2% and 0.4% unlevelness was observed. As the aim of these experiments was to determine the minimum dyeing depth in which level dyeing could be obtained on cotton fabric, it can be said that optimum dyeing depth is 0.6%.

4. CONCLUSION

In this study optimum pretreatment conditions were determined in order to make cotton fabrics dyeable with bromothymol blue which is a halochromic dye. According to the experimental results it can be concluded that the optimum conditions for cationization of cotton fabrics is found to be 2.5% polyethylene polyamine compound based cationization agent, pH 7 and 60°C for 15 minutes. Optimal dyeing depth is 0.6%. It is necessary to investigate cationization with chitosan which is a natural biopolymer in further studies. Because it would be better solution for a smart wound dressing which will be used in medical textiles area.

5. ACKNOWLEDGEMENTS

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INVESTIGATION OF ELECTRICAL RESISTANCE OF POLYPROPYLENE FIBERS DOPED CARBON NANOTUBE

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Abstract: In this study, it was aimed to produce core-sheath bicomponent polypropylene fibers doped carbon nanotube to use electromagnetic applications. Monofilament bicomponent spinning machine was used. Two different dope ratio of carbon nanotube masterbatch was used at core section of bicomponent yarns. At the same time, extruder feed ratio was changed at core and sheath section of fibers. When the dope ratio of carbon nanotube was increased, electrical resistance was decreased. Extruder feed ratio affected the electrical resistance results. When it was increased, electrical resistance was decreased.

Keywords: Carbon nanotube, electrical resistance, polypropylene fibers, bicomponent spinning

1. INTRODUCTION

Electromagnetic shielding (EMS) is important to block electromagnetic radiation. Electromagnetic radiation could be harmful to electronic devices, environment and humans [1]. Electrically conductive fibers and textile surfaces are widely used for industrial materials like sensors, electrostatic discharge and electromagnetic interference shielding in clothing also in military applications [2]. The role of textiles as EMS is mainly due to their desirable properties in terms of flexibility, versatility, low mass and low cost [1]. Carbon nanotubes (CNTs) have been used as multifunctional filler in polymer fibers with improved mechanical, electrical and thermal properties [3]. CNTs can be semi-conductive or conductive due to their structure. In this study, it was aimed to improved electrical property of polypropylene yarns using CNTs.

2. MATERIAL AND METHOD

2.1 Polypropylene fibers

Polypropylene fibers are widely used in textile industry. They are preferred due to their low cost, low density, high tenacity and high chemical resistance. Properties of polypropylene chips which used in this study were given in Table1.

Table 1. Properties of polypropylene chips

Description	Value
Melting flow rate (MFR), (2160 g, 230°C)	20-28 g/10m
Tensile strength	350 kg/cm^2

2.2 Carbon nanotubes

Carbon nanotube masterbatch (%20 multiwalled carbon nanotube) was used at core section of fiber. It was supplied by Grafen Kimya Sanayi. Properties of CNT masterbatch were given in Table 2.

Table 2. Properties of carbon nanotube masterbatch

Description	Value
Carbon content	20 %wt
PP content	80 %wt
Moisture content	0,1 %wt
Surface resistivity	10^7 Ω/sq

2.3 Bicomponent spinning

Fibers were produced core-sheath bicomponent spinning method. Monofilament bicomponent spinning machine was used. The ratio of core /sheath was 30/70. Different extruder feed rate was used.

2.4 Electrical conductivity measurement

In electrical conductivity measurements, four point probe technique was used. Measurements were done at Uludağ University Textile Laboratory. Schematic view of four point probe configuration was given in Figure 1.

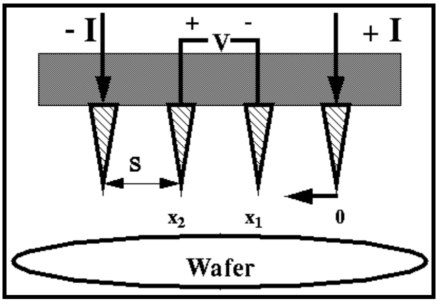

Figure 1. . Schematic view of four point probe configuration

3. RESULTS AND DISCUSSION

Two different dope ratio (%1 and %2) of CNT masterbatch were used at core section of fiber. With the raising dope ratio electrical resistance was decreased as expected. Electrical resistance values are at the range of 2.073-2.969 M ohm. Extruder feed ratio of core and sheath section of polymers also affected electrical resistance results.

4. CONCLUSION

There have been a lot of studies about CNTs and their technical applications. Conductive textile surfaces are widely used as electromagnetic shielding material. Therefore, fabrics which make of these fibers will be used EMS applications. In future work, higher amounts of CNT masterbatch will be used at core section. Mechanical properties will be measured also. Different fabric structure will be produced to obtain EMS efficiency.

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INVESTIGATION OF MECHANICAL PROPERTIES OF *PLATANUS ORIENTALIS L.* SEED FIBER/POLYPROPYLENE NONWOVEN COMPOSITES

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Abstract: Nonwoven fabrics will be more important in the future due to their properties and advantages of their production technologies. Production rate of the nonwoven fabrics are faster than the conventional processes. According to the result of the final researches, the main application areas of the nonwoven fabrics are technical textiles[1-2]. Using of natural fibers in composite structures for transportation, geotextile and construction are rapidly increasing [3-4].

Natural fibers which obtained from renewable sources have some advantages such as high specific strength and hardness [5], low cost, low density [6], renewable [7], degradable, non toxic and low CO2 emission.

In this study, Platanus orientalis L. fiber which is a new seed fiber was prepared in different ratios, then interlaid between two needle punched polypropylene fabrics with polyurethane based adhesive paste. Tensile strength, elongation, izod impact properties and SEM images of the lignocellulose fiber reinforced composites were investigated. Mechanical properties of the composites were increased depending on the fiber ratio.

Keywords: Platanus orientalis L. fibers /PP composite, mechanical properties, SEM

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NEW RESEARCH AND EDUCATION CENTER FOR INTERACTIVE MATERIALS

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Keywords: interactive material, research center, education, technical textiles, protective clothing, interactive clothing

1. INTRODUCTION

With the new Research and Education Center for Interactive Materials the Reutlingen University is investing in an exciting future topic. Partner of the School of Textiles & Design is the renowned Institute of Textile Technology and Process Engineering Denkendorf (ITV), but also the faculties for Chemistry, Computer Science and Technology. Additionally the new master's degree program Interdisciplinary Materials Science will start in October 2015. The center is funded with a total of 555,000 euros in the form of an endowed professorship by Südwesttextil, the association of the textile- and clothing industry in Southwest Germany.

With the establishment of the research and education center as an innovator Reutlingen University and ITV Denkendorf want to revive the field of textiles and simultaneously carry on the tradition of the region. "We focus on the topic of interactive materials, as they will become more and more important in the future. The students will specialize in an area with a high demand. Teaching and research are closely linked in the new center, so that the center will provide an interesting research platform for the industry as well.

The Center for Interactive Materials enables organizations to transform technical innovations into emotional and functional products. There are machined research projects in the fields of mobility, lightweight design, health, safety, environment, recycling and comfort. In all these areas new materials will be developed. These materials often generate an interface between man and machine. They interact on different sensory levels such as optics, acoustics, haptics or smell. Firemen’s clothing that recognizes great danger signals or pillows that can detect diseases out of the human breath - these are just two examples of the extensive use of interactive materials in everyday life.

In October 2015 the new master's degree program in Interdisciplinary Materials Science will start at the Reutlingen University. The association of the textile- and clothing industry in Southwest Germany is supporting the "engine for textile innovations" and has established a professorship at the University for this purpose. The new program is aimed at undergraduate students from the fields of study textile and clothing technology, design, engineering, computer science, chemistry and process engineering. Through its projects and research-oriented interdisciplinary thinking are encouraged, exploit synergies and technical depth are generated.

INSULATED SHELTER MATERIALS FOR HUMANITARIAN USE

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Abstract: A lot of emergencies are on-going in cold regions. Within the humanitarian sector there is a great pressing to distribute insulated tents. The envisioned tent should be low cost, lightweight, easy transportable, rapid deployable and should provide sufficient insulation to maintain a liveable temperature within the shelter. Research has been performed to identify the most suited combinations of materials based on nonwovens. After manufacturing prototypes, these tents were intensively investigated in Mongolian wintertime in order to correlate the lab results with field data. By combining a nonwoven with a heat reflective layer, temperature differences up to 40°C (inside compared to outside) could be maintained.

Keywords: insulation, shelter material, nonwoven, lightweight, heat reflection

1. INTRODUCTION

Within the European project S(P)EEDKITS[1], emergency kits for rapid deployment are being developed. The need to have an insulated family tent for emergencies in cold areas was expressed by the humanitarian sector. The tent needs to be low cost, lightweight, easy transportable, rapidly deployable and provide sufficient insulation to maintain a liveable temperature within the shelter, preferably above 15°C. The idea arose to base the concept on the existing family tent and simply replace the current inner tent (made from a fabric of 130 g/m² PES/CO 40/60) by an insulated version.

