BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI

Tomul LIX (LXIII)

Fasc. 4

TEXTILE. PIELĂRIE

2013 Editura POLITEHNIUM

BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
PUBLISHED BY
“GHEORGHE ASACHI” TECHNICAL UNIVERSITY OF IAŞI
Editorial Office: Bd. D. Mangeron 63, 700050, Iaşi, ROMÂNIA
Tel. 40-232-278683; Fax: 40-232-237666; e-mail: polytech@mail.tuiasi.ro

BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
BULLETIN OF THE POLYTECHNIC INSTITUTE OF IAŞI
Tomul LIX (LXIII), Fasc. 4 2013

TEXTILE. PIELĂRIE

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LMS APPLICATIONS BASED ON OPEN SOURCE SOFTWARE IN THE STUDY OF TECHNICAL TEXTILES

BY

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Received: August 30, 2013
Accepted for publication: September 6, 2013

Abstract. The study of technical textiles requires the knowledge of many processing phases and phenomena. The traditional approach to teaching these processes has the disadvantage of a presentation largely of information, not directly corresponding to the real phenomenon. For this purpose the use of multimedia presentations is required for the connection between information and the described phenomenon. These presentations can be made in a classical manner, in the course room, but for better understanding one can use different e−learning systems. The goal of this paper is to present an LMS (Learning Management Systems) based on open source software that can be applied to study the processes of obtaining technical fabrics. This software can be used to create interactive lectures. Training lectures may be generated in the style of the classic lecture, but can be presented within a web page. The teacher can use the same course, a number of pages that the student can learn according to his needs. He can attach multimedia or can refer to existing material on the Internet. The lecture can be saved in different formats, so it can be loaded on an e−learning platform. Xerte is an e−learning environment created by authors at Nottingham University; it provides open source tools making it easy for both technical and non technical content authors to create very interactive learning resources.

Key words: technical textiles, LMS, open source, e−learning.

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This paper is the full version of the paper published in abstract only at Technical Textiles – Present and Future Symposium, Iaşi, October, 2013

1. Introduction

A field description of engineering training in distance education allows us to test the interaction paradigm in current social realities. The training engineer's work is about tuning software to provide undergraduate students with a virtual learning method. It therefore appears to confirm the interaction paradigm: learning is a dynamic of human actions and software reactions, similar to a serious game in a virtual world. But the course's final assessment through a case study reveals the limits of the interaction paradigm. This complex problem, based on real−life situations, is rather seen as a "mental experience" by the very professionals working in this educational institution. We therefore put aside the interaction paradigm to take into account cognitive realities stressed by the training engineers' pedagogical activity (http://halshs.archives−ouvertes.fr/docs/00/77/65/81/PDF/distance_education_engineering.pdf).

E−learning is a very important movement in the field of learning and teaching, it plays a big role in modern education, it is the subject of many investigations and many have developed theories and ideas on how to properly implement E−learning materials in environments which prove beneficial to both the learner and the teacher. Another 'up and comer' in the technology world is mobile applications, combining these two technologies is showing amazing potential. BBC Bitesize (http://bitesizerevision.pearson.com/) has already developed exciting learning possibilities with the use of iPhone applications, and it should only make sense that companies with prowess in interactive e−learning, such as Xerte, should follow suit and add a new dimension to their learning environments.

Authors at Nottingham University provide the open source tools Xerte. It is a standalone fully featured e−learning environment designed to allow the creation of rich interactive material for users who are familiar with scripting. Xerte Online Toolkits uses a server−based suite of tools designed to allow those who are not so familiar with scripting the ability to create interactive learning resources quickly through a web browser. Learning Objects created in Xerte by experienced scripter's can be used in the Xerte Online Toolkits environment by those less experienced in scripting. Xerte allows for collaboration via its 'Xpert' repository of Learning Objects, making it easy to share and re−use materials and providing those without knowledge of programming the chance to use powerful Learning Objects created by programmers. The Xerte project is currently being experimented with on a mobile platform, developing with the Xerte team on the mobile application is the route this project will take.

2. Material and Methods

Xerte is a suite of tools for the rapid development of interactive learning content. In developing Xerte the authors have sought to make it very easy to perform simple, common tasks, yet possible to do anything you want. Xerte seeks to provide a focus on the types of problems and situations that developers of interactive learning content encounter frequently. Xerte provides a visual, icon − based authoring environment that allows learning objects to be easily created with the minimum of scripting. Functionality that would be time consuming to develop from scratch in other tools can be created very quickly in Xerte (Tenney, 2011).

The Xerte interface is presented in Fig. 1.

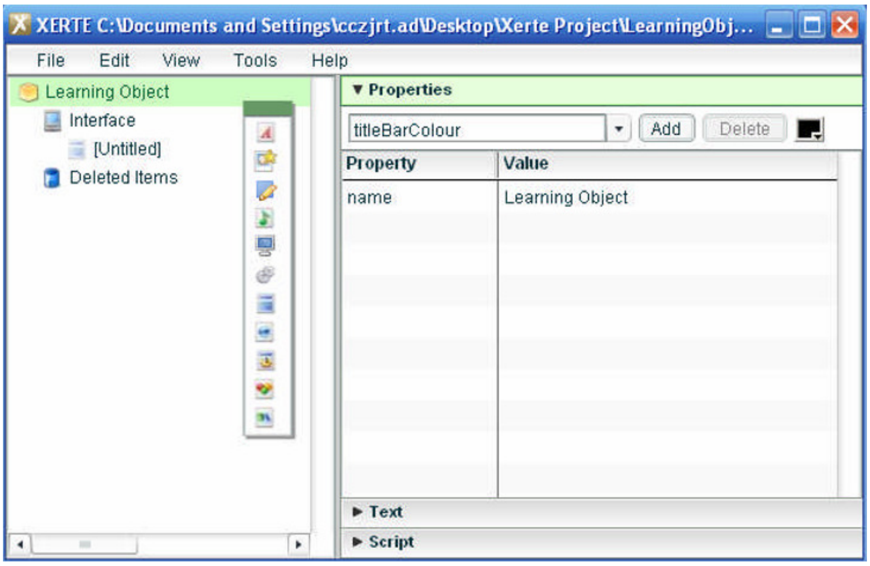

Fig. 1 – The Xerte interface.

On the left−hand side of the interface there is the document tree. It can construct a learning object by adding icons to this tree from the icon palette. There are eleven different types of icons. Some are used for adding media to a learning object, whilst others provide structure and interactivity. The icons are shown in the icon palette. To add icons to the tree you can:

− Drag the type of icon you want to add from the icon palette to the place in the document tree where you want to put the icon.

− Select the icon in the document tree to which you want to add a new icon and double click the type of icon you want to add in the icon palette.

− Right click the icon in the tree you want to add a new icon to, and choose the type of icon from the context menu.

3. Results and Discussions

The course of industrial technologies for technical textiles − woven fabrics is structured in the following areas: raw materials, the classification of yarns, the characteristics of yarns (warp and weft yarns) and technologies for the processing of them. This material is structured in several chapters which form individually “unit” in Xerte. Each project can be accessed by the students as many times as it requires deepening their knowledge. Checking the status of the learning process can be done with the aid of verification tests that may be of several types (true or false, multi−choice, etc.). The project of the course created in Xerte is saved as .rlo file and media folder. It allows the intervention of the teacher at any moment by adding multimedia content (important in understanding the technology) or making links to materials in other formats (.doc., .pdf, .ppt, etc.). The structure of a learning unit is presented in Fig. 2.

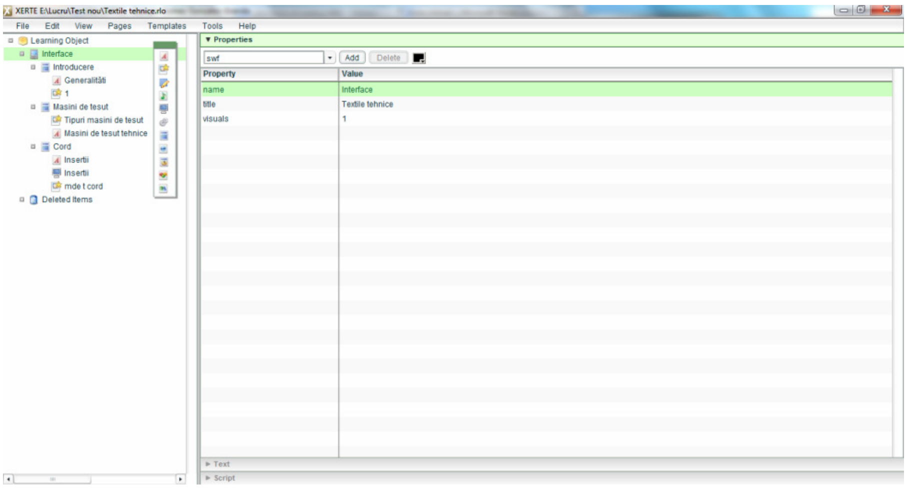

Fig. 2 – The structure of course unit.

The development of the learning process is carried out through a series of learning activities that are connected logically between them. Creating a course module involves adding a page in the document panel tree, with the module name. One can be adding different content by selecting the corresponding icon. Some icons are used for adding text or media, whilst others provide structure and interactivity. These icons are shown in the icon palette. The icons and pages can easily move around in the document tree by dragging and dropping them. Xerte will prevent the placement of icons where they do not belong. Icons have some mandatory properties, which must always be set and some optional properties which can be defined by the user. Optional properties are added from the drop−down list at the top of the properties inspector, which will show a list of the available optional properties.

The results of creating a course are presented in Fig. 3. It can be seen that in the same page text, images and movies can be added, in order to support the information presented in the course.

Fig. 3 – Page content.

The project can be published into a folder and you find all the files you need to deploy to the web server. It can be test the learning object and upload the files to a server, creating a link to rloObject.htm.

Xerte is a LMS and support SCORM 1.2 (Sharable Content Object Reference Model). Fig. 4 shows that the files (1) have .rlo extensions (2) that support the SCORM. This package contains all files required for upload into a SCORM−compliant system, such as WebCT, Dokeos or Moodle and zips into the zip file.

4. Conclusions

Standard teaching methods are falling behind new modern approaches, and it is important that teachers should keep up and integrate technology into their lessons (Bose, 2010).

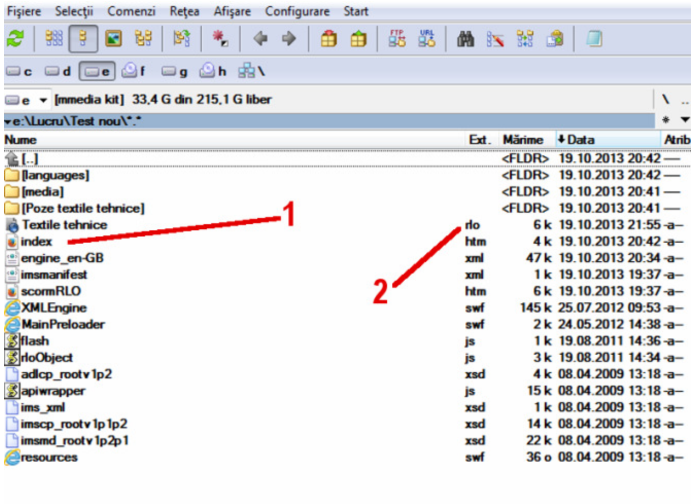

Fig. 4 – SCORM content package.

However, one of the main barriers for the increase of e–learning materials is the teachers themselves, who feel that integrating new methods into their lessons takes up too much time and training to be worthwhile (Hew & Brush, 2006).

Xerte is a LMS for developing interactive courses that can easily be used to produce content without doing any programming, but there are certain limitations. These limitations refer to fact that the user must possess a certain level of knowledge in programming using the ActionScript that are required when more sophisticated presentations and lectures are intended.

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APLICAȚII ALE LMS BAZATE PE SOFTWARE OPEN SOURCE ÎN STUDIUL TEXTILELOR TEHNICE

(Rezumat)

Studiul textilelor tehnice necesită cunoştinţe despre multe faze de prelucrare şi fenomenele ce se produc în acestea. Abordarea tradițională în predarea acestor procese are dezavantajul de a prezenta în mare parte informații care nu au corespondență directă cu fenomenele reale. În acest scop este necesară utilizarea unor prezentări multimedia pentru a crea legătura între informație şi fenomenul descris. Aceste prezentări pot fi făcute clasic, în sala de curs, dar pentru o mai bună aprofundare se pot folosi diferite sisteme de e−learning. Scopul acestei lucrări este de a prezenta un LMS (Learning Management Systems) bazat pe software open source, care pot fi aplicate pentru a studia procesele de obținere a țesăturilor tehnice. Acest software poate fi utilizat pentru a crea cursuri interactive. Cursurile pot fi generate cu o structură similară cu cea a cursului clasic, dar pot fi abordate ca o pagina web. Profesorul poate genera, în acelaşi curs, un număr de pagini, pe care studentul le poate studia în funcție de scopul sau nevoile sale. El poate ataşa materiale multimedia sau se poate referi la materiale existente pe Internet. Cursul poate fi salvat în formate diferite, astfel încât să poată fi încărcat pe o platformă de e−learning. Xerte este un sistem de e−learning open source, creat de autori de la Universitatea din Nottingham, oferind instrumente ce fac mai uşoară, atât pentru autorii cu pregătire tehnică sau cât şi pentru cei cu pregătire non−tehnică, crearea de resurse interactive de învățare.

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TEXTILE. PIELĂRIE

MOISTURE ABSORPTION CAPACITY AND PRINCIPAL MECHANICAL PROPERTIES OF SILK YARNS

BY

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Received: August 28, 2013
Accepted for publication: September 9, 2013

Abstract. High air permeability, hygroscopicity, mechanical properties are some characteristics of the silk yarns allowing their use in the field of modern technical materials. Thus, silk yarns offer the possibility of obtaining ecological products with new functional properties for use in medicine, for photonics, optoelectronics and high−technology. In the present paper moisture absorption capacity, principal mechanical properties of the yarns from silk (grege, degummed, dyed) are analyzed.

Key words: silk, force−extension curve, yarn, sorption−desorption.

1. Introduction

Moisture content for any modern composite is important (Zhang & Wyeth, 2007). Natural silk produced by the spiders, lepidoptera, with high mechanical properties, with particularly polymer structures, is bio−compatible, an excellent material for photonics, optoelectronics, for use in medicine and high−technology (http://users.ox.ac.uk/~abrg/spider_site/index.html/; Vollrath,

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This paper is the full version of the paper published in abstract only at Technical Textiles – Present and Future Symposium, Iaşi, October, 2013

2012). Silk as emitted by the silkworm consists of two main proteins, sericin 20−25% and fibroin 70−75% (Asandei & Grigoriu, 1983). Silk yarn consists of two filaments that are cemented together by silk gum or sericin. This protein has a protective role and o link one, giving to the silk filament yarn a coarse to touch. One, sericin is soluble in hot water, the other, fibroin, is not. A fundamental finishing process for silk yarn and silk fabric is the degumming. After degumming in hot water, the sericin is removed, leaving the silk brighter and softer (Vlad, 1964). Degummed silk is white, soft and flexible.

Due to its good permeability and light absorbing ability, silk is regarded as the "Queen of Fibers" (Mustață, 2005). Silk has excellent qualities of acoustic absorption, has the function of anti−ultraviolet radiation, dust absorption and strongly heat−resistant (http://www.travelchinaguide.com/intro/). In 1989, in Romania at Lugoj, a wide range of filament yarns and spun yarns from silk was being produced: Nm 12, Nm 60, 100, 140, 200 and twisted yarns with the doubling 2 or 3, (Manualul inginerului textilist, 2002; Ionescu−Muscel, 1990). The increasing of the silkworm was one of the occupations with long tradition in Romania. Since the XIVth century, this activity was recorded in almost all zones of our country. Production of the silkworm cocoons was 4000 tons in 1986 and over 12 800 tons in 1989.

In the last time, the researcher's efforts from the silk industry are directed to obtain materials that have environmental protective characteristics through to the end of their life cycle. Silk yarns, ecological, non−toxic and biodegradable materials, which absorb easily the humidity and burn without leaving residues are exploited in yarns for fabrics or knitting with the destination of technical clothing or items, multi−warped products such as: shoemaking thread.

The aim of this paper is the analysis of the moisture absorption capacity and principal mechanical properties of the yarns from silk, as justification of their modern fields of use.

2. Materials and Methods

The yarns investigated were filament yarns from silk (grege, dyed yarns, and bleached yarns). The water absorption in these types of yarns modifies their mechanical properties and it is important to know the transfer mode of these characteristics. There were measured the breaking strength of the filament yarns from silk in dry and in wet stage.

For the serial testing in wet stage, the yarns were stressed after 10 minutes moisten and their drying between two sheets of absorbent paper. For establishing the average quality characteristics were performed 30 measurements. Measuring of the breaking strength yarns was made according to ISO 2062 on TINIUS OLSEN H5 K−T yarn tester (UK) by automatic registering of the load–displacement curve. This device is in the M.Sc. laboratory of the Department of Technology and Design of the Textiles

Products. The initial length of the tested sample was 100 mm for silk yarns. The capacity of yarns deformation and their stability to support tensions were reflected by the diagrams of the load –extension. There were registered and studied five force – extension curves for each type of yarns.

Table 1 presents the coding for the studied yarns.

Table 1
Samples Coding Yarns

Types of analysed yarns	Sources of yarns and finishing way	Coding is similar to average of length density, T_{tex} (fineness, Nm)
Silk yarns	Filament yarn from grege	3 tex (Nm 333)
	Filament yarn from dyed silk	1 tex (Nm 1000)
	Filament yarn from degumming silk	2 tex (Nm 500)
	Multifilament yarn from degumming silk	25 tex (Nm 40)

Before starting the test, yarns have been conditioned to the standard conditions, (SR EN ISO 139/2005).

3. Results and Discussions

High mechanical properties of the degumming silk are reflected by the breaking strength over 40 cN for each filament $(8-15)x10^{-4}$ mm diameter. Filament yarn 2 tex from degumming silk tested in dry stage has 48.65 cN average breaking strength, 21% the coefficient of variation for the breaking strength and 7% the average elongation. Fig. 1 presents the force−extension curves for the 2 tex filament yarn from degumming silk, tested in dry state.

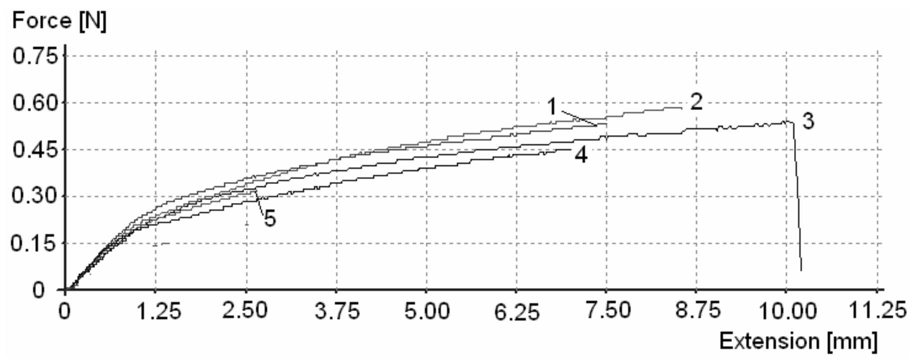

Fig. 1 − Force−extension curves of the 2 tex filament yarn, from degumming silk tested in dry state, curves: 1−5.

Multifilament yarn 25 tex from degumming silk tested in dry stage has 435.9 cN average breaking strength while the coefficient of variation for the breaking strength is 33% and the average elongation is 6%. The tenacity of this type of yarn ranges between 16−23 cN/tex, with 19.5 cN/tex as average value. Fig. 2 presents the force−extension curves of the 25 tex multifilament yarn, from degumming silk tested in dry state.

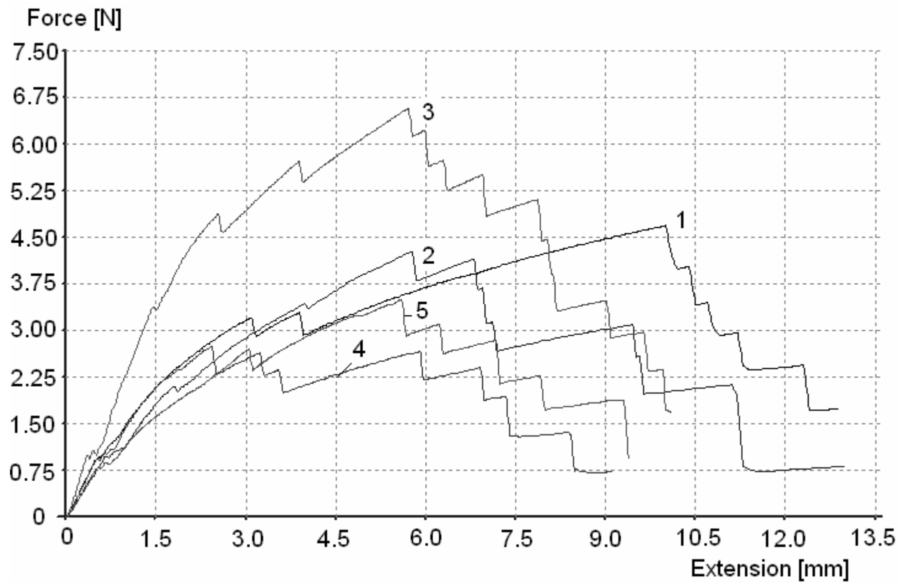

Fig. 2 − Force−extension curves of the 25 tex multifilament yarn, from degumming silk tested in dry state, curves: 1−5.

The high hygroscopicity of the silk yarns influences their mechanical characteristics. Thus, the behaviour of the silk filament yarns at breaking in dry and wet state was monitored.

Figs. 3 and 4 present the force−extension curves of the yarns tested in dry state and in wet state, after 10 min of moistening.

For the filament yarn 3 tex extracted from grege yarns the decrease of the tensile breaking strength in wet state is about 12% in comparison with the resistance obtained in dry state (Fig. 3). The tenacity of this type of yarn, in wet state, is reduced by 44%, while the length density increases over 45%.

The strength of the dyed silk decreases with about 10% in wet state and its tenacity decreases with about 36% in wet state (Fig. 4). In the same time, the length density of the filament yarn increases from 1 tex to 1.6 tex.

Moisture absorption capacity of the yarns for fabrics or knitting has a direct impact on the comfort level and on the mechanical properties (Mustaţă & Potop, 2011; Mustaţă & Racu, 2007).

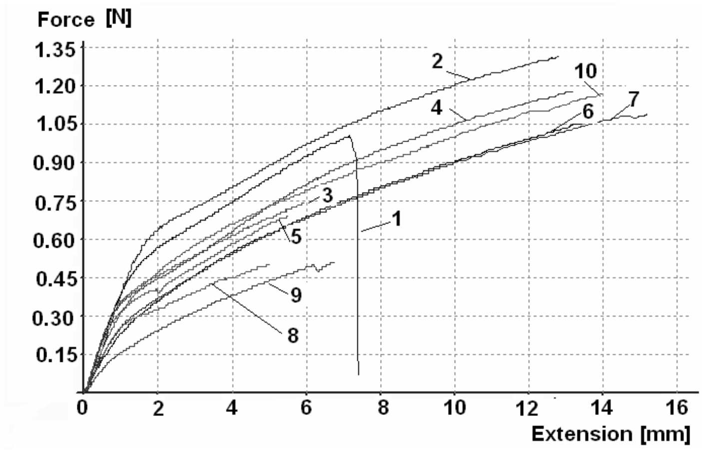

Fig. 3 − Force−extension curves of the silk filament yarn 3 tex, from grege tested in dry state, curves: 1−5 and in wet state after 10 min in water, curves 6−10.