2. EXPERİMENTAL SET-UP

2.1 Laboratory testing

The evaluation of the insulation properties of the materials was done with a radiant panel based on EN ISO 6942 (2002): Protective clothing – Protection against heat and fire – Method of test: Evaluation of materials and material assemblies when exposed to a source of radiant heat. All samples were irradiated with a heat flux of 10 kW/m² until they started to show a damaged surface or a recording time of 1 minute had passed.

2.2 Field testing

Two prototypes of the insulated inner tent were manufactured by Sioen Industries, a partner in the S(P)EEDKITS project. The inner tent consists out of a nonwoven laminated with an aluminised PE tape fabric. Two different nonwoven thicknesses were used: 2 cm and 4 cm.

The tent prototypes were sent to a test site of the Shelter Research Unit of the Red Cross and Red Crescent in Ulaanbaatar, the capital of Mongolia. The tests were performed in wintertime (January 2015) with an ambient temperature below -20°C at night time. Data loggers were mounted in the tents and the inside temperature was recorded. Two electric heaters of 2 kW were placed in the prototypes to mimic the use of stoves. As a comparison, the same experiment was done with a standard non-insulated family tent. Beside temperature other parameters were also evaluated like CO_2 concentrations, noise reduction, acceptability by the end users.

3. RESULTS

3.1 Laboratory testing

In order to identify the most suited material several types of nonwovens were evaluated varying in thickness and density. Figure 1 illustrates that an airtight PE foil has almost no insulation capacities as temperature rises fast upon irradiation. In contrast, the test shows that an aluminised PE foil has a good thermal performance due to its heat reflective properties. By laminating an aluminised PE foil to a nonwoven, a significant increase in insulation properties is shown. As a comparison, all the standard PES/CO 40/60 materials which are used nowadays to construct the tent for humanitarian use clearly show low insulation properties.

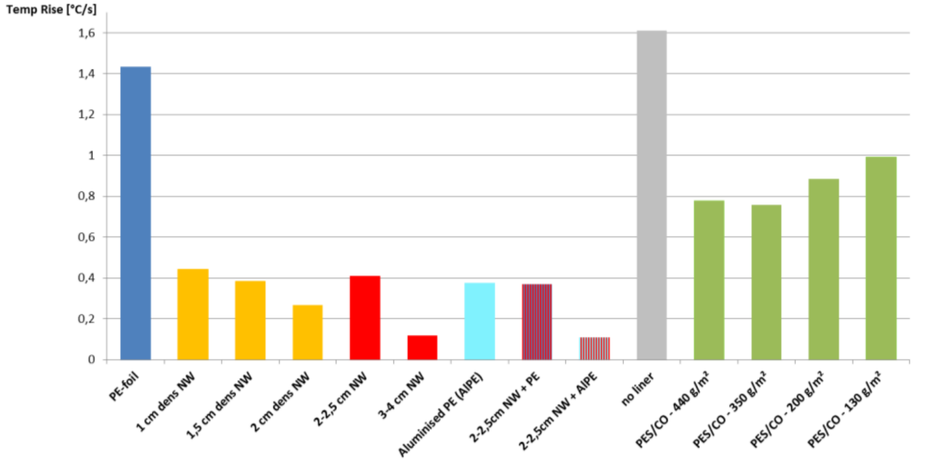

Figure 1. Temperature rise of different material compositions measured with the radiant panel test (flux 10 kW/m²)

3.2 Field testing

Based on the lab results, a ranking of the materials according to their thermal performance could be made. Field testing was needed in order to be able to evaluate the effect on the inner temperature of a tent; this cannot be predicted based on the lab results.

Two types of tent materials were selected to perform the field test: a 2 cm lower density nonwoven (R = 0.5 m².K/W) laminated to an aluminised PE tape fabric (total weight ca. 600 g/m²) and a 4 cm lower density nonwoven (R = 1 m².K/W) laminated to an aluminised PE tape fabric (total weight ca. 1050 g/m²). The low density nonwovens were selected due to weight constraints for transport.

As can be seen in Table 1, temperature differences of 40°C can be reached between the inside and the outside of the shelter. The threshold of 15°C which was set as a comfortable living temperature was reached in the inner tent.

Table 1. Temperature measurements in the inner tent of the family tent (Mongolia)

	Exterior	Standard tent	2 cm nonwoven	4 cm nonwoven
Temperatures	-20.7°C	+ 4.4°C	+ 7.3°C	+ 20,0°C

4. CONCLUSION

Insulated family tents for humanitarian use can be made by replacing the PES/CO inner tent by an insulated inner tent. Best results were obtained by using a tent material which consists out of a 4 cm thick nonwoven laminated to an aluminised PE tape fabric. By reflecting the heat on the inside of the tent temperatures up to +20°C can be reached at ambient temperatures of -20°C. The prototype was easily erected and easily transportable. The concept shows a lot of potential but still needs be to further improved.

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NOVEL APPROACHES FOR YARN SPINNING BY ELECTROSPINNING SYSTEM

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Abstract: This work describes different methods for yarn spinning from nanofibers by use of electrospinning system. Although nanofiber production by electrospinning is highly explored especially during last decades, research on yarn spinning from nanofibers is quite limited drawing attention of researchers just recently. Therefore these quite limited but novel approaches have been explored and discussed by this work presenting potential applicability of these systems. By these new approaches presented here, either a twisted yarn of continuous length including nanofibers or a yarn of parallel bundles of nanofibers can be produced depending on the system design. These yarns can be high strength, either more rigid or lighter, or might be designed for a specific function by careful selection of material or production technique.

Keywords: Twisted Yarns of Nanofibers, Yarns of Parallel Nanofiber Bundles, Nanofiber Spinning, Electrospinning

1. INTRODUCTION

Electrospinning is a surface production method designed to produce fibres with a fineness generally ranging between 50-500nm [1]. In recent years, these developed surfaces have a wide range of application potentials for high-performance filters, hydrophilic textiles, and fibre-reinforced composites such as biomedical textiles, tissue production, nano or micro electrical appliances, electromagnetic protection, photovoltaic appliances and so on. Among the main advantages of this method, the simple mechanism used, easy modifications on process parameters, and wider array of the polymers to be used in comparison with the other methods could be mentioned leading a high exploration of this system especially during last decades.

Recently, however, there are a few research works focusing on the production of uniaxial fibre bundles or continuous twisted yarns by means of electrospinning method allowing nanofibers to be used in traditional textile industry such as weaving, knitting or embroidery applications opening gates to the great number of applications. For such applications; the high length-diameter ratios and the increased fibre-matrix adhesion cause high specific surface areas and this may lead to stronger, harder, lighter and fibre-reinforced materials. The combination of textiles and nanofiber-based yarns may also lead to new opportunities in smart and electronic textile fields [2]. Therefore, the available novel approaches are discussed thoroughly in this work to explore future potential of these systems.

2. LITERATURE

It is well-known that the foundations of electrospinning were laid in 1930's. In fact, by his 7 patents between 1934-1944, Anton Formhals made the first base for the formation of yarns by electrospinning method. In those works, he presented different techniques although fundamental principles were being quite similar. By his four patents, Formhals obtained parallel fibre bundles with the electrospinning technique. However no technical data related to those yarns were presented [3, 4, 5, 6]. On the other hand, more recently, Smit (2005) introduced a system for parallel fibre bundles obtaining average diameter ranging between 285nm to 1000 nm [2]. Pan (2006) also introduced a system for parallel fibre bundles having a production speed of 3-14.9 m/s and 346-670 nm average fibre diameter values [7].

In regard to the twisted yarns with nanofibers, similarly, the first work also belongs to Formhals with his three patents [8, 9, 10]. However, more recently, Kim (2005) presented a different system producing yarns having fineness of 75-120 deniers [2]. By a different approach, Teo produced yarns by using vortex-bath system at 80m/min [2]. With a different system, Lotus also obtained twisted yarns having fibre diameters of 98.6nm-362nm [11]. On the other hand, Aslı obtained yarns of 4.5 denier at 150 m/h [12]. By using systems that are different from each other in his patent, Lee obtained yarns of fineness ranging between 0.4-5.1µm. In another work carried out between 2007 and 2009, Dabrian reported yarn delivery speed of 14m/sec while the yarn diameters were around 160-170µm [13]. In his works in 2007 and 2009, Bazbouz introduced a system producing yarns of 5-10 µm diameter [16,17] while Afifi reported yarns of 30-450 µm diameter [18]. Kim also obtained yarns by electrospinning including fibers having 186- 480nm diameter values [19]. Above all, more recently Ali (2012) obtained a twisted continuous yarn having 30-450 µm. diameter containing fibers of 480nm-1.5µm diameter [20].

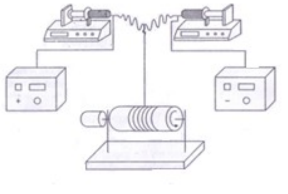
3. MAIN FINDINGS

We investigated yarn production systems from nanofibers by categorising available approaches into two different main sections. Some examples for these systems are given below.

3.1. Systems for Yarns of Parallel Bundle of Nanofibers

Although there are different approaches available in literature, just an example for parallel bundles of nanoyarn production systems is shown in Table 1.

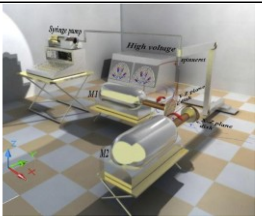
Table 1. A Typical System Developed for Parallel Bundle of Nanofibers by Electrospinning

Reference	Schematic View of Production Technique	Yarn Details
Pan (2006) [7]		Winding speed: - 3-4.2 m/h for PVA - 14.9 m/s for PVP Average fiber diameter: 346nm (PVA) 670nm (PVP)

3.2. Systems for Twisted Yarns of Nanofibers

There are quite different approaches used for twisted yarn production by electrospining method. However, only two typical of these systems are shown in Table 2 below including main yarn details as well.

Table 2. Typical Systems Developed for Twisted Yarns of Nanofibers by Electrospinning

Reference		Production System	Yarn Details
a	Bazbouz (2008) [16]		Yarn diameter: 5-10 µm
b	Ali (2012) [20]		Yarn diameter: 30-450 µm Fiber diameter: 480nm-1.5µm

4. RESULTS AND CONCLUSIONS

In this work, novel approaches for yarn spinning from nanofibers are explored and categorised in terms of fibre alignment within the yarn, the system design and yarn properties obtained. However, only the most prominent of these are given here. Mainly, the current available systems are based on the designs presented by different patents of Formhals going back to 1930's although there are new successful and original systems available as well. This work shows the potential application of these approaches leading to a conclusion that there is a need for further improvement in yarn production from nanofibers which is going to be the topic of our next work.

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PLASMA APPLICATIONS AND INDUSTRIAL TEXTILES

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Plasma is a mixture of ions, electrons and neutral particles and has diverse implementation in variety branches of science, technology and in industry. Plasma technology also provides several advantages over the conventional chemical process whish considered low-cost, rapid processing, intensive reduction of pollutant and ecologicafl technology. It is used in many areas such as in electronic industry, tool making industries, medical devices, film technology and automotives. Recent decades, there is an increasing research on plasma application of textiles. It is mostly research on atmospheric pressure plasma application of textile surfaces on roll to roll systems. Besides, it provides efficient fast and low cost processing for coating, painting, whitening and other processes particularly in the textile industry. Textile industries are moving towards the application of water- less or low water based processing technologies.

Plasma treatments on textile industry can change surface morphology, surface chemistry, wettebility, soaking capacity, shrinkage, surface energy and adhesive properties. Plasma application changes the upper atomic layers of textile surface and leaves the bulk characteristics unaffected. Wettability can be problem for some applications such as dyeing, finishing and detergency. The plasma treatment has severely advanced textile hydrophilic/ hydrophobic characteristics.

Variety configurations of plasma processing such as atmospheric pressure plasma, and low-pressured (vacuum) plasma have been used to modify textile surfaces by generating active species of plasma on the surface. The radio-frequency powered (RF) plasma sources provide easier control for surface properties and good stability of fabrics at the low cost. For instance, exposure of plasma species of oxygen generates of high energy hydrophilic functional groups on the surface and results in increased wettability. Atmospheric pressure plasma systems are used widely for surface modified process because of environmentally friendly, wide variety of subjects, simple and quick, water and energy saving effect process. Also, vacuum plasma provides control of the parameters such as air permeability and moisture, besides, the elimination of the volatile toxic chemicals for the treatments. The nonthermal plasma treatment is for most textile materials are heat sensitive processes and large variety of chemically active functional groups can be incorporated into the textile surface.

In our work, different potential applications of atmospheric plasma and vacuum plasma treatments were used to enhance and examine the basic properties of textile materials. Atmospheric plasma was applied for sterilization process, denim chemical process and improvement surface properties of industrial textiles such as denim and wool. It was observed after plasma treatment that hydrophilic/ hydrophobic characteristics were improved for their potential applications.

Atmospheric pressure plasma roll to roll system which has 200 cm dimensions and 27 electrodes was set up and the experiments have been made in industrial scales. Atmospheric pressure plasma roll to systems was used to gain permanent hydrophilic surface property to wool. Vacuum roll to roll plasma system was also set up and denim and wool fabrics were used in this system. Vacuum plasma provides control of the parameters such as air permeability and moisture, besides, the elimination of the volatile toxic chemicals for the treatments. The reason of usage of nonthermal plasma is for most textile materials are heat sensitive. Different chemicals (hydrazine, methyl methacrylate (MMA), styrene, hydrochloric acid (HCl), hexamethyldisiloxane (HMDSO), Styrene) were used for modify denim and wool surface properties. The aim of this vacuum system, denim and wool fabrics acquire hydrophilic and hydrophobic property. Also, through hydrophilic denim, improvements were seen in the painting sensitivity.

DEVELOPMENT AND CHARACTERISATION OF NONWOVEN FABRIC FOR APPAREL APPLICATIONS

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Abstract: The cost of making apparel fabrics is very high because of their manufacturing processes that start from the ginning to weaving or knitting. The researchers and research companies are working on reducing the manufacturing cost either by developing innovative system of manufacturing for conventional process of making fabric or making the fabric by unconventional methods. But due to advancement in technology, now researchers are trying to develop the durable nonwoven fabric for apparel applications through hydroentanglement process. Making fabric through unconventional method gives extra benefits in term of cost and time and it also help in improving the environment by reducing the carbon footprint.

Mostly, the concept of nonwoven are relate to the disposable or limited uses in routine life. Its classic examples are wipes, interlining and protective clothing. Before, it was considered that the nonwoven fabrics are not good for apparel applications because of their limitation in stretchability and elastic recovery, tensile properties and flexibility. But now because of advancement in technology and the availability of the innovative fibres, the researcher are doing research to get the durable nonwoven fabric from the hydro process that can withstand against the woven fabric in term of aesthetic and tensile properties.

In this report, the fabric was developed through unconventional methods by using two techniques of manufacturing processes. In one process, the fabric was hydroentangled after the needle punching process and in second process; the fabric was hydroentangled directly from the carding process. After the development of the fabric the fabrics was tested according to the British Standards and compared the attained results with the standard fabric of the woven and commercially available nonwoven fabric (Evolon®) in term of tensile, flexibility, absorbency and air permeability tests and found the satisfactory results.

SCREENING OF FLAME RETARDANTS IN TEXTILE COATINGS VIA HIGH-THROUGHPUT TECHNOLOGIES

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Abstract: More and more flammable materials are being used indoor. In order to save lives and prevent material damage the standards on flame retardancy are becoming more severe. On the other hand the use of flame retardants is increasingly being restricted by European regulations and eco labelling requirements.

In order to be able to screen the performance of multiple environmental friendly flame retardants, a design of experiments was setup. A large number of coated (acrylic/polyurethane) textile samples were produced via an automated platform (respectively a high-throughput formulation and a high-throughput application platform) and evaluated for their performance. Via data analyses general conclusions could be drawn.

Keywords: high-throughput, data analysis, flame retardant, design of experiments, textile coating

1. INTRODUCTION

Over the past 30 years, the lapse of time between the moment a fire breaks out and the moment the fire has become life threatening has decreased from 17 to hardly 3 minutes due to the use of flammable materials in-house. One of the most widely used and very effective flame retardants (FR) in textile, decabromodiphenyl oxide (deca-BDE), has come under attack as it has been put on the SVHC list (Substances of Very High Concern). There is an urgent need in the industry to find suitable environmental friendly alternatives. Hence the Belgian project FR4tex[1] was initiated in order to perform research in this area. Next to the incorporation of the FRs in the fibres itself, FR coatings and finishes have also been evaluated.

2. EXPERIMENTAL SET-UP

2.1 High-throughput screening

The coating pastes were formulated and applied on the automated platform at Flamac. 100 ml samples of the coating pastes were produced. The ingredients of the formulation were added while stirring in the following order: 1) binder, 2) ammonia, 3) dispersing agent, 4) FR additive, 5) thickener. The amount of thickener was determined in advance via manual lab experiments. Subsequently, the pastes were applied onto a PES/CO 50/50 fabric of 232 g/m² via knife coating, also in an automated way. Finally, the coatings were dried via multiple passages under an IR-field. The aim was to apply approximately 50 g/m² coating on the fabric. In a first series an acrylate binder was used, in a second trial flame retardants were added to a polyurethane binder.