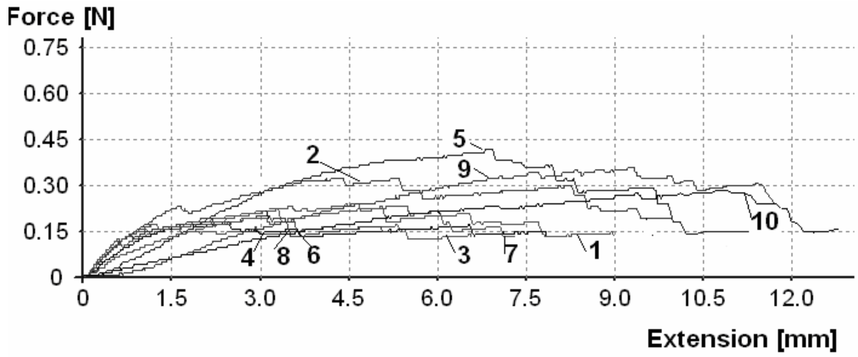

Fig. 4 − Force−extension curves of the silk filament yarn 1 tex, extracted from coloured weave tested in dry state, curves: 1−5 and in wet state after 10 min in water, curves 6−10.

The percentage of water absorption for the silk yarns was calculated by weight difference between the samples immersed in water and the dry samples, (Mustaţă, 2010; Manualul inginerului textilist, 2002), using the following equation:

$$\Delta M(t) = \frac{m_t - m_0}{m_0} \cdot 100 \tag{1}$$

where: $\Delta M(t)$ is moisture uptake, m_0 and m_t are the mass of the specimen before and after drying, respectively.

For the grege yarns the maximum water content is about 200%, see Fig. 5. This high value of water absorption of the silk yarns could be attributed to the chemical structure of these yarns. The maximum water absorption degree for dyed silk yarns was obtained after an interval of stationary in water for 15 min.

The filament yarn from the degumming silk has reached the maximum water absorption degree after 10 min of wetting.

Hygroscopicity is different for the grege yarns, degumming silk and coloured silk, as seen in Fig. 5. This means that natural pigments and sericin, substances on the silk yarns influence significantly hygroscopicity. Thus, the water sorption speed is different in these three cases.

Maximum water degree absorption coincides with the saturation of hydroxyl groups situated on the macromolecular chain of silk (Fibroin & Sericin) to the grege yarns, degumming and dyed silk yarns.

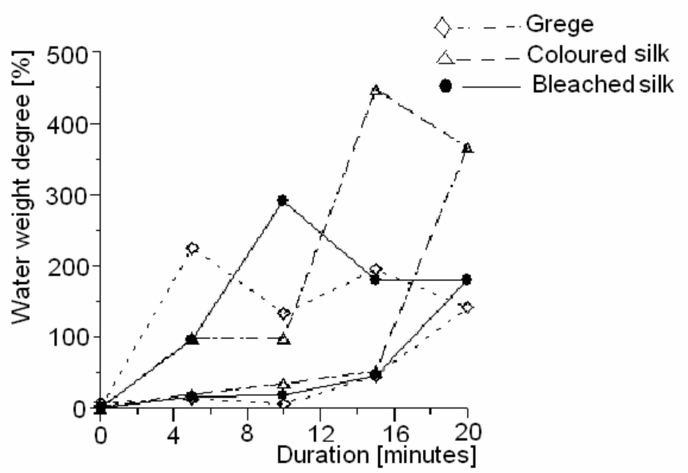

Fig. 5 − Sorption – desorption curves of the filament silk at 28ºC temperature and 35% relative humidity.

The desorption process was monitored at ambient temperature until balance was reached. The samples were weighed every five minutes until the quantities of water absorbed and transferred were equal and constant. In order to determine the sorption−desorption balance, the entire water absorbed by the silk filament yarns is removed by drying at 28ºC temperature and 35% relative humidity in 20 min. The desorption is slower, to limit state of equilibrium (Fig. 5). Silk yarns lost about 80% of moisture content, during the first 5 min of drying in air at 28ºC ambient temperature and 35% relative humidity. Then, after each interval of 5 min of drying, the decrease is by 5−10% of the water content of silk yarns.

The silk yarns hygroscopicity has a direct impact on the amount of water in woven fabrics, as well as on their main physical and mechanical characteristics. In order to maintain the normal behaviour for silk products used in high humidity environments for a longer duration, the detailed knowledge of the complex phenomenon of sorption−desorption of water and its influence on the product characteristics is required.

4. Conclusions

Hygroscopicity and the finishing process of the silk yarns (degumming and dyeing) affect their mechanical characteristics.

High strength of the silk yarns in dry and wet state, together with fineness, hygroscopicity and the bio−compatible structure of the constituent polymer justify the use of the silk yarn in medicine and other high−tech destinations.

The excellent properties of the silk, as well as the fact that it is a Romanian native and traditional raw material that has existed for centuries are some arguments in favour of the investments for development of the silk industry.

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CAPACITATEA DE ABSORBȚIE A UMIDITĂȚII ŞI PRINCIPALELE PROPRIETĂȚI ALE FIRELOR DE MĂTASE NATURALĂ

(Rezumat)

Permeabilitatea ridicată la aer, higroscopicitatea, proprietățile mecanice deosebite sunt câteva caracteristici ale firelor de mătase naturală care recomandă folosirea lor în materiale tehnice moderne. Astfel, mătasea naturală oferă posibilitatea obținerii de produse ecologice cu noi proprietăți funcționale pentru utilizarea în medicină, pentru materiale fotonice, optoelectronice şi de înaltă−tehnologie. În această lucrare sunt analizate capacitatea de absorbție a umidității şi principalele proprietăți mecanice ale firelor din mătase naturală crudă, degomată, vopsită.

BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LIX (LXIII), Fasc. 4, 2013
Secţia
TEXTILE. PIELĂRIE

A STUDY REGARDING THE HEAT TRANSFER IN WOVEN FABRICS COATED WITH CARBON BLACK PARTICLES

BY

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Received: August 30, 2013
Accepted for publication: September 16, 2013

Abstract. In this paper, heating textile fabrics obtained by the method of coating carbon black particles onto woven cotton fabrics were tested in standard environmental conditions (22 ± 2°C, 65 ± 2% RH) in order to characterize the heat transfer of these samples. The heating fabrics have inserted stainless steel yarns into the warp and the weft. The experiments are focused on measuring the temperature of a glass filled with water which was put on top of the heating fabric. The heating fabric is connected to a power supply (6 V, 9 V and 12 V). The time required for heating the sample to warm the water is between 10−30 min. The maximum temperature achieved is 50°C for an applied voltage of 12 V, corresponding to a percentage value of 18.6% of carbon black particles in the conductive mixture. The voltage values were selected considering that for an application in the field of heating, such as a heated jacket, it can have removable batteries embedded that can be recharged and can be bought from the market. The increase of the temperature of the water, which is heated using a power supply, is important for further suitable applications of the samples. A possible application is to use these heating flexible fabrics into blankets, heating bags, gloves, etc.

Key words: conductive textiles, heating fabrics, conductive yarn.

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This paper is the full version of the paper published in abstract only at Technical Textiles – Present and Future Symposium, Iaşi, October, 2013

1. Introduction

Textiles are structures with good properties: they are flexible and mechanically stable. Controlled conductivity is one of the challenges of electro−textiles, different materials and ways of processing being available: carbon black, some metals and recently conductive polymers are currently engineered in the market as fibers, yarns, pastes, etc. (Ramachandran & Vigneswaran, 2009; Akbarov *et al.*, 2005; Akbarov *et al.*, 2006; Dall Aqua *et al.*, 2004; Dietzel *et al.*, 2000; Kuhn *et al.*, 1994; Gregory *et al.*, 1992), that could be applied to fabrics by different standard techniques: weaving, knitting, coating, laminating, printing, etc. (Dhavan *et al.*, 2004a; Kurt, 2006; Locher & Tröster, 2007). Some of these techniques are not versatile enough to achieve stable and homogeneous conductive tracks or surfaces with a predefined geometry. Mainly some attempts have been made to create conductive paths with high conductivity by weaving monofilament conductive metal yarns (Dhavan *et al.*, 2004b) and recently other attempts involved techniques used in printed flexible electronics on fabrics by using conductive inks or pastes (Negru *et al*., 2012).

The fields of applications of conductive fabrics are very different, one of the applications consist in using these electro-conductive fabrics in the field of heating, for heating car seats, divers suits, heating blankets, heating boots, gloves, etc. (Bhat *et al*., 2006; Hakansson *et al*., 2004).

Conductive fibers and yarns allow flowing of electric current. There are raw materials that exhibit specific electrical properties which are maintained throughout the production process, for example yarns with metallic content of stainless steel (chromium, nickel and iron), so the material can support perspiration and can be washed. Yarns and metal filaments of brass, stainless steel, aluminum, copper or nickel are currently used for obtaining conductive fabrics, especially given the role of electronic circuits embedded components in woven fabric (Post *et al*., 2000), due to the following advantages: low costs of production, can be bought easily, good strength, biologically inert and possesses good electric conductivity.

Fields of application of electro-conductive fibers or filaments are:

− antistatic: rugs and protective clothing, which prevent the static electricity charge; heating: in automotive industry for seat heating, the warming costumes used by the divers; warming blankets for horses requiring infrared therapy after injury; warming bikers costumes; warming boots and gloves for the skiers;

− explosion−proof: electro-conductive fibers can control sparks and avoid for example explosions in dust filters or bulk containers;

− electrical conductivity: when using electro-conductive fibers the flexible character of fabrics can be kept;

− production processes: woven metal materials are used in production processes must offer resistance, on the one hand at high temperatures and on the other hand against mechanical forces.

Carbon particles are generally used as the matrix polymer fillers or as a main component of solutions that can be deposited on textile surfaces. When an electric current flows through a solid or liquid with finite conductivity, electric energy is converted to heat through resistive losses in the material. The Joule heating effect is in some cases unwanted, and efforts are made to reduce it. However, many applications rely on Joule heating; some of these use the effect directly, such as cooking plates, heating flexible fabrics embedded in blankets, heating bags, gloves. This paper focuses on the use of layers to carry power over clothing by coating conductive layers based on carbon black on textile fabrics.

2. Materials and Methods

The experiments for obtaining conductive fabrics by the method of coating with solutions based on carbon black were made in the laboratory GEMTEX from ENSAIT, Roubaix, France.

The main materials used in this paper are the textile fabric, the conductive solution based on carbon black (CB), and the stainless steel (SS) yarns. The fabric is made of cotton yarns. The electrical circuit which provides power supply of conductive fabric consists of stainless steel wires, which are placed both in the warp direction and the weft direction, as it can be seen in Fig. 1.

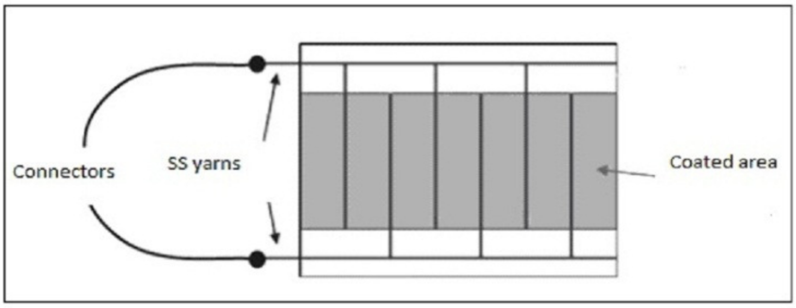

Fig. 1 – The schematic representation of the fabric with stainless steel yarn inserted and coated with carbon black solution.

The sample of the fabric is coated with the conductive solution, ensuring electrical conductivity to the entire fabric. The coating process was performed using a magnetic print device, used in industry for printing various patterns on fabrics or knits.

The fabric is placed on a magnetic board and a rectangular template is placed on top of the fabric; the conductive solution is spread using a metal cylinder that moves under the action of magnetic forces when the device is starting. The coated samples are then dried in the conditioned room for 24 h.

A 50 mL beaker filled with water was placed above the fabric. Due to the Joule effect, the surface of the conductive fabric was heated, interesting being the fact that the fabric radiates enough warmth to heat also the water container.