2.2 Flammability test

The limiting oxygen index (LOI) is the minimum concentration of oxygen, expressed as a percentage, which will support combustion of the fabric. It is measured by passing a mixture of oxygen and nitrogen over a burning specimen, and reducing the oxygen level until a critical level is reached (1% accuracy).

Tests are performed according to the ISO 4589-2 (1996) - Amend. 1 (2005) norm, after conditioning at 23°C, 50% relative humidity. The norm was slightly altered due to the small test specimens. The first highlight stripe is made at 1 cm (instead of 2 cm) and the distance between the two stripes is 7 cm instead of 8 cm.

3. RESULTS

3.1 Design of Experiments

On the high-throughput platform FR coated textiles were produced, which were evaluated for their burning behaviour (LOI-measurements). Several types of flame retardants with different chemical composition were selected to perform the screening. Halogenated flame retardants were evaluated next to nitrogen (N) and/or phosphorous (P) based additives. The others-group in Table 2 represents ceramics, minerals, graphite etc. In order to evaluate synergistic effects, nitrogen and phosphor based FRs were blended in different ratios in the experiment with an acrylic binder. In the experiment with a polyurethane binder the P-based FRs were mixed with the others-FR (50/50 ratio). Also the concentration of dispersing agent and flame retardant was varied.

Table 2. Overview of the Design of Experiments (DoE) used to screen the flame retardants in an acrylic binder

Flame retardant groups	Type of FR	# of FR's	Composition of FR					Conc. of FR on total formulation	Conc. of Dispersant 1	Total # of experiments
Halogenated	Halogenated	4	100					20–40 %	0.5–1%	20
Flame retardant groups	**Type of FR**	**# of FR's**	**Composition of FR**					**Conc. of FR on total formulation**	**Conc. of Dispersant 2**	**Total # of experiments**
Non halogenated	N-based	1	25	50	75	0	100	20–40 %	5–10 %	128
	P-based	6	75	50	25	100	0			
	N-P based	8	100					20–40 %	5–10 %	24
	Others	6	100					20–40 %	5–10 %	40
Total number of experiments										212

3.2 Data analysis

The LOI measurement results of the FR coated textiles were evaluated and subjected to data analysis. The outcome gave an insight on the influence of the concentration of each individual FR (see Figure 2). By using these graphs the FR concentration needed to obtain a wanted LOI value can be predicted. Synergistic effects between FRs were also be visualised. The efficiency of the FR in acrylic and polyurethane binders could be compared. It was shown that the dispersing agent and thickener had no effect on the FR behaviour.

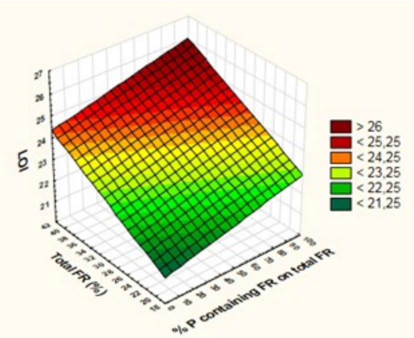

Figure 2. 3D surface plot of LOI as a function of the flame retardant concentration

4. CONCLUSION

High-throughput technologies have been successfully used to accelerate the production, and thereby the screening, of different FRs in textile coating applications. Via data analysis, the results of the burning behaviour analysis were interpreted and general trends could be observed.

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SPRAY COATING OF NONWOVEN MATERIALS TO BE USED IN LAMINATION OF PROTECTIVE GARMENTS

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Abstract: Aim of this study is to explore alternative materials to be used in lamination process of protective garments. For this purpose; meltblown polypropylene (PP) and nanoweb polyamide (PA) fabrics were coated with solvent based polyurethane (PU) via spray coating to be used as lamination materials. To determine the comfort related properties; air permeability, water vapour permeability and waterproofness of samples were measured.

Keywords: spray coating, meltblown, nanoweb, polyurethane, protective garments.

1. INTRODUCTION

Lamination and coating processes are the base methods to obtain a barrier for protective garments, against penetration of water and liquid chemicals [1]. These two methods can be used individually to obtain a waterproof and breathable effect. But in some cases, additional finishing or combination of these three methods can be required to obtain a more durable and efficient function.

As lamination films, hydrophilic solid films or microporous membranes can be used. In addition, in last decades, special webs are searched to be an alternative to these films because of the high cost of quality microporous membranes. In the literature, webs containing nanofibers were used for this purpose [2, 3]. As an alternative in this study, as a starting work, hydrophilic PA nanoweb is planned to be modified to be used as a lamination material. A cheaper and more common fabric structure, a meltblown PP is also used. Hydrophobic properties of these nonwoven fabrics were modified by spray coating of a solvent based PU.

2. MATERIALS AND METHODS

2.1 Materials

Materials of the study were spray coated nonwoven fabrics. As nonwoven fabrics; meltblown PP and nanoweb PA were used. For spray coating dimetyl formamide based PU was selected. As experimental parameters; 2 different fabric types, 2 different PU inclusion and two different number of coating layers were used. Spray coating was done by a hand spray gun (Sata Mini Jet). Details about the specimens are given in Table 1.

Table 1. Details of spray coated nonwoven specimens

Fabric code	Fabric type	Spray coating	PU inclusion of coating solvent % (w:w PU:DMF)
MBPP210	meltblown PP	2 layers	10%PU
MBPP310	meltblown PP	3 layers	10%PU
MBPP220	meltblown PP	2 layers	20%PU
MBPP320	meltblown PP	3 layers	20%PU
NWPA210	nanoweb PA	2 layers	10%PU
NWPA310	nanoweb PA	3 layers	10%PU
NWPA220	nanoweb PA	2 layers	20%PU
NWPA320	nanoweb PA	3 layers	20%PU

2.2 Methods

Air permeability, water vapour permeability and waterproofness of samples were tested. Air permeability of samples were tested by using Textest FX 3300 type Air Permeability Tester with using 100 mm/s ($l/m^2/s$) air pressure. For determining the absolute water vapour permeability (RET), Permetest was used. Waterproofness was tested by using SDL ATLAS M018 Hydrostatic Head Tester with 60 cm H_2O/dk water pressure gradient

3. RESULTS AND DISCUSSION

Results of the tests are given in Figure 1.

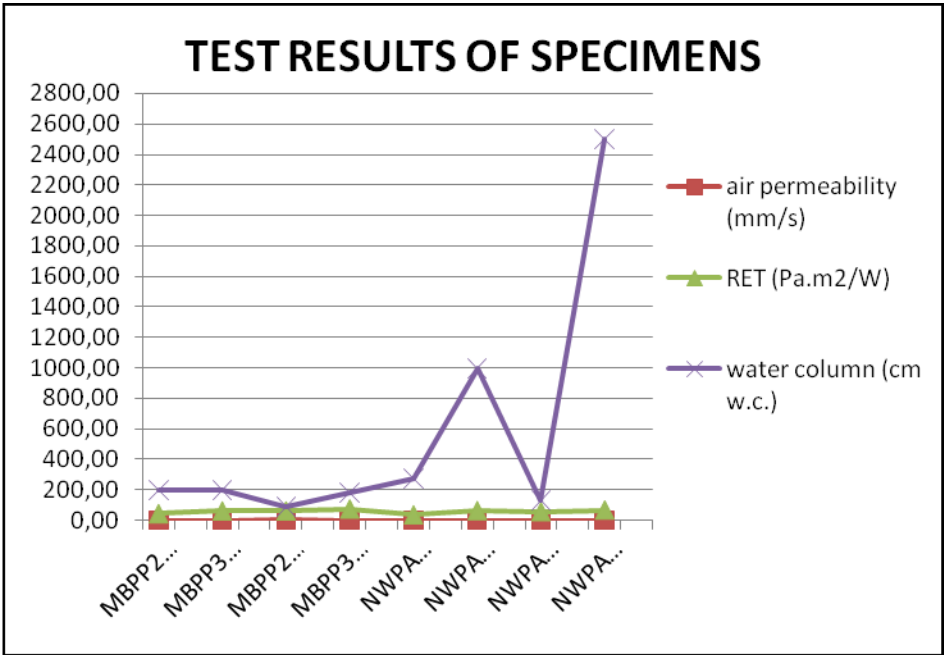

Figure 1. Test results of specimens.

Air permeability results were between 0 and 1.15 mm/s for all coated specimens while raw meltblown PP and nanoweb PA had 153.5 and 6.75 mm/s air permeability, respectively. Coating process reduced the air permeability of specimens and all the spray coated specimens were belong to windproof fabrics [1]. Results were similar for PP and PA fabrics for both 10 % and 20 % PU Inclusion and 2 and 3 layers of coating.