3. Results and Discussions

The samples of plain weave fabric with stainless steel yarns coated with conductive carbon black particles were investigated from the carbon black percentage point of view (Negru *et al*., 2012). Conductive fabrics were characterized by measurements of electrical resistance and temperature at different voltage values between 3 and 12 V, under standard conditions of temperature and humidity (room temperature 22 ± 2°C, relative humidity 65 ± 2%). In Table 1 are shown the mean values of the temperature of the water after a period of 30 min. The water temperature was measured with a thermometer with mercury. 10 temperature measurements were made for each sample, for values of the electrical voltage applied to 6 V, 9 V and 12 V.

Table 1
The Mean Values of the Temperature of the Water

Voltage (V) / CB (%)	6V	9V	12V
10.42%	21°	22°	23°
15.25%	24°	32°	42°
16.27%	25°	36.5°	50°
17.84%	28.5°	42°	48°
18.7%	29.5°	40°	50°

The percentage of CB in the coating mixture is different, with values between 10.42% and 11.6%. The conductive fabric samples were connected to a source of electric current through two warp threads from stainless steel and supplied with electrical voltage with values of 6 V, 9 V and 12 V. Above the fabric was placed a 50 mL beaker filled with water. Due to the Joule effect, the surface of the conductive fabric was heated, interesting being the fact that the fabric radiates enough warmth to heat also the water container.

In Fig. 2 it can be seen that the maximum temperature achieved is 50°C for an applied voltage of 12 V, corresponding to a percentage value of 18.6% of CB particles in the conductive mixture. Electrical mains voltage values were chosen in the idea that for an application in the field of heating, such as a heated jacket, it can have removable batteries embedded that can be recharged and can be bought from the market.

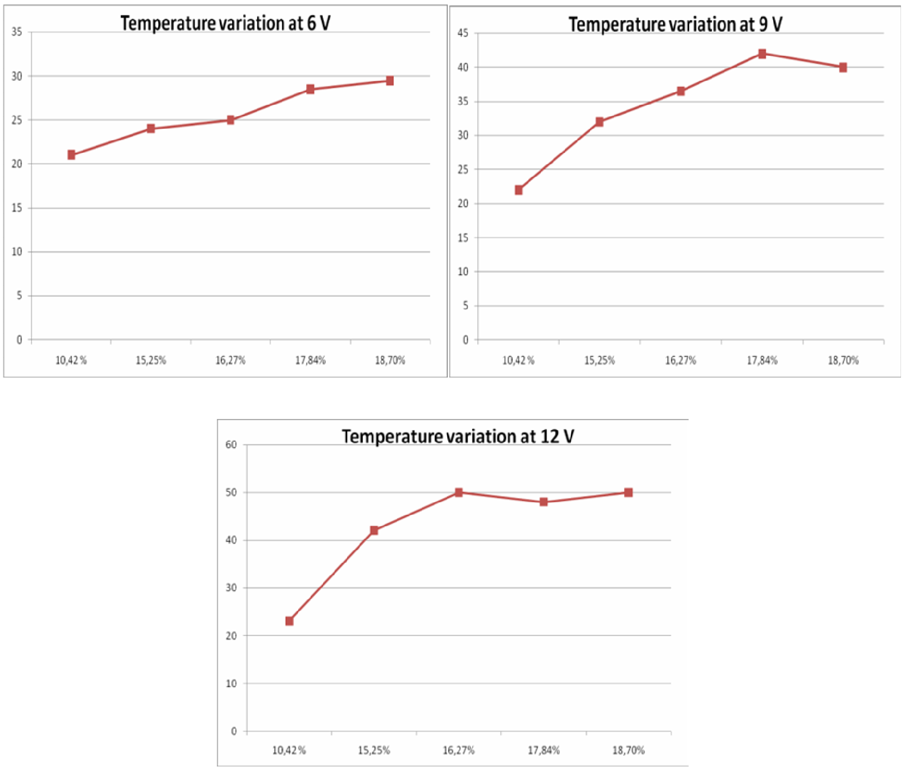

Fig. 2 – The variation of the temperature achieved at 6 V, 9 V and 12 V for different concentrations of CB particles.

The heating process is rapid, approximately 10 min to heat the fabric. In the process of measurements it can be observed that the temperature is not homogenous; the temperature is big in the centre of the sample and is decreasing on the sides (corners). The results are satisfactory for at least 16% CB percentage at 12 V, considering that the external temperature is 22°C. After approximately 120 min, the heating is reaching the maximum value and the temperature of the water remains constant.

A possible application is to use a flexible fabric heating element that can be integrated into a protective garment to ensure the necessary heat in those parts of the body they need, such as middle or extremities.

Acknowledgements. The authors would like to thanks to GEMTEX Laboratoires, ENSAIT from Roubaix, France where the samples were produced and the measurements were carried out.

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STUDIU PRIVIND TRANSFERUL DE CĂLDURĂ ÎN ȚESĂTURI ACOPERITE CU PARTICULE DE CARBON NEGRU

(Rezumat)

În această lucrare materiale textile de încălzire obținute prin metoda acoperirii cu particule de carbon negru a țesăturilor din bumbac au fost testate în condiții de mediu standard (22 ± 2°C, 65 ± 2% HR) pentru a caracteriza transferul de căldură al acestor probe. Țesătura conductivă de încălzire are introduse în urzeală şi bătătură fire din oțel inoxidabil. Experimentele sunt axate pe măsurarea temperaturii unui pahar plin cu apă care a fost pus pe țesătura de încălzire. Țesătura de încălzire este conectată la o sursă de alimentare (6 V, 9 V şi 12 V). Timpul necesar pentru încălzirea apei din recipient este între 10−30 min. Temperatura maximă atinsă este de 50°C pentru o tensiune aplicată de 12 V, corespunzând unei valori procentuale de 18,6% a particulelor de carbon negru din soluția conductivă. Valorile tensiunii de alimentare au fost alese în ideea că pentru un obiect de îmbrăcăminte cu încălzire, cum ar fi o jachetă, aceasta poate avea baterii încorporate care pot fi reîncărcate şi pot fi cumpărate de pe piață. Creşterea temperaturii apei, care este încălzită folosind o sursă de alimentare, este importantă pentru stabilirea unei destinații precise şi adecvate a mostrelor. O aplicație posibilă este de a utiliza aceste materiale flexibile de încălzire în pături, şosete, mănuşi, etc.

BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LIX (LXIII), Fasc. 4, 2013
Secţia
TEXTILE. PIELĂRIE

DIVERSIFYING THE TYPES OF FLAX YARNS BY HEAT−SETTING

BY

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Received: August 26, 2013
Accepted for publication: September 10, 2013

Abstract. In recent years, new areas of use of flax fibres are developed, industry specialists focusing on new generations of materials which include natural fibres in their composition. The paper presents the results of the researches which aimed at the possibility of carrying out new flax type yarns, in order to highlight the quality and properties offered by natural fibres in the blending. There are presented the manufacturing technology used to obtain the thermal−treated yarns and the mechanical and physical characteristics of the yarns, analyzed in terms of the influence of thermal moistening treatments.

Key words: flax, wet spinning, heat treatment, yarn characteristics.

1. Introduction

At present, specialists in flax industry and research focus on new generation of materials that ensure environmental protection by the end of their life cycle. Global concerns about the future of our planet become a unique opportunity to promote flax, which due to its ecological properties gives

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This paper is the full version of the paper published in abstract only at Technical Textiles – Present and Future Symposium, Iaşi, October, 2013

performance and competitiveness to the new materials in which is used (Cuzic−Zvonaru *et al*., 2001; Mustață, 2004).

Flax respects the environment, surrounding flora and fauna, maintains soil qualities, and protects crops and water resources around the world (CELC, 2010). Flax does not require additional irrigation and water coming from rain is sufficient to ensure good plant growth. Flax cultivation generates positive effects on eco−system diversity and provides a "pause" with benefits to soil quality.

Because of the support of the essential characteristics of flax, in recent years the development of new fields of use of flax fibres has occurred, which no longer limited their use mostly in the field of technical textiles (Grigoriu & Racu, 2012). Considering the issues mentioned above, this paper presents the research results which aimed at the extension of the use of flax yarn to the knitwear field.

2. Materials and Methods

On a wet spinning frame it was processed a roving made of polyester and flax fibres together with a polyester filament yarn as core yarn. After the roving passing through the drafting device, the fibres were twisted together with a polyester filament yarn. Therefore, on the spinning frame it was installed an extra thread guide, which was meant to guide the filament yarn to join with the roving fibres behind the delivery cylinders of the drafting device. The main physical and mechanical characteristics of the polyester fibres and of the polyester filament are presented in Tables 1 and 2.

Table 1

The Main Physical and Mechanical Characteristics of the Polyester Fibres

No.	Characteristics	Measurement unit	Values
1.	Linear density of fibres	[den]	4
2.	Deviation limits of the nominal linear density	[%]	±10
3.	Tenacity	[cN/tex]	3.8−4.0
		[cN/den]	3.1−4.4
4.	Nominal cutting length of fibres	[mm]	80
5.	Breaking elongation	[%]	20−48
6.	The adhesion length of the fibres	[mm]	75
7.	Neps on one gram of sliver	−	0.6
8.	Uster unevenness	[%]	5.6
9.	Sliver linear density	[g/m]	20

Table 2
The Main Physical and Mechanical Characteristics of the Polyester Filament

No.	Characteristics	Measurement unit	Values
1.	Linear density of yarn	[tex]	50
2.	Number of filaments	–	30
3.	Breaking strength	[N]	3.881
4.	Coefficient of variation of the breaking strength	[%]	8.60
5.	Breaking elongation	[%]	473.4
6.	Coefficient of variation of the breaking elongation	[%]	25.45
7.	Tenacity	[cN/tex]	7.76
8.	Coefficient of variation of the tenacity	[%]	8.60

The yarn with filament core which resulted on the spinning machine has 23% flax and 77% polyester (30.3% represents the polyester filament and 46.7% represents the polyester fibres). Yarns obtained on the wet spinning machine were dried and then heat treated.

From yarns wrapped on bobbins were obtained hanks of yarns, having a length of 100 m each. For this purpose was used a reel for yarns, equipped with a counter for measuring the length of yarn. In order to carry out the heat setting on a laboratory stage, a water recipient with a capacity of 3 litres and a sieve stand were used. In order to determine the optimal time of the heat setting, hanks have been treated at different times, for 5 min, 10 min, 15 min, 20 min and 25 min. The principal characteristics of yarns were measured in order to determine the way in which the heat setting influenced the mechanical properties of yarns.

3. Results and Discussions

Analyzing the graph shown in Fig. 1 it can be found that the yarn modifies its linear density value after the heat setting, depending on the duration of the process. It is noted that treatment duration of 5 min gives a linear density of 152 tex. For the period between 10 and 20 min were obtained linear density values relatively similar and durations greater than 20 min have resulted in slight increases of the linear density values. The linear densities of the treated yarns were maintained in the range of 144−152 tex, all values being larger than the linear density of the untreated yarn.

After applying heat setting, yarns have shrank even more as the duration of steam treatment is longer, reaching after 25 min at a shrinkage of approximately 11%. The shrinkage resulting from thermal treatment is that which makes the linear density of the yarn to increase on average by 4.7%.

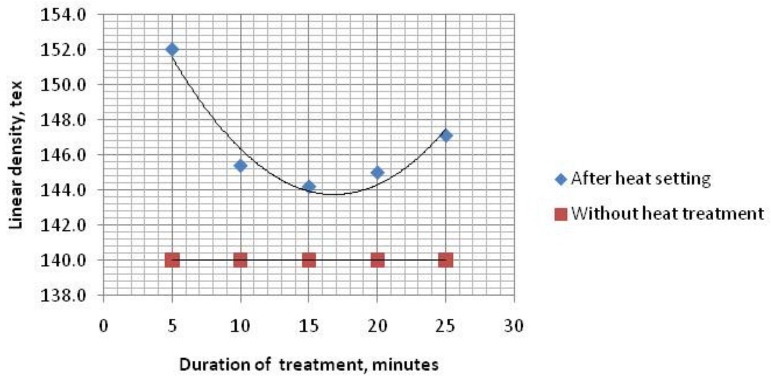

Fig. 1 – Influence of the thermal treatment on the linear density of the yarn.

Analyzing the Fig. 2 it can be observed that as a result of the application of heat treatment on yarns, the breaking strength ranges between 14.17 N and 19.16 N. For a 5 min treatment in steam, there were obtained the highest values of breaking force, followed by a decrease of approximately 5 N for a treatment of 10 min. Treatment durations of more than 15 min led to approximately constant values for the yarn breaking strength.

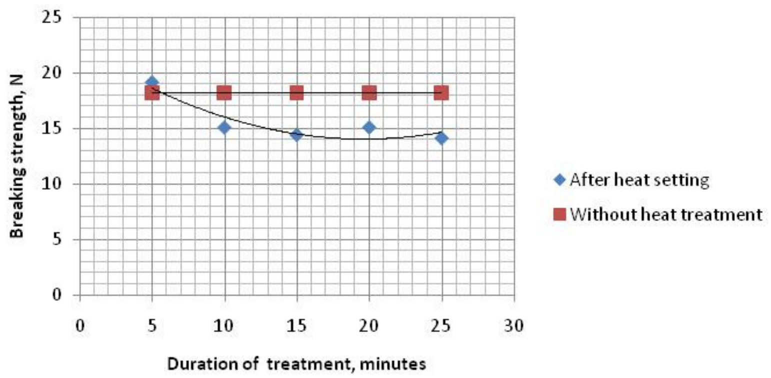

Fig. 2 − Influence of the thermal treatment on the breaking strength of the yarn.

Analyzing the Fig. 3 it is observed that breaking elongations of yarns have modified depending on the duration of treatment, thus, for 5 min was obtained the highest elongation, that is 19.28%, and then, for 15 min of treatment resulted a decrease of the elongation to a value of 16.95%. For the treatment of 20 min there were obtained increasing values up to 18% and for 25 min the trend was slightly decreasing, reaching up to 17.4%.

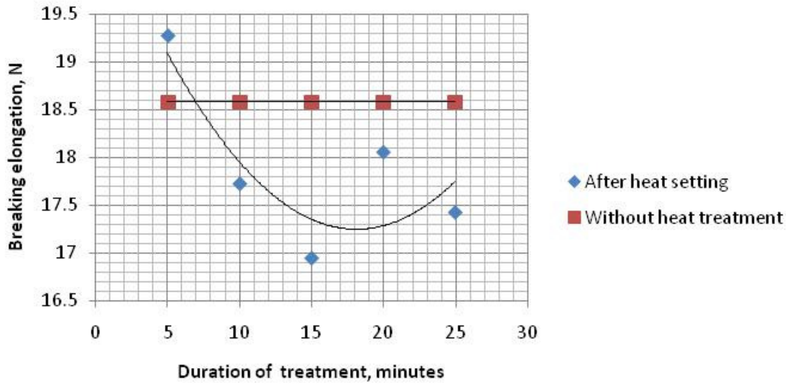

Fig. 3 − Influence of the thermal treatment on the breaking elongation of the yarn.

After heat setting, the tenacity values have shown a slight decreasing trend in the first 10 min of treatment, then it was noted that for the durations varied from 10 to 20 min were achieved approximately constant tenacity values, as can be seen in Fig. 4. Steam treatment time of 25 min has led to a decrease in yarns tenacity of approximately 23% in comparison with untreated yarns.

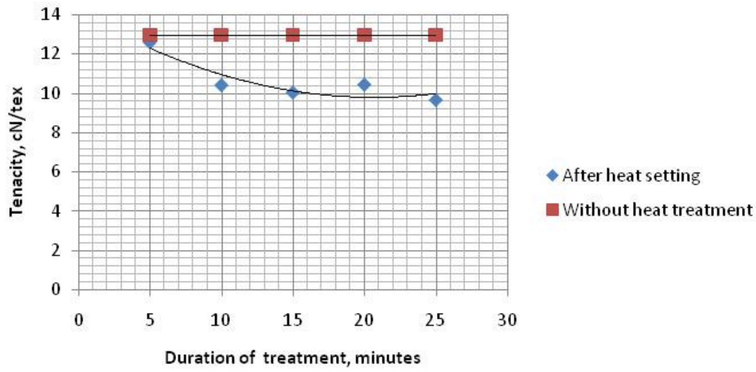

Fig. 4 − Influence of the thermal treatment on the yarn tenacity.

4. Conclusions

− Because of yarns shrinkage after heat setting, the values of the yarns linear densities were higher compared to those obtained for the untreated yarns; the linear density of the yarn increases on average by 4.7%.

− As a result of the application of heat treatment on yarns, the breaking strength decreases.

− For treatment duration of 5 min there were obtained the highest yarn elongation, that is 19.28%, and the highest values of the breaking force.

− Heat setting has led to a decrease in yarns tenacity, but for the 5 min treatment the values was close to that of the untreated yarn.

− The optimal duration of treatment is of 5 min, as the recorded characteristic values were similar to those of the untreated yarns.

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DIVERSIFICAREA TIPURILOR DE FIRE DE IN PRIN TRATAMENTE UMIDO−TERMICE

(Rezumat)

În ultimii ani au fost extinse domeniile de utilizare ale fibrelor de in, specialiştii din industrie axându-se pe realizarea de noi generaţii de materiale care să includă fibre naturale în compoziţia lor. Lucrarea prezintă rezultatele cercetărilor care vizează posibilitatea de a realiza noi fire tip in, în scopul de a pune în evidenţă calitatea şi proprietăţile oferite de fibrele naturale în amestec. Sunt prezentate tehnologia de fabricaţie utilizată pentru obţinerea firelor tratate umido−termic, precum şi caracteristicile fizico− mecanice ale firelor, analizate din punctul de vedere al influenţei pe care tratamentele umido−termice o exercită asupra lor.

BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LIX (LXIII), Fasc. 4, 2013
Secţia
TEXTILE. PIELĂRIE

PRACTICAL ASPECTS REGARDING THE KNITTING OF GLASS FIBRE

BY

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Received: August 26, 2013
Accepted for publication: September 10, 2013

Abstract. Knitted reinforcement for composite materials requires the use of high performance fibres as raw materials. This includes glass fibre (most common), carbon and aramid fibres. Glass fibres present the advantages of being cheaper and with good tensile behaviour. However, their brittleness raises a problem when subjecting them to knitting because of the interlooping specific to this process. It is necessary to define the way the glass filaments are destroyed during knitting and the technological limitations imposed by the yarns. The paper presents an experimental study concerning the influence of the technological parameters (position of the quality cam) on the tensile behaviour of yarns, in order to evaluate the level of filament breaking that occurred in the process. Single jersey samples were knitted using 5 levels for the quality stitch cam. After relaxation, yarns taken from the samples were tested to determine their tensile characteristics. The results were compared to the witness (normal yarns) and conclusions were drawn as to the relevance of influence factors and the way in which glass filaments break during knitting.

Key words: glass fibre, weft knitting, fibre breaking, tensile testing.

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1. Introduction

Advanced composite materials require the use of textile preforms with complex architecture, characterised by damage tolerance, reliability and cost effective production. 3D preforms have a high level of through-thickness and interlaminar strength, the overall distribution of textile material and the specific mechanical behaviour are controlled, while the entire process becomes automatic (Scardino, 1989). All major types of processes can be used to make such shaped preforms, each presenting specific advantages and disadvantages.

Due to their high deformation and drapeability weft knitted materials are well suited for the production of three-dimensional fabrics. The 3D knitted preforms have the advantage of controlled anisotropy, through the insertion of straight uncrimped yarns. The last developments in flat machines made it possible to knit three-dimensional preforms using high modulus yarns of glass, carbon and aramid fibres. Knitting-to-shape enables a variety of fabrics with different geometrical forms, including near-net-shape and sandwich fabrics.

The use of high modulus fibres in knitting requires special attention to the process, mainly because of their extreme brittleness, high friction and stiffness. These characteristics are problematic when it comes to bending (looping), specific to knitting. During the knitting cycle, the yarns are subjected to tension – with high peaks, due to their virtually zero extension – and to bending, sometimes simultaneously. The result consists in filament damage, with a negative influence on the mechanical properties of the fabrics.

Previous studies (Lau & Dias, 1994; Savci *et al*., 2001) have characterised the knittability of the glass fibre through yarn testing – tensile strength, straight and loop, and friction – and microscope examination of the yarns in the weft knitted fabrics. One of the experiments (Lau & Dias, 1994) used a V-bed machine and a circular knitting machine, while in the other (Savci *et al*., 2001) the samples were knitted on an ANVH-BLM-ES (Stoll) 8-gauge machine.

The conclusions were as follows:

− The high modulus yarns can withstand the bending curvatures of the knitting elements, even if the process will cause filament damage.

− The fabrics present considerable wale and course distortion, caused by the yarn twist and the friction between yarns and knitting elements. This distortion is increased by the use of a presser foot.

− Most filament breakage occurs at the needle loop, due to the tension peak in the looping point. If the robbing back occurs, the point of maximum tension appears before the needle reaches the lowest position in the channel.

− An increase in the filament breakage was evident at higher stitch length.

− The measured stitch length has the largest correlation with the stitch quality cam settings.

2. Materials and Methods

Knitting glass fibre requires a preliminary stage to determine the optimum technological conditions that ensure minimum fibre damage while maintaining the fabric quality. The fabric density, essential for the fibre fraction volume of the composite reinforcement gives this quality. High fibre fraction volume is a sine-qua-non condition for the performance of the composite materials (Ciobanu, 2011).

The experimental work is based on the direct study of the yarn after knitting, in order to identify the damage degree of the glass fibres inflicted by the knitting process. All experimental work was carried out at University of Minho, Portugal.

All models for the mechanical behaviour of the glass knitted fabric are based on the Young's modulus for the glass yarns. During the knitting process the filaments are damaged in a significant proportion, therefore altering the initial value of Young's modulus and altering the fabric properties. No previous study indicated the relation between technological parameters and the final value of the Young's modulus.

Two types of glass fibre were considered for the experiment: EC 11 408 Z28 T6 – Vetrotex and EC 13 136 Z30 P 100. The yarns are knitted using single jersey, as being the simplest possible structure, illustrated in Fig. 1.

The fabrics were produced on a CMS 320 TC (Stoll) flat machine with the following characteristics:

− gauge 10
− negative feeding – IRO NOVA (Fig. 2)
− holding down sinkers and presser foot (Fig. 3)

Fig. 1 − Aspect of a single jersey fabric, 408 tex.

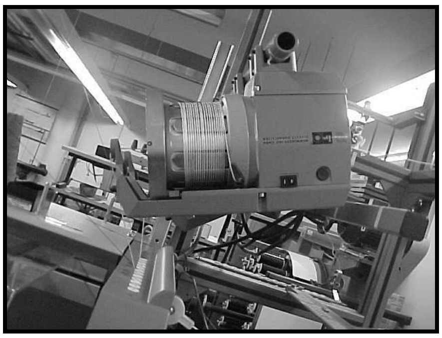


Fig. 2 − IRO NOVA negative feeding (Ciobanu, 2011).

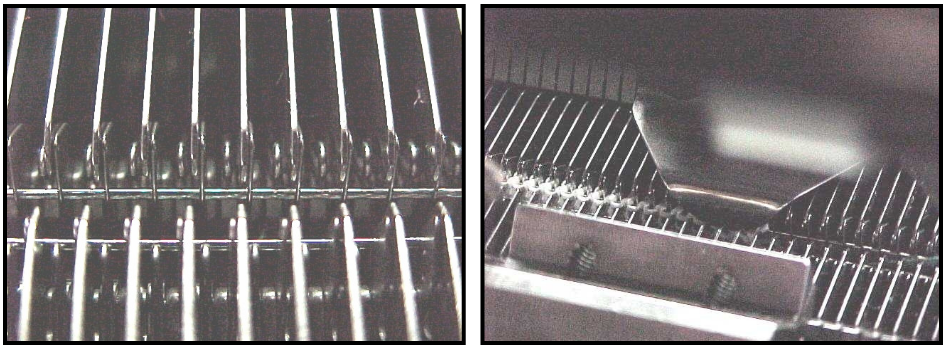


Fig. 3 − Holding down sinkers and presser foot (Ciobanu, 2011).

Based on previous experience, the fabrics are knitted with different values for the stitch quality cam, presented in Table 1.