RET values of raw meltblown PP and nanoweb PA were 0.7 and 0.2 Pa.m^2/W, respectively. These values correspond to high relative water vapour permeability between 91-97 %. When the nonwovens were spray coated, RET values were obtained between 34.20-72.60 Pa.m^2/W. This means that the relative air permeability of samples reduced to approximately 10-17% after spray coating. The RET values were higher for 3 layers of coating and 20 % PU inclusion. Nanoweb PA specimens gave better results than meltblown PP equivalents. But still, results were very close for every type of specimens.

Waterproofness of specimens were given in terms of the height of the water column which is obtained when the third drop was observed on the tested sample surface. According to results, almost all of the coated specimens gave higher values than 130 cm w.c. So these specimens can be considered as waterproof [1]. Except than NWPA320, the results were obtained between 87.35-993 cm w.c.. NWPA320 gave an extreme value.

4. CONCLUSION

According to test results, spray coating reduced the air permeability and relative water vapour permeability of specimens, dramatically. Waterproofness of the samples increased. But the balance between air permeability, water vapour permeability and waterproofness has not been achieved, yet. In the future work, hydrophilic components can be added to the coating solution in order to increase the relative water vapour permeability. Also applied amount of PU solution and PU:DMF concentration will be differed to obtain required values.

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STRUCTURAL PROBLEMS IN STRETCH TROUSERS DESIGNS AND ALTERNATIVE SOLUTIONS

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Abstract: Products vary with improvements in textile industry. Clothing products, presented for consumers should make easy practical usages of daily life, should not decrease body performance. As of body performance, lower part of human body shows a particularisation as one of the most motion-intensified body parts. In this respect, angle changes between legs variable from 0 degree up to 180 degrees should be considered while designing clothing. Convenient fabrics for these angle changes, lycra fabrics satisfy consumers for their own body movements. In clothing designs, stretch trousers supply conformity. But some structural problems may emerge before clothing production process. We may identify these ones as problems which stem from pattern drawing carelessness. In this paper it will be discussed that what kinds of pattern drawing problems can be and how they can be eliminated before production process starts.

Key Words: pattern, seam allowance, crotch, waistline, leg width

1. INTRODUCTION

1.1 Practical Clothing For Daily Life and Body Performance

Lower part of human body shows a particularisation as one of the most motion-intensified body parts. In this respect, angle changes between legs variable from 0 degree up to 180 degrees should be considered while designing clothing. Convenient fabrics for these angle changes, lycra fabrics satisfy consumers for their own body movements. Lycra fabrics may be produced by weaving or knitting, and they may contain cotton, wool, synthetic in optimal tested ratios.

Physical dimension changes of the fabric (stretching, shrinking, hanging etc.) and the type of clothing (underwear and outerwear) must be taken into consideration on additions and decreases in pattern sizes [2].

In recent years, thanks to innovations in fiber and polymer fiber technology, fibers gain physical and chemical properties. These fibres called "high performance fibers" are used in the production of a lot of different textile structures [3]. High performance fibers are made more functional with a variety of finishing processes for clothing used in sports and daily activities.

For stretch trousers, the type of fabric consists of 95% cotton, 5% lycra jersey elasticized tube cloth. Stretch trousers, due to their wrapping properties for body are made of elastic jersey. Therefore the measurements must be subtracted from the normal measurements considering the stretching ratios of lycra jersey elasticized cloth. The size measurement is made in order to prepare patterns of stretch trousers (stretching ratio 12% in width, 5% at length) [5].

2. PATTERN DRAWING AND PROBLEMS

2.1 Process In Pattern Drawing

Consumer researches have shown that in the last century, modern consumers meet the clothing needs in line with a more dynamic and comfortable new life styles. The comfort is a fundamental and universal need for these consumers. Now not only the appearance of the garment, but also the feeling it gives for body is expected [6].

Preparation of the pattern is the most important thing in apparel design and production. Reflection of fashion on clothing and clothing conformity with body require well structurized patterns.

In Turkey in confection sector, we use German originated pattern preparation system, Müller. In scope of this system measurements such as waist circumference, hips circumference, knee width, leg width, calf of the leg width are required width measurements for stretch trousers. Knee height, sitting height, calf of the leg height, inner trousers height are necessary for lenght measurements (table 1).

Table 1. Required measurements for stretch trousers patterns according to Müller Pattern Preparation System

Width Measurement	waist circumference
	hips circumference
	knee width
	leg width
	calf of the leg width
	ankle width
Length Measurement	knee height
	sitting height
	calf of the leg height
	inner trousers height

2.2 Pattern Drawing Problems

Various stretch trousers designs from fabrics produced by weaving or knitting which is a more widely used technique for this aim can be developed. However, conformity of the structural aspects of design for the user's physiological body feature is as important as the aesthetic aspect. Considering the structural aspects, errors on large and small pattern parts stemming from drawings may continue in cutting, sewing and finished products stages as well. Generally consumers primarily pay attention to the aesthetic aspect, but when it comes to usage, then, they face with some problems. This is the issue of what should be specified and suggested for solutions.

Problems typically include:

- Low waistline and low crotch at height

- Low waistline and high crotch at height

- Undesirable crotch curves

- Lack of sufficient knee width measurement

- Lack of sufficient calf of the leg width measurement

- Lack of sufficient leg width/ankle width measurement

- Lack of sufficient seam allowance when compared to transverse stretching rate of fabric

- Problems of fabric at longitudinal stretching ratio

3.CONCLUSIONS

For appropriate stretch trousers patterns for body it should be paid attention to these issues:

- We should not determine low waistline and low crotch at height. Because ideal sitting height can not be provided.

- We should not determine low waistline and high crotch at height. There will be undesirable crotch curves on front trousers.

- We should not draw unwanted crotch curves beyond standard forms for body feature.

- We should take sufficient measurements around knee, calf of the leg, leg and ankle.

- According to a research result, for a pair of stretch trousers stretching ratios are 12% in width, 5% at length. Thus when calculating measurements we should pay attention to these ratios. This is the same issue for seam allowance of front trousers crotch, back trousers crotch and inner trousers seam line.

-These issues are valid for both men and women clothing.

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STUDY OF RESIN TREATMENT EFFECTS ON THE MECHANICAL PROPERTIES OF COTTON YARNS BY THE EXPERIENCE PLAN METHOD

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Abstract: This paper presents a study of resin treatment effect on the mechanical properties of diverse cotton yarns, by the experience plan method. Three type of yarn were used (a 100% cotton yarn “TY”, a sized 100% cotton yarn “TF”, and a cotton yarn containing 5% of Elasthanne”YE”) and treated with two crosslinking agents (Glyoxalic and Acrylic resin). Furthermore, the effect of the chemicals properties of resins and the treatment conditions (curing temperature, curing time, dry time and dry temperature) are also studied to understand the mechanical behavior and surface morphology (SEM) of the treated samples. Thermal analyzes by DSC and TGA complete the study by providing the necessary information for the comprehension of the thermal behavior of the studied resins.

Keywords: cotton yarn, glyoxalic resin, Acrylic resin, surface properties, mechanical properties

STUDY ON THE WET FEEL SENSATION OF FLEECE KNITTED FABRICS FOR INCONTINENCE UNDERWARE

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Abstract: This paper describes the development of a knitted structure to be used as first layer in the absorption system for incontinence underwear reusable garment. Several knitted fabrics have been produced varying the composition (polyester and viscose) and the dimensional properties of a fleece knitted structure, treated with a hydrophilic softener. Dry feel has been evaluated based on standard ISO 11948-2:1998. In this study we can verify that the combination of hydrophilic and hydrophobic fibrous materials improve the reduction of the wet feeling and the application of surface treatments with hydrophilic softeners increases the rate of liquid absorption.

Keywords: Incontinence, urine absorption, Wet feel and weft-knitted

1. INTRODUCTION

The International Society for Incontinence defines urinary incontinence as "the involuntary loss of urine, which determines a social or hygienic discomfort and can be objectively demonstrable" and vary from a little occasional loss to the utter inability hold urine. [1] [2] Urinary incontinence may be preceded by alert or couldn't be conscious or unconscious, such as during sleep, and may be defined in a simple way as the commitment mechanisms in the storage and urine emptying. This commitment has proven more common in females and at more advanced ages, however, should not be considered as a natural aging process. [3] Although the elderly are the group most likely to suffer from urinary incontinence, this condition isn't directly related to aging. The impact caused by aging associated to decreased urethral compliance or absence of detrusor contractility. Furthermore, age tends to lower the support of the bladder neck, the length of the urethra and the pelvic floor muscles competence that provides additional support to the urethra. [4] According to the Continence Foundation of Australia, Australia there are more than 4.8 million of incontinence (urinary and fecal), and urinary incontinence affects about 13% of men and 37% of women.

However, approximately 70% of incontinent people does not seek counseling and/or medical treatment. [5] Several products may be found I the market for this purpose, such as disposable devices, like diapers and dressings. However new solutions are appearing in the market based on reusable underwear. Main features and challenges for these products are dry feel, retention capacity and absorption of urine, beyond the odor control thereof.