Table 1
Technological Parameters Used for Knitting the Samples

Yarn count [tex]	Quality stitch cam (NP)					Take down (WM)
	NP 1	NP 2	NP 3	NP 4	NP 5	
408	10.0	10.5	11.0	11.5	12.0	20
136	9.5	10.0	10.5	11.0	11.5	18

Each sample had 100 wales and 100 courses. The fabrics were relaxed until they presented no dimensional variation. The structural parameters are illustrated in Table 2. As expected, the wales and courses are distorted.

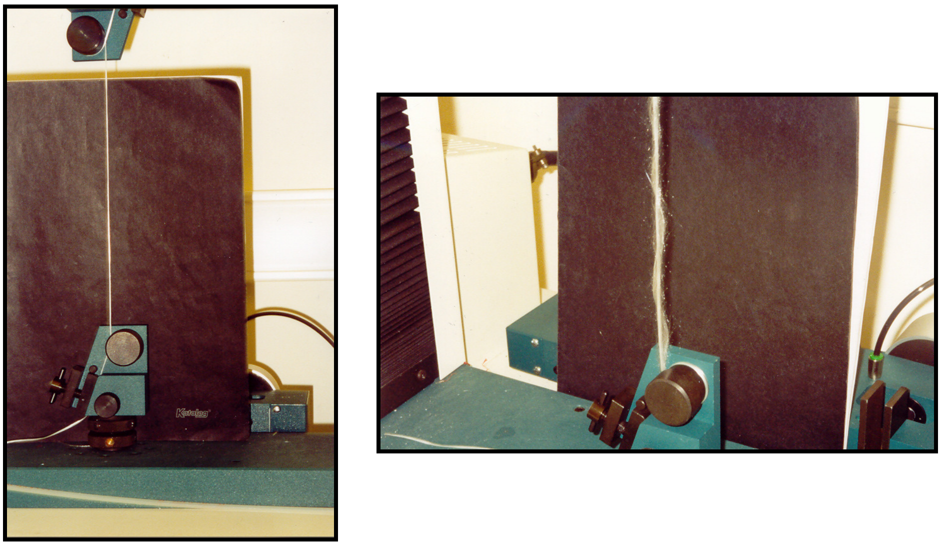
Table 2
Values for the Structural Parameters, in Relaxed State

Yarn [tex]	NP 2			NP 3			NP 4			NP 5		
	D_s	D_v	l_g	D_s	D_v	l_g	D_s	D_v	l_g	D_s	D_v	l_g
408	48	69	7.28	46	64	7.8	48	61	8.25	42	57	8.85
136	56	88	6.00	50	84	6.51	44	78	7.17	40	70	7.52

After relaxation 10 yarn lengths were drawn from the fabrics in order to determine their tensile properties, avoiding the edges, visibly more damaged then the rest. The tensile strength was tested on a TINIUS OLSEN (HOUSENFIELD) H10K-S, according to ASTM D 2256. The aspect of the tests before and after breaking is illustrated in Fig. 4.

According to the previous studies, the glass yarns break in less than the minimum 20 sec indicated by the standard. Therefore, the testing speed selected was the minimum value of 50 mm/min. The length of the samples was 250 mm.

The data confirmed the breaking of the glass yarns took place in less than 7 seconds. The experimental results are compared with the properties of the yarns before knitting.



Before testing After testing

Fig. 4 − Tensile testing of glass yarns (Ciobanu, 2011).

3. Experimental Results

3.1. Knitting Conditions

The experience of knitting on flat electronic machines showed that the needle could be pulled inside its channel without restrictions for the lowest point. For each yarn count, it is an inferior limit for the stitch length, guaranteeing the quality of the fabric. For this limit the degree of filament breaking is so high the yarn is almost completely destroyed and will break at unravelling (Ciobanu, 2011).

Fig. 4 presents the aspect of a 408 tex glass fibre jersey fabric produced with the quality stitch cams in the limit position, in this case NP = 10.5. The destroyed filaments are placed more at the level of the sinkers loops and not at the level of the needle loops. This situation sustains the idea of other cause for yarn damage than the tension peaks. Furthermore, the significant filament breakage repeats at every two courses, corresponding to the reverse carriage displacement when the needles receive less yarn.

If the stitch length is even lower, the yarn gets out of the needle hooks and it cannot be knitted. This situation is exemplified in Fig. 5, for a jersey fabric made of 204 tex glass fibre. The filaments appear to be completely destroyed, creating a plush effect.

Fig. 5 − Aspect of the jersey fabric the knitted with NP1 = 10.5.

Fig. 6 − General aspect of a fabric knitted with the stitch length under inferior limit – 136 tex.

3.2. Test Results

The experimental results were calculated based on the raw data from the testing machine, according to the established methodology[4], to obtain the following values:

1. Breaking strength, [N];
2. Breaking tenacity, [cN/tex];
3. Young's modulus E, [N/tex];
4. Breaking elongation, [%];
5. Breaking toughness, [J/g];
6. Time to break, [sec].

The results are centralised in Table 3, presented bellow.

Table 3
Experimental Results for the 3 Types of Glass Yarns

Yarn [tex]	Stitch cam	Breaking force [N]	Breaking tenacity [cN/tex]	E modulus [N/tex]	Breaking elongation [%]	Breaking toughness [J/g]	Time to break [sec]
136	Witness	75.67	55.59	27.37	2.2	6.64	6.89
	NP 3	23.59	17.27	14.79	1.38	1.45	4.14
	NP 4	30.92	22.73	18.26	1.42	1.93	4.24
	NP 5	37.51	27.58	21.24	1.55	2.47	4.66
408	Witness	229.87	56.34	84.65	2.46	6.86	6.76
	NP 2	118.73	29.10	61.18	1.87	3.01	5.60
	NP 3	156.59	38.37	69.52	2.00	4.29	6.01
	NP 4	165.05	40.45	70.08	2.12	4.86	6.38
	NP 5	167.83	41.14	71.66	2.15	4.87	6.44

3.3. Discussions

The differences in strength and tenacity, compared to the normal values, show that the knitting process has a negative influence on the tensile properties. Furthermore, the decrease in strength is in a direct correlation with the stitch length – the lower the stitch length, the lower the tensile properties. Figs. 7 and 8 present the representative graphics for each type of yarns, illustrating the variation of the breaking force with the elongation.

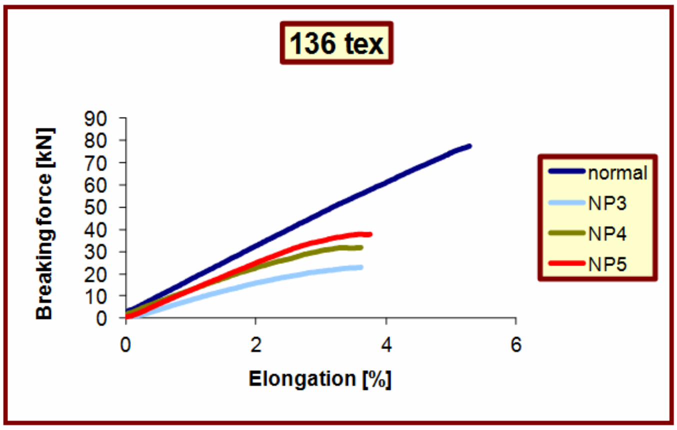


Fig. 7 − Variation of the breaking force with the elongation for the EC 13 136 Z30 P 100 glass yarn.

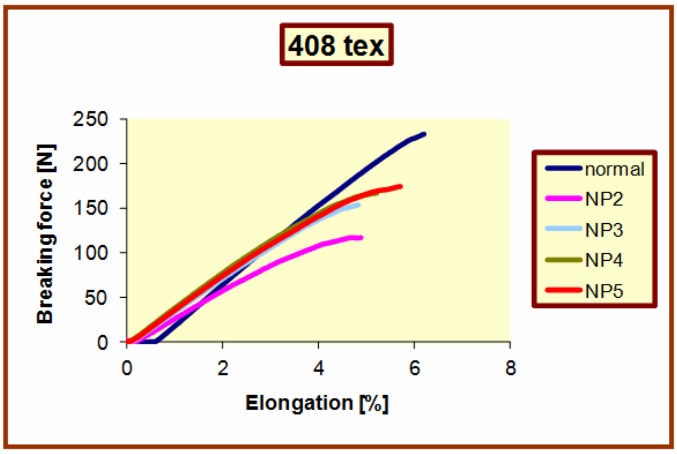


Fig. 8 − Variation of the breaking force with the elongation for the EC 11 408 Z28 T6 glass yarn.

The calculated data and the graphics are emphasising the contradiction with Dias and Law, concerning the cause of filament breakage during knitting. If the tension occurring in looping points is responsible for the filament damage, then higher stitch length should present lower values for the breaking force. As seen, this did not happen. One answer for this difference could be the feeding mechanism. In this case, the yarn was fed using an IRO NOVA feeding device, ensuring the proper quantity of yarn for the process. Without it, knitting proved impossible.

The breaking phenomenon is produced by the friction between the yarns and the knitting elements, especially the knock-over plates that can act like knifes during robbing back. Longer stitch lengths lower the tension in yarns, leading to less filament damages.

The differences between the normal values and the ones for the knitted yarns 136 tex are varying from - 71% in case of the smallest stitch length (6.00) and - 55% for the highest stitch length (7.52). In the case the 408 tex yarn, the difference interval is - 48.34% to - 26.99%. A slightly higher decrease is registered for breaking toughness. A superior number of filaments ensure a better knittability, the yarn maintaining better tensile properties.

Even if the best properties are obtained for the highest stitch length – corresponding to NP5 value for the quality cams, this must be balanced with the fabric density, essential for the overall performance of the fabric in the composite material. Therefore, the optimum technological parameters appear to be those for the fourth situation, with NP4 value for the stitch quality cam. In practice, if the strength level is lower, value NP3 can also be used, due to the higher fabric density.

4. Conclusions

Glass fibre is the most common fibre used as reinforcement for composite materials. Due to its brittleness, glass fibre is difficult to knit, requiring previous experiments to determine the optimum technological parameters for the process.

The initial conclusion is that glass fibre is knittable, it withstands the bending of filaments around the needle hook, under strain. However, the amount of filament breaking is significant and its reduction is important in maintaining the yarns strength. Therefore, the knitting process must studied to determine the influence factors and the extent to which glass filament can be protected.

The present paper studied the tensile properties of two types of glass multi-filament yarns: EC 11 408 Z28 T6 and EC 13 136 Z30 P100. The yarns were previously knitted, relaxed and taken from the samples, and were tested on a Tinius Olsen (Housenfield) testing machine. The experimental data indicates, as does the yarn behaviour during the knitting process that the filament damage increases with the decrease in stitch length.

This comes in opposition with the previous studies that pointed the tensions produced in the looping point as cause of the fracture.

Based on the tensile properties of the knitted yarns, the optimum technological parameters correspond to the NP4 value for the stitch quality cam.

Future work must also consider the importance of fibre ageing and the influence it has on the mechanical properties. Preliminary studies show that a significant reduction in tensile characteristics after at least half a year.

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ASPECTE PRACTICE PRIVIND TRICOTAREA FIRELOR DE STICLĂ

(Rezumat)

Tricoturile folosite pentru ranforsarea materialelor compozite necesită utilizarea fibrelor de înaltă performanţă ca materii prime, inclusiv fibre de sticlă (cele mai folosite), de carbon şi aramidice. Fibrele de sticlă prezintă avantajele de a fi cele mai ieftine, menţinând caracteristicile mecanice. Totuşi, faptul că sticla este casabilă ridică probleme la tricotare datorită buclării firelor pe durata procesului. Devine necesară definirea modului în care filamenetele de sticlă sunt distruse pe durata tricotării, precum şi limitările tehnologice specifice. Lucrarea prezintă un studiu experimental privind influenţa parametrilor tehnologici (adâncimea de buclare) asupra comportării firelor de sticlă la tracţiune, pentru a putea evalua nivelul de distrugere a filamentelor pe durata procesului de tricotare. S-au produs mostre de tricot glat cu 5 adâncimi de buclare. După relaxarea mostrelor, s-au prelevat fire care au fost testate pentru a stabili comportarea la tracţiune. Rezultatele au fost comparate cu firele testate fără a fi tricotate, fiind trase concluzii privind relevanţa factorilor de influenţă consideraţi şi modul în care se produce ruperea filamentelor.

BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LIX (LXIII), Fasc. 4, 2013
Secţia
TEXTILE. PIELĂRIE

THE ANALYSIS OF RANDOMIZATION LEVEL OF FIBER DISTRIBUTION, USING POLAR DIAGRAMS OF THE TENSILE CHARACTERISTICS OF NONWOVEN FABRICS FOR GEOTEXTILES

BY

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Received: August 27, 2013
Accepted for publication: September 18, 2013

Abstract. Generally, geosynthetics are planar structures obtained from polymeric materials, egg. synthetic fibres, and that are used in building works with rocks, gravel and ground. The geosynthetics materials have uniform properties and are available on any emplacement. Through their reinforcement function, the geosynthetics improve considerably the mechanical properties of the soil. Thus, it is possible to make difficult constructions, such as vertical support structures close to vertical, steep slopes, highly compressible foundation land, etc. The analysis of the tensile characteristics of nonwoven geotextiles is essential because these geotextiles come in contact with materials with regular or irregular form (such as gravel, pebbles, composite network), or take the form of objects (various underground pipes or area) where the geotextiles are used as filter systems. This paper proposes an indirect but effective method for assessing the degree of randomization of the distribution of fibres in the nonwoven material.

Key words: nonwoven fabrics, fibre, geotextiles, randomization.

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This paper is the full version of the paper published in abstract only at Technical Textiles – Present and Future Symposium, Iaşi, October, 2013

1. Introduction

Analysis of the tensional characteristics of nonwoven textiles, for geotextiles, is important because these geotextiles come in contact with materials with regular or irregular form (gravel, pebble, composite) or take the form of objects (pipes underground or surface), when the geo-textiles are used as filter systems. Therefore, it is necessary that properties of these materials to be as uniform in any direction of material. Appreciation the level of randomization is studied by uniformity of breaking force and elongation at break on various directions application. Due use of the nonwoven fabrics in complex areas, is important to obtain randomized fibre layers. The mathematical model presented in (Bulacu *et al*., 2009) analysed the influence of the independent variables x_1 and x_2 (x_1- density interweaving [punches/cm^2] and x_2 depth penetration of interweaving needles of fibrous layer [mm]). Thus, we can say that the effect of randomization given of card Spinnbau is multiplied by a number of times equal to the number of folds, trough folding system, from machine Thibeau.

2. Materials and Methods

The 250 mm x 50 mm samples, from all variants of the nonwoven fabrics, resulted from the experimental program (Bulacu *et al.*, 2009) were taken along six directions with 30º increment, considering the main directions as 0° - 180° longitudinal direction, and 90° - 270° as transverse directions. The samples were tested to determine their tensile characteristics - breaking strength and elongation.

3. Results and Discussions

The results of product characteristics determined according (Zamfir *et al*., 2010) for the experiments 5, 6, 7, 8 presented in Table 1 were used to draw the histograms in Figs. 1 and 2, namely the breaking force P, [daN] and elongation at break ε, [%].

Table 1

The Values of Force and Elongation at Break for Materials Resulted from Experiments 5, 6, 7, 8

Testing direction and code	Experiment 5 (−1,414, 0)		Experiment 6 (+1,414, 0)		Experiment 7 (0, −1,414)		Experiment 8 (0, +1,414)	
	P [daN]	ε [%]	P [daN]	ε [%]	P [daN]	ε [%]	P [daN]	ε [%]
0º - 180º d1	29.80	67.0	30.92	70.2	28.04	56.2	31.06	65.8
30º - 210º d2	40.48	66.2	47.66	65.2	33.40	60.2	37.44	70.2

Table 1
Continuation

Testing direction and code	Experiment 5 (−1,414, 0)		Experiment 6 (+1,414, 0)		Experiment 7 (0, −1,414)		Experiment 8 (0, +1,414)	
	P [daN]	ε [%]	P [daN]	ε [%]	P [daN]	ε [%]	P [daN]	ε [%]
60º - 240º d3	47.90	65.0	46.46	63.0	25.24	65.2	44.48	62.8
90º - 270º d4	45.00	77.6	45.36	64.4	47.46	62.6	45.60	56.8
120º - 300º d5	41.24	72.2	32.12	68.0	37.60	66.6	33.10	62.2
150º - 330º d6	39.40	74.2	47.56	66.6	30.26	63.8	40.60	57.2

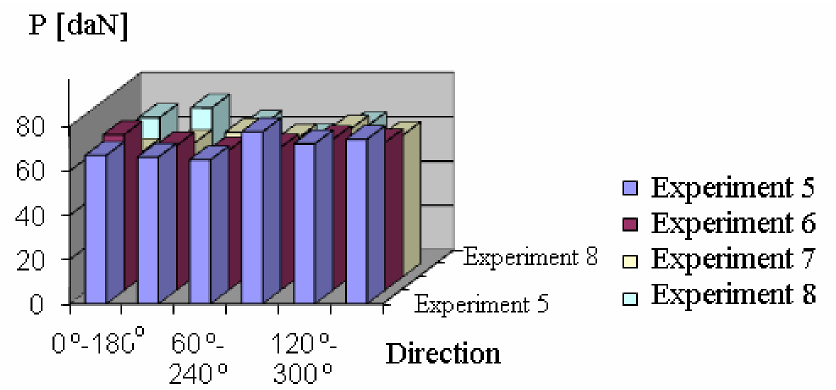

Fig. 1 − Variation of the breaking force P, [daN] for experiments 5, 6, 7, 8.

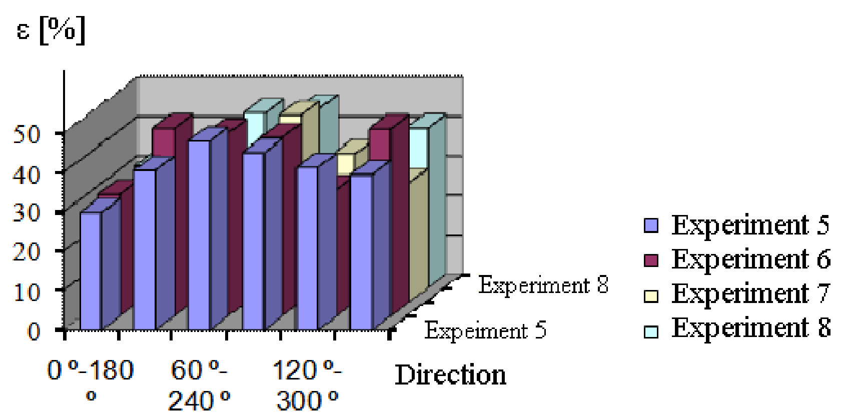

Fig. 2 − Variation of the elongation at break ε, [%] for experiments 5, 6, 7, 8.

The histogram from Fig. 1 shows that on each polar testing direction the breaking force present insignificant variations, while these values are significantly different when comparing between the directions. These differences amount to 15 daN, representing approx. 15% of the breaking force.

The histogram for the elongation at break (Fig. 2) shows that the differences between the results obtain for direction d1are 18 daN, while for other direction (*egg*. for variables coded 0 and 1.141) they are relatively constant and have a deviation of about 15%. In both cases this variances are statistically acceptable.

The characteristics data of the products obtained for experiments 1, 2, 3, 4 placed in the centre of experimental program (+1 and −1) are presented in Table 2, and the graphics of variation for the breaking force P [daN] and elongation at break [%] are shown in Figs. 3 and 4.

Table 2

Values of Breaking Force and Elongation at Break for Materials Resulting from Experiments 1, 2, 3, 4

Testing direction and code	Experiment1 (−1, −1)		Experiment 2 (+1, −1)		Experiment 3 (−1, +1)		Experiment 4 (+1, +1)	
	P [daN]	ε [%]	P [daN]	ε [%]	P [daN]	ε [%]	P [daN]	ε [%]
0º - 180º d1	30.76	61.0	26.32	50.4	32.74	48.8	35.16	54.2
30º - 210º d2	34.00	75.6	31.58	74.8	45.48	74.4	46.70	71.6
60º - 240º d3	25.88	74.2	32.10	58.6	32.98	69.8	36.62	69.8
90º - 270º d4	43.90	79.4	44.74	68.2	43.46	58.2	45.10	81.2
120º - 300º d5	36.40	75.0	31.56	49.2	45.34	67.2	36.98	73.8
150º - 330º d6	35.40	77.6	43.48	72.4	33.30	68.2	42.90	66.8

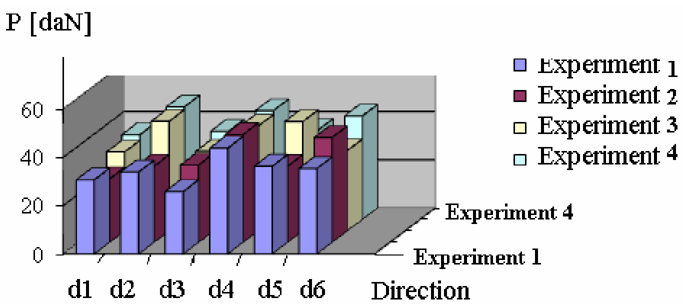

Fig. 3 − Variation of breaking force P, [daN] - experiments 1, 2, 3, 4.

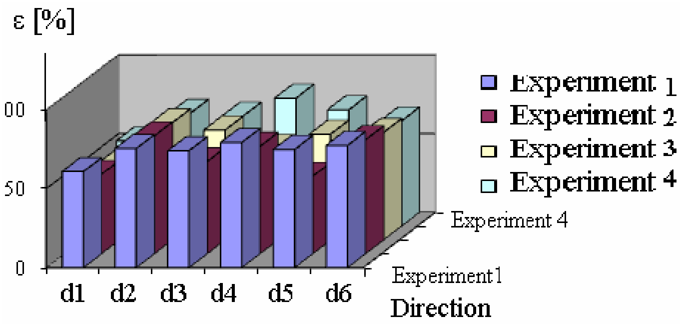

Fig. 4 − Variation of elongation at break [%] - experiments 1, 2, 3, 4.

The histogram of Fig. 3 shows that the load at break has a significant variability in the values of both on the polar direction and on the experiment direction. Thus on the d1 direction, the breaking load shows differences of up to 18 daN, representing 35% in relative values. With respect to the experiment direction the data shows the same significant variability. Regarding to the elongation at break (Fig. 4) it is found that for any polar direction, the values are relatively constant, but in the case of the experiment direction, there are significant variations ranging between 26 daN and 42 daN, for example a variation of approx. 25% in relative values. In this case the results can be considered as acceptable.

The characteristics data of the products obtained for the centre of the experimental matrix - experiments 9, 10, 11, 12 (code values 0 and 0) are presented in Table 3, and the graphics of variation for the breaking force P [daN] and elongation at break [%] are shown in Figs. 5 and 6.

Table 3

The Characteristics of Products from Centre of Experimental Program

Testing direction and code	Experiment 9 (0. 0)		Experiment 10 (0. 0)		Experiment 11 (0. 0)		Experiment 12 (0. 0)	
	P [daN]	ε [%]	P [daN]	ε [%]	P [daN]	ε [%]	P [daN]	ε [%]
0º - 180º d1	25.04	38.2	33.28	74.0	28.76	63.8	30.0	42.6
30º - 210º d2	38.80	66.2	36.84	64.6	44.00	66.0	43.7	71.8
60º - 240º d3	34.46	51.6	45.40	63.4	31.96	61.6	38.5	60.8
90º - 270º d4	43.30	61.6	44.00	78.0	33.48	74.4	44.7	57.4
120º - 300º d5	34.54	61.8	32.68	79.6	43.60	69.8	43.5	70.0
150º - 330º d6	31.80	59.8	42.76	79.6	35.30	77.2	37.6	49.6

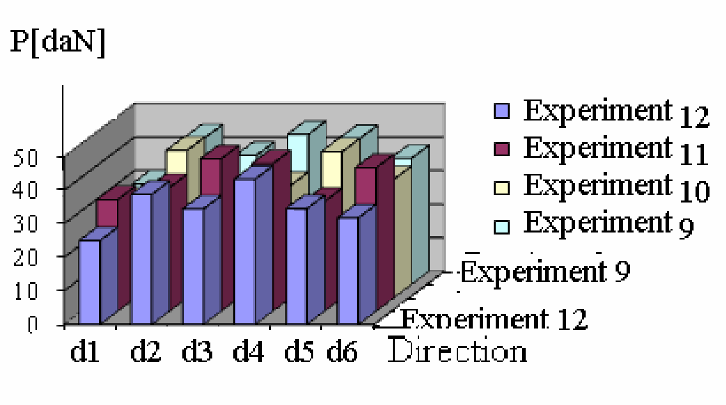

Fig. 5 – Variation of breaking force P, [daN] - experiments 9, 10, 11, 12.