2. MATERIALS AND METHOD

Development of fleece knitted structure: varying composition fleece knitted structure; polyester, viscose and blend. Surface treatment: varying finishing softening and varying coating. Performance evaluation: 25 ml of aqueous NaCl solution, test is based on the ISO 11948-2 standard: 1998.

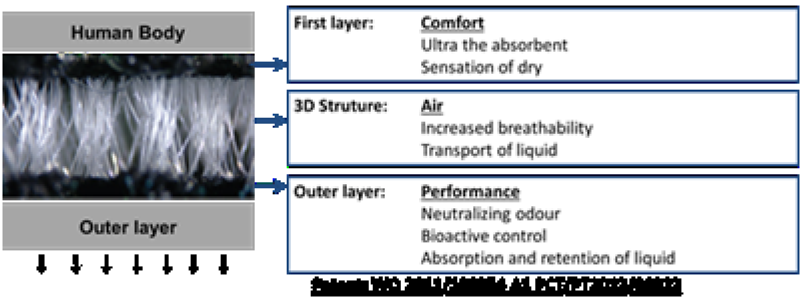

Figure 1. Multilayer device - performance technology

3. RESULTS AND DISCUSSION

In this study we can verify that the combination of hydrophilic and hydrophobic fibrous materials improve the reduction of the wet feeling and the application of surface treatments with hydrophilic softeners increases the rate of liquid absorption.

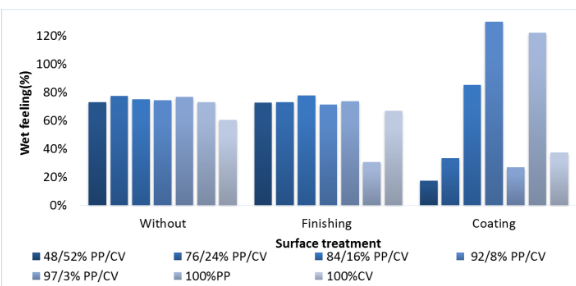

Figure 2. Wet feeling

4. CONCLUSION

Fleece knitting with more polyester in structures in the rings have better results. Structures with chemical finishes improvements feel dry but with specialized coatings perform better. Structures with finishes boasts faster wicking's.

ACKNOWLEDGEMENT

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THERMAL INSULATION PROPERTY OF CELLULOSE POWDER COATED TEXTILES

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Abstract: In this investigation thermal insulation property of cellulose powders in textile coating as filler materials was researched. Pre-treated 100% polyester woven fabrics were coated with cellulose powders in concentrations of 60 g/kg by knife coating technique. To determine effect of the particle size cellulose powders which have 8 and 18 μm particle sizes were coated to polyester fabric. The measurements of thermal resistance values of coated fabrics were performed with Sweating Guarded Hot Plate (SDL Atlas) that works in accordance with TS EN 31092 standard. Thermal resistance values of fabrics were increased after coating and in parallel with this heat transfer coefficients were decreased.

Keywords: Cellulose powder, textile coating, thermal resistance, heat transfer coefficient, polyester fabric

1. INTRODUCTION

In Turkey that is foreign dependent in terms of energy sources by 70%, according to data of The Ministry of Environment and Urbanism, 35% of the total energy consumption is spent in buildings and also constitutes around 65% of this energy is spent for heating and cooling purposes. However, it is quite inefficient due to losses in buildings used for the energy expended. Lost an average of 25% of the energy used in buildings, occurs from the windows. Therefore, the reduction of losses occurring in the windows and thermal insulation in buildings are quite important issues for our country as well as consumers [1].

In most cases, insulation prevents heat losses to environment. In other cases it protects from the heat that came from environment. Thermal insulation is a resistance that decreases heat transfer.

The materials that have heat transfer coefficient (λ) lower from 0,065 W/mK are approved as "thermal insulating material" in classification according to ISO and CEN standards [2].

Using of various textile materials as thermal insulator in textile industry has been prevalent. A scientific research that is conducted in Gavle University (Sweden) indicated that, energy is spent on heating and cooling can be reduced by 20-30% with the use of energy-efficient curtains in windows [3].

Various studies showed that thermal insulation properties of fabrics that coated with appropriate filler materials can be improved [4-5].

The aim of this study is investigate thermal insulation property of polyester fabrics coated with cellulose powders that have low heat transfer coefficient. Within this scope, cellulose powders that have two different particle sizes have been used at constant concentration rate.

2. MATERIAL AND METHOD

2.1 Polyester fabric

A satin weave polyester fabric which was desized and heat-set by the supplier was used in the experiments.

Table 1. Properties of the fabric

	Warp	Weft
Raw material	100 % polyester	100 % polyester
Density	47 1/cm	23 1/cm
Weave structure	4/1 Satin	
Weight	248 g/m²	

2.2 Coating Materials

The wood sourced cellulose powders which have 8 and 18 µm particle sizes were used in experiments. The other coating chemicals were given in Table 2.

Table 2. Properties of coating chemicals used in the study

Chemical	Property
Binder	Self-crosslinking acrylate-based copolymer, anionic
Cross-linking agent	Low formaldehyde melamine resin , nonionic
Synthetic thickener	Ammonium salt of carboxylic acid polymers, anionic.
Anti-foam	Emulsion of modified siloxanes, nonionic
Ammonia	25 %
Water	Soft water (reverse osmosis)

2.3 Coating, Drying and Curing

Pre-treated 100% polyester woven fabrics were coated with cellulose powders by knife coating technique on a lab coater (Rapid Auto-Coating). The cellulose powders used in the study were at two different particle sizes. To investigate the effect of particle size on thermal insulation property of coatings, the cellulose powders which have 8 and 18 µm particle size were added to coating paste for constant 60 g/kg concentration rate. Then samples were dried at 110 ˚C for 5 minutes and they were cured at 140 ˚C for 4 minutes on a lab type steamer (Rapid Model H-TS-3).

2.4 Thermal Resistance Measurement

The measurement of thermal resistance (R_{ct}) values was performed with Sweating Guarded Hot Plate (SDL Atlas) that works in accordance with TS EN 31092 standard.

3. RESULTS AND DISCUSSION

Cellulose powders which have two different particle sizes were used as filler materials in coatings.

Table 3. Thermal resistance results of fabric samples coated with cellulose powders in different particle sizes.

Samples	Thermal resistance- R_{ct} (m^2K/W)	Thickness (mm)	Heat transfer coefficient- λ (W/mK)
Raw fabric	0,0128	0,466	0,0364
Coated fabric (8 µm)	0,0154	0,526	0,0341
Coated fabric (18 µm)	0,0169	0,534	0,0315

According to the results, the coated fabrics showed higher thermal resistance and lower heat transfer coefficient values than the raw fabric. It was showed that, the particle size is an efficient parameter for cellulose powders used as filler material for thermal insulation.

4. CONCLUSION

Thermal isolation and energy efficiency are important and current topics and there are some studies to provide thermal insulation with textiles products. Coating is one of the best known methods for these applications. These pretrial results showed that, fabrics coated with cellulose powders have higher thermal resistance values than raw fabric as we expected. In further studies, different binder types will be used and effect of binder type on coating properties will be researched. Also, different filler materials that can be used as thermal insulators will be researched and tried.

5. ACKNOWLEDGEMENT

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THERMAL CHARACTERIZATION AND FLAMMABILITY OF POLYPROPYLENE FIBRES CONTAINING SEPIOLITE-APP

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Abstract: Polypropylene is a commonly used fiber forming polymer, however it burns rapidly. Polypropylene textiles used in transportation vehicles and public areas must be flame retarded in order to ensure safety requirements. Recently, efforts have been made to improve the fire behavior of polypropylene textiles by flame retardants using various techniques. Considering the major challenges in flame retardant application for textiles those are; the deterioration of mechanical properties due to the high loading of additives and washing durability, melt compounding approach has been employed in this study. An ammonium polyphosphate based intumescent flame retardant was successfully used with Eskişehir sepiolite –a hydrated magnesium silicate with a needle-like structure- to improve the fire resistance of polypropylene. The thermal stability of flame retarded polypropylene has been evaluated by thermal-gravimetric analysis. The flammability of polypropylene has been measured in terms of limit oxygen index and cone calorimeter tests.

Keywords: polypropylene, intumescent, flame retardant, sepiolite, phosphorus

1. INTRODUCTION

Polypropylene (PP) has been widely used in textiles thanks to its high tensile strength and low-cost features, however it burns rapidly, without leaving a char residue due to its wholly aliphatic carbon structure [1]. Flame retardant (FR) materials such as halogenated, phosphorus and metallic compounds have been used to increase flame retardant properties of polypropylene. However due to the environmental and health concerns the use of halogenated flame retardant materials, in particular, is limited [2]. Therefore there is an increasing demand for the development of novel and efficient flame retardant systems. Intumescent flame retardant (IFR) systems have been considered as alternative flame retardants for polyolefins due to their low smoke generation, low release of toxic gases and anti-dripping properties [3]. However, relatively low flame retardant efficiency of IFR systems require the use of more additives which may further impair the mechanical properties of materials that is a major concern for textile applications in particular. Various clays have been reported to improve flame retardant efficiency and the mechanical properties of IFR-PP formulations [4]. In this study the effects of Eskişehir sepiolite on fire retardant behavior of various IFR-PP formulations were investigated.

2. MATERIAL AND METHOD

2.1. Preparation of FR polypropylene samples

Ammonium polyphosphate (APP) based IFR (Exolit AP 760, Clariant) and Eskisehir sepiolite were used to increase flame retardant properties of isotactic PP. Eskisehir sepiolite was wet-milled by planetary mill using ethanol as the dispersing medium, then ethanol was removed by evaporation under vacuum. APP/sepiolite/PP mixtures were compounded by a twin-screw extruder operated with a constant temperature profile of 170°C and molded by injection. A total FR content (APP/sepiolite) of 20 wt% in PP and various proportions of sepiolite (1 wt%-10 wt%) in FR formulation (APP/sepiolite) were studied (Table 1). Maleic anhydride grafted polypropylene (MAPP, Sigma Aldrich) was used to improve the compatibility of sepiolite and PP matrix.

Table 1. Sample compositions

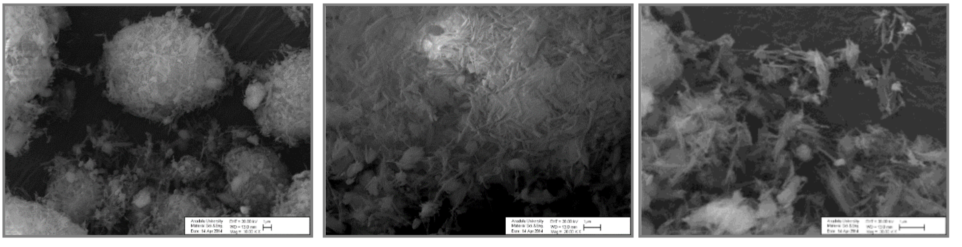
SAMPLE ID	PP wt %	MAPP %	Sepiolite wt %	APP wt %
Reference	100	-	-	-
PP/IFR20/SEP1	80	-	0.2	19.8
PP/IFR20/SEP2.5		-	0.5	19.5
PP/IFR20/SEP10		-	2	18
PP/IFR20		-	-	20
PP/MAPP/IFR20	75	5	-	-
PP/MAPP/IFR20/SEP2.5	75	5	0.5	19.5

2.2 Characterization of sepiolite and evaluation of fire behavior of PP/FR samples

Particle size measurement was performed using a zetasizer (Malvern, NanoZS 3600). Morphologies of the samples were analyzed by SEM (Zeiss Supra 50VP) and the following elemental analysis (EDX Oxford Instruments Inca Energy) were performed. Flammability was measured according to ASTM D2863 in terms of limit oxygen index using a LOI test apparatus (Dynsco). Time to ignition (TTI), heat release rate (HRR) and peak heat release rate (pHRR) of the samples were measured by cone calorimeter (Fire Testing Technology, FTT). Thermogravimetric analysis were performed by TGA/DSC (TA Instruments Q600) up to 1300°C under N_2 flow, and simultaneous FTIR analysis (Bruker Tensor27) were performed where the principal mass loss was observed.

3. RESULTS AND DISCUSSION

Sepiolite powder with a homogenous size-distribution was successfully produced by wet milling process. SEM micrographs at various magnifications confirmed the needle-like structure of sepiolite particle.



a) b) c)

Figure 1 SEM micrographs of sepiolite at different magnifications

LOI value of neat PP (19%) increased to 28% by the addition of 20 wt% APP and increased further to 32.2 % when 2.5 wt% APP was replaced by sepiolite in FR formulation. The degradation of reference PP sample initiated at about 400°C and the material was almost fully decomposed at 500°C. Even though the onset temperature of decomposition was lower for the sample (PP/IFR20/SEP2.5), a more stable residue was produced at the decomposition temperature of the reference PP. Evolved gases produced where the major mass loss was observed for samples were qualified by FTIR analysis. The major gases produced by the thermal decomposition of PP/IFR20/SEP2.5 are listed in Table 2.

Table 2. Results of the evolved gas analysis by FTIR for sample PP/IFR20/SEP2.5.

Compound Name	Molecular Formula	Molecular Weight
2,4-Dimethyl-1-heptene	C_9H_{18}	126.24
3-Ethyl-2-methyl-1-pentene	C_8H_{16}	112.22
Pentane,3-methylene-	C_6H_{12}	84.16
2,3-Dimethyl-1-butene	C_6H_{12}	84.16
2,3-Dimethyl-1-hexene	C_8H_{16}	112.22

4. CONCLUSION

Eskişehir sepiolite has been successfully used to improve the fire performance of IFR system as confirmed by the LOI and cone calorimeter measurements. When MAPP was added to replace 5 wt% PP, the fire resistance was further improved. Such increase was attributed to the formation of ester bonds between hydroxyl groups of sepiolite and anhydride carbonyl groups of MAPP. Therefore MAPP itself has no or little effect of fire retardancy of polypropylene but it enhances the LOI by providing a more homogenous distribution of additives in the polymer [5].The decomposition behavior of flame retarded polypropylene samples have been investigated by TGA and compared to neat polypropylene. The PP/IFR/SEP2.5 has been presented as an effective flame retardant for the production of flame retardant polypropylene fibers.

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WATER REPELLENCY PROPERTIES OF COTTON FABRIC TREATED WITH STEARIC ACID AND SILANES MODIFIED ZINC HYDROXIDE

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Abstract: In this research, colloidal zinc hydroxide (CZHs) were prepared and modified with stearic acid. Modified CZHs were added to nanosols containing vinyltrimethoxysilane (VTEOS), glycidyloxypropyltriethoxysilane (GLYEO) and phenyltriethoxy silane (PTEOS) together with tetraethoxysilane (TEOS) as precursor to increase the their adhesion to cotton fabric. Then the cotton fabrics were treated with these solutions by pad-dry-cure process. It was investigated water repellency properties of cotton fabric samples, their washing durability and inherent properties as whiteness, tear strength and bending length. Microstructural and structural properties of fabric samples were analyzed by scanning electron microscopy and FTIR-ATR spectrometer respectively.

Keywords: Sol-gel technology, superhydrophobic surfaces, silanes, zinc hydroxide, cotton fabric.

1. INTRODUCTION

Recently, there are a lot of researches about using ZnO for producing superhydrophobic surfaces [1-13]. It was carried out hydrophobic modification of ZnO films with long chain fatty acids and their sodium salts [1-7, 13]. Wu et. al. investigated wettability of ZnO surfaces modified with different alkanoic acids and produced stable superhydrophobic surfaces with modification with fatty acids whose chain length was higher than 16 [3]. In other research, it was found that stearic acid passivated zinc oxide nanotowers provide superhydrophobicity with high contact angle as 173^o [4]. Badre et. al. prepared superhydrophobic surfaces by electrodeposited ZnO films treated with fatty acid molecules as stearic acid, oleic acid and elaidic acid [6]. Badre et. al. created electrochemically deposited ZnO nanowire array film and then modified with stearic acid. The contact angle value of the film was 176^o [7]. Lakshmi and Basu have used stearic acid modified ZnO nanoparticules in sol-gel matrix containing methyltriethoxysilane together with tetraethyltriethoxysilane (TEOS) for producing superhydrophobic surfaces [1]. In this research, CZHs were prepared and modified as Ref. 1 and were treated with nanosols containing VTEOS, GLYEO and PTEOS together with TEOS as precursor to increase the washing durability of the fabric samples treated with these solutions. The water repellency properties of cotton fabrics treated with these solutions, their washing durability were evaluated.

2. MATERIAL AND METHODS

2.1. Materials

It was used zinc sulphate, sodium carbonate, sodium hydroxide, distilled water, stearic acid to prepare modified CZHs and TEOS, VTEOS, GLYEO and PTEOS as precursors and hydrochloric acid for acidic hydrolysis to prepare nanosols in this study. Scoured and bleached 100 % plain-weave cotton fabrics (weight 110 g/m^2, 22 picks/cm, 32 ends/cm) as substrate were used in this research. All experiments were carried out for two times.

2.2. Water Repellency Coating Process

In first step, 50 ml zinc sulphate solution (0.1 M) was taken to 2 neck glass flask with condenser and heated to 70 ^{o}C in water bath on magnetic stirrer. 50 ml sodium carbonate solution (0.1 M) and 50 ml sodium hydroxide solution (0.1 M) were added to the solution at 70 ^{o}C by dropping funnel and the solution was stirred during 30 min. Deposited zinc hydroxide was centrifuged and washed with distilled water and ethanol to remove over reagents and side products. Obtained white CZH residues were dispersed in ethanol and 20 ml colloidal suspension was prepared. The suspensions were alleviated to 5 ml and evaporated at room temperature.

In second step, the modification of CZH powders was carried out by adding 3 ml ethanol and 2 ml stearic acid solution (3.5% w/v in ethanol) with CZH colloidal suspension and then the solution was stirred during 2 hours. Swelling process of CZH was performed thanks to transformation of surface hydroxyl groups of voluminous stearate. After hydrophobic modification, excessive stearic acid was removed from modified CZH suspension by repeated centrifuging and washing with ethanol. Modified colloidal suspension was evaporated at room temperature during a few hours.

In third step, 2.24 ml TEOS and 2 ml VTEOS (S1 recipe), GLYEO (S2 recipe) or PTEOS (S3 recipe) were solved in 2.28 ml ethanol to prepare nanosols. 0.72 ml HCl solution (0.01 M) was added nanosols to acidic hydrolysis and then stirred during 24 hours. The prepared nanosols were diluted with 7.2 ml ethanol and stored in closed glass bottle. CZH suspensions (in 5 ml ethanol) to certain volumes of nanosols (75%:25% v/v of nanosol:CZH suspension) were added and stirred for 30 min. The fabric samples were padded (90% pick up) with the solution and dried at 80 ^oC for 1 hour.

3. RESULTS AND DISCUSSIONS

The add-on values of the fabric samples were changed from 7.56% (S2) to 12.61% (S3) which is reasonable owing to coating textile materials. It is clear from Table 1 that the treated fabric samples have higher contact angle values from 143^o to 154^o before washing process. Prior to washing, the highest contact angle values as 154^o were obtained for S3 fabric samples treated with nanosols containing PTEOS as precursor. However the fabric samples lost their water repellency properties after washing process except for S2 fabric samples treated with nanosols containing GLYEO as precursor. Thus the fabric samples treated with nanosols containing GLYEO as precursor have the durable superhydrophobic properties. It should be on account of the crosslinking effect of GLYEO.

4. CONCLUSIONS

In summary, ZnO is one of substantial functional materials with remarkable characteristics. Production of ZnO nanostructures have been carried out by different methods in literature. There are a lot of researches about developing superhydrophobic surfaces by modification of ZnO surface on various substrates. In this research, improving durable superhydrophobic surfaces by sol-gel process of modified ZnO with stearic acid on cotton fabric was investigated. In sol-gel process, it was used VTEOS, GLYEO and PTEOS as precursors together with TEOS and the durable superhydrophobic surface on cotton fabric was obtained for using GLYEO as precursor. Moreover their inherent properties did not significantly get worse.

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2BFUNTEX : TRANSFER OF INNOVATIONS IN FUNCTIONAL TEXTILES TOWARDS INDUSTRY

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Abstract: 2BFUNTEX is a 4-years FP7 European Coordination Action which started on 1st January 2012. The objective is to bring together all innovation actors in the field of functional textile structures and textile related materials, fostering a multidisciplinary approach between universities, research institutes, industry (especially SMEs) and sector associations. The 2BFUNTEX international team aims to identify technological gaps and eliminate barriers resulting in a faster industrial uptake of functional materials with new functionalities and improved performance. Technological needs are being mapped, new joint international research disciplines are identified and multidisciplinary teams have been created. Training materials for research and industry purposes are being elaborated and implemented, increasing the number of well-trained people in this field. Multidisciplinary teams that collaborate along a specific research topic will play a key role. Through the development of an interactive website with an extensive database, collaboration will be boosted and rapid industrial uptake catalysed and enhanced.

Keywords: functional textiles, coordination action, industrial uptake, multidisciplinary teams, linking innovation actors

1. INTRODUCTION

2BFUNTEX aims at developing a platform for current and future actions in research, education and technology transfer in the field of functional textile structures and textile related materials to support the textile industry in the most efficient and effective way to transform into a dynamic, innovative, knowledge-driven competitive and sustainable sector. 2BFUNTEX will be a platform for all innovation actors involved in European projects including interested companies not yet active in the field and users.

The 2BFUNTEX main objective is to support research and industrial innovation actors, i.e. universities, research institutes along with industry, in their efforts to define joint research projects and actions in the above mentioned field.

Multidisciplinary teams have been created (a.o. on flame retardancy) oriented towards untapping the experienced potential related to functional materials, with the aim to enhance transfer of the vast knowledge available at universities and research institutes to industry and to favour rapid industrial uptake.

2. OBJECTIVES

The overall objectives of 2BFUNTEX comprise :

- **collection of all relevant information** related to ongoing research and activities in the field of functional textile structures and textile related materials using modern detection methodologies (such as the 2BFUNTEX website);
- **detection of synergies and gaps and the creation of project ideas** in the field of functional textile structures and textile related materials**.** The information received will be used to create project ideas to be elaborated in tangible project teams and concrete RTD projects to enable the effective technology transfer to industry;
- **development of an interactive database** with information on activities on functional materials. This is a tool box to find information on status of technology, people involved, contacts, etc.. In addition, ongoing projects can use the database as a portal for disseminating information and contacting targeted people;
- **provision of training and education** to increase the number of well-trained people who continue their (research) activities in functional materials related industry and to better train people already employed in industry;
- **a variety of dissemination activities**, such as : development of an interactive website (comprising the aforementioned database); distribution of written materials (brochures, photo book, …); publication of newsletters; visits to industry; organisation of and participation in conferences, workshops (for SMEs), brokerage events, training courses, …; participation at fairs and exhibitions;
- **creation of multidisciplinary teams (MDTs)** performing research in the field of functional materials and oriented towards industry aiming at the creation of new business worldwide. The final goal of 2BFUNTEX is to consolidate all information gained in solid collaborations between research and industry resulting in the enhanced identification of new functional materials and rapid translation of research ideas into industrial products.

3. MAIN RESULTS ACHIEVED SO FAR

An Open Innovation Platform (OIP) on functional textiles was created which is available via the project website www.2BFUNTEX.eu and includes several databases : on projects, technologies available (including equipment and testing facilities), events and trainings, and training materials. All researchers (from universities, research institutes and R&D centres in companies) are invited to register and upload information on their own current and future actions in research, education and technologies available.

On the Open Innovation Platform, industry (as well as researchers) can express their needs (e.g. new technologies, products, processes, testing, research partners, …), which are treated confidentially, in order to connect industry with available technologies or research capacities. For companies www.2BFUNTEX.eu will also be the place to visit to detect new technologies and business opportunities.

A bibliometric analysis of published literature was performed by the Austrian Institute of Technology (AIT), one of the 2BFUNTEX partners, to get an overview of research in the field of functional textiles. Topics were identified with their relation to each other, as well as top organisations, journals, cited references and other relevant information for each topic. Then a thorough investigation and identification of patents clusters in functional textiles and fibres was done. Bibliometric analyses were performed to map patents. The basic idea was to get an overview of 'hot' patent topics and applications in the domain of "functional textiles". The results are made publicly available on the 2BFUNTEX OIP in the section "Publications" and support the MDTs in selecting and developing their innovation ideas.

A database with the main tests according to standards, related to the determination of properties that should be applied in materials for textile applications, has been published on the 2BFUNTEX website, as well as an overview of 'Possibilities for eco-design concept in textile materials'.

Based on the collected training materials & training needs, six topics were identified for the development of course modules : smart textiles, nanotechnologies, electrospinning, sustainable materials, textile recycling and protective functional textiles. These 6 courses are also available on the 2BFUNTEX OIP.

Several successful scientific conferences were organised by the 2BFUNTEX partners and five 2BFUNTEX newsletters were published and widely disseminated across Europe towards main textile stakeholders, as well as published on the 2BFUNTEX website.

Eight multidisciplinary teams (MDTs) that collaborate along the following specific research topics were identified and set up : antimicrobial textiles, smart textiles, nanotechnologies, flame retardancy, biotechnologies, electrospinning, plasma and sustainable textiles. Each MDT is led by a research and an industrial team leader and will identify some tangible gaps between available technologies and medium to long-term industrial needs. All MDTs are also open to researchers and industrial persons from outside the 2BFUNTEX consortium.

4. CONSORTIUM

The 2BFUNTEX consortium includes 26 partners from 16 European countries. They represent a balanced mix between nationality (of great importance for the collection of information on national/regional projects, dissemination to local industry), technical expertise, market expertise, size (large enterprise and SME but also small research groups and large groups) and type (research institute, university, industry, SME). The full list of 2BFUNTEX partners is available on the 2BFUNTEX website.

An Industrial Advisory Board (IAB) is set up to validate the strategy and progress of the project and give information on the industrial needs in the field of functional textiles and textile related materials.

5. INFORMATION

More information is available via the website : http://www.2BFUNTEX.eu

Questions can be sent to the e-mail address : info@2bfuntex.eu

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