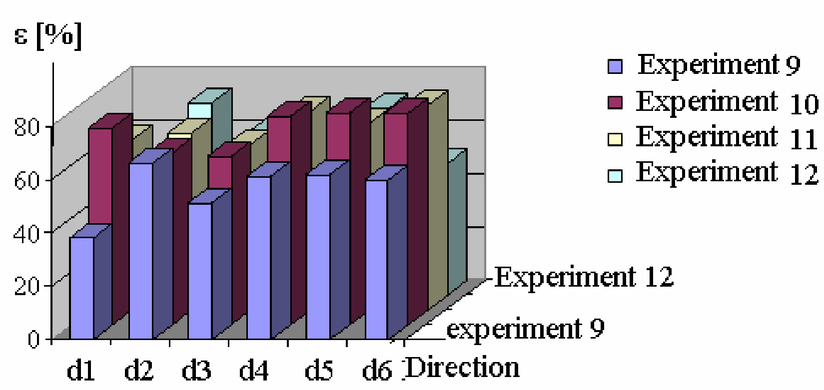

Fig. 6 – Variation of elongation at break ε, [%] - experiements 9, 10, 11, 12.

The histogram from Fig. 5 shows that breaking force presents insignificant variations both at polar diagram and experiment directions.

Thus, the breaking force has a variation between 25-32 daN, with a difference of 7 daN, which is about 3%, while on the experiment direction the same parameter presents variations between 25-43 daN, namely a difference 18daN, which is about 15%.

The elongation at break (Fig. 6) shows an significant unevenness. Thus, on d1 polar direction, there are variations of 38-46%, representing about 20% in relative value. The same unevenness it observed when comparing between experiments, showing a variation between 48-74%, about 20% in relative values.

From the above results, the effect of randomization for all analyzed experiments is evident. There is some variability of the features without it reaching exaggerated values. It can say that the randomization is obvious.

4. Conclusions

The parameters which were analysed (X1- density interweaving [punches/cm^2] and X2- penetration depth of interweaving needles in the fibrous layer [mm]) showed the degree of randomization of the fibrous layers.

The paper analyzed the uniformity degree of geotextiles, by establishing the mechanical properties of samples taken from polar directions with 30º increment, and analyzed the uniformity of these properties. The analysis performed demonstrates that the randomized fibres ensure an acceptable level of quality of the nonwoven fabric for geotextiles.

Given the nature of the raw material, from recycled fibres, it is found that the variation of the analyzed parameters has obvious but statistically acceptable limits. The fabric nonwoven from recycled PET fibres, obtained by carding- folding- interweaving technological processes on an Asselin-Thibeau Spinnbau machine present a high degree of fibre randomization in the layers influencing the structure and mechanical properties of the geotextiles. The randomization can be considered as the combined effect of the action rolling system, the system of disorientation and interweaving process.

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ANALIZA NIVELULUI DE RANDOMIZARE A DISTRIBUȚIEI FIBRELOR FOLOSIND DIAGRAME POLARE PENTRU CARATERISTICILE DE TRACȚIUNE ALE MATERIALELOR GEOTEXTILE NEȚESUTE

(Rezumat)

În general, geosinteticele au structuri planare, obținute din materiale polimerice, de ex. fibre sintetice, fiind folosite pe şantiere de construcții, împreună cu roci, pământ şi agregate. Materialele geosintetice au proprietăți uniforme şi sunt disponibile în orice amplasare. Prin funcția de armare, geosinteticele îmbunătățesc considerabil caracteristicile mecanice ale solului. Astfel, se pot realiza construcții dificile, precum structuri pentru suport, cu dispunere verticală, structuri în pantă, structuri cu fundații în sol puternic compresibil, etc. Analiza caracteristicilor de

tracțiune ale materialelor geotextile nețesute este esențială, deoarece acestea vin în contact cu materiale cu geometrie regulată sau neregulată (pietriş, agregat, rețele compozite) sau preiau forma unor obiecte (diferite conducte), îndeplinind funcția de filtrare. Lucrarea propune o metodă indirectă, dar eficientă de abordare a evaluării fradului de randomizare a distribuției fibrelor în materialul nețesut.

BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LIX (LXIII), Fasc. 4, 2013
Secţia
TEXTILE. PIELĂRIE

AIR PERMEABILITY AND THERMAL PERFORMANCE

BY

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Received: August 10, 2013
Accepted for publication: September 2, 2013

Abstract. The features of protection and the comfort of protective clothing against thermal risks are assessed under standards specified in the applicable test methods. The performance of protection depends largely on the performance characteristics of the materials. One of the most important factors is air permeability which has a major influence on heat-protection performance, but also is one of the main parameters which defining comfort of protective clothing. This paper aims to present the results of tests on various materials used for making protective clothing against thermal risks, and how their structure influence the air permeability of clothing.

Key words: protective clothing, thermal risk, air permeability.

1. Introduction

The protection and ergonomic requirements for protective clothing against thermal risks are usually diverse, based on the field of use. In some cases, the protective clothing must be designed according to the specific needs of a place of employment (*e.g.* clothing for protection against the thermal effects of an electric arc) (René Rossi *et al*., 2000). A good way for framing of

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the requirements of the protective clothing is presented in Fig. 1.

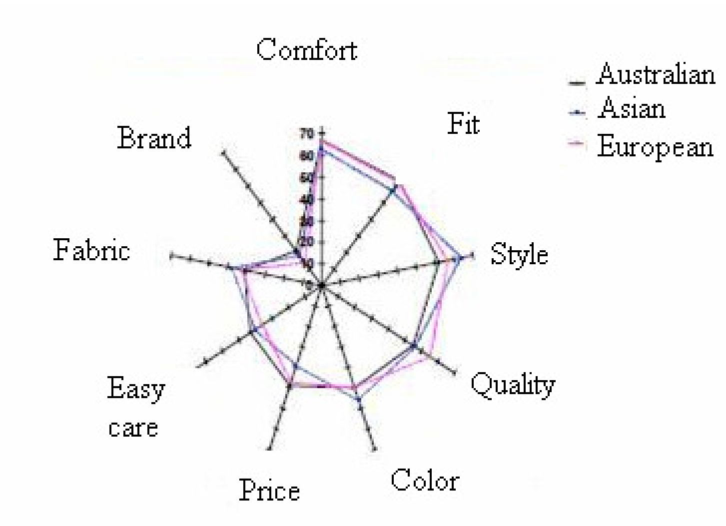

Fig. 1 – The requirements of the protective clothing against thermal risks.

It can be seen from the image that the users place comfort and design at the forefront of their concerns with regard their protective clothing. This can actually be interpreted as a concern with the design concept, namely how it answers the needs of the workers, those which are particularly connected with sizes and adapting sizes and how light the clothing is (René Rossi, 1999).

The air permeability is a factor which influences the performance of protective clothing and it can be evaluated by the convection heat transfer index (HTI) and on the radiant heat transfer index (RHTI).

2. Materials and Methods

To study the influence of air permeability on the convection heat transfer index (HTI) and on the radiant heat transfer index (RHTI), were analysed several types of materials which are usually used for obtaining protective clothing against thermal risks. Their characteristics are:

− 100% cotton fabrics with flame retardant treatment;

− Fabrics made out of several types of fibres, included in different proportions (cotton, PES, PPAN-fr, aramid, etc) with flame retardant treatment.

For perform the necessary tests the following methods are used:

a) *Determining the heat transfer (convection) – The heat transfer index* (*HTI*) is determined according to the international standards ISO 9151 or EN 367 and it represents the time measured to obtain a rise in temperature of (24.0 ± 0.2)ºC when the fabric or series of fabrics are exposed to a flame induced thermal flux incident of 80 kW/m^2. The index of heat transfer is determined using test tubes compressed under a standardized weight, which has the role to minimize the thickness of the air layer between fibres or between the layers of fabric. In this case the HTI does not have to be considered as being the time in which the individual protective equipment shields against the flame.

b) *Determining the heat transfer (radiation) – the radiant heat transfer index* (*RHTI*) is determined according to the international standard EN ISO 6942:2002. In the European standard two methods for testing for any type of material are described, but the density of the caloric flux has to be set with care according to the uses for which the material was designed and results have to be interpreted correctly [HSE Thermal comfort]. Workers in various industries or fire fighters can be exposed to a relatively low intensity radiant heat or medium or high intensity for relatively shorter or longer periods of time. It is recommendable to test fabrics for protective clothing against high and medium densities of the caloric flux. The fabric is characterized by the performance under Method B and time length $RHTI_{12}$ and $RHTI_{24}$.

Based on standard specifications for each type of protective clothing against thermal risks, the tests are carried out for different types of heat and radiation flux.

To be able to compare results of the tests, the testing was carried out only for the medium level of exposure, at 20 kW/m^2.

− Low level, between 5 and 10 kW/m^2;
− Medium level, between 20 and 40 kW/m^2;
− High level, at 80 kW/m^2 (EN 469 – clothing for fire fighters).

c) *Determining the air permeability* is done according to the SR EN ISO 9237:1999 standard, which specifies this parameter to be tested for in the materials at a difference in pressure of 100 Pa or 200 Pa, according to the specific weight of the fabric being tested.

The machine used to determine this parameter allows testing different textiles due to its 4 flow meters, so that the reading of the air flow which passes through the test tubes can be done from 0 mL/min to 10 L/min. The 10 test tubes are fitted in turns in the machine, the device is started and the air flow, qv (L/min), is measured for each test tube, each individual value being recorded.

The method requires the calculation of the average of the 10 values. The air permeability is calculated according to the size of the air absorption opening through the test tube. Our lab’s testing device is designed with an opening of 5 cm^2 for which the following formula is applied:

$$R = \frac{\dddot{q}_v}{A} * 167 \qquad (1)$$

where: $\ddot{q}_v$ – is the arithmetic average of the air debit, [L/min]; R – is the permeability to air, [mm/s]; A – is the surface of the tested woven fabric, [cm^2].

According to the standard for testing and the standards regarding protective clothing, the value of this parameter needs to be expressed in (mm/s), the unit equivalent of (L/m^2.s).

The results effectuated on 24 fabrics for determining transfer index for convection and radiant heat, are represented in function the air permeability values in Figs. 2 and 3.

3. Results and Discussions

It was found that the performance parameters of protection against convection and radiant heat are influenced by the air permeability. The air permeability is in its turn determined based on a series of factors, among which mainly the structure of the fabric, the binding and the thickness of weaving. The HTI and RHTI vary relatively less for fabrics with one layer, by 1-2 units. For the indices to rise by one additional unit, the fabric has to present certain structural characteristics which also attribute it a reduced permeability to air. To outline any rise in the convection and radiant heat indices, the air permeability was presented a reduced scale of 1/10 which allowed a clearer observation of the intersection points of the parameters under study.

Based on the results obtained and the trend of the values presented in Figs. 2 and 3, it can be seen that the fabrics with a lower density, allow more air to flow through the fabric have the best performance with regard to the air permeability, but the convection and radiation heat transfer are at the inferior limit . It is notable that circa 50% of the results obtained for the air permeability tests, on several fabrics, ranges between 100 and 200 mm/s, which are the optimum values according to studies regarding the comfort provided by protective clothing, unless users are exposed at air flows.

The analysis of the results obtained through tests show that the air permeability is very little influenced by the composition of the fabrics, respectively the percentage of synthetic fibres.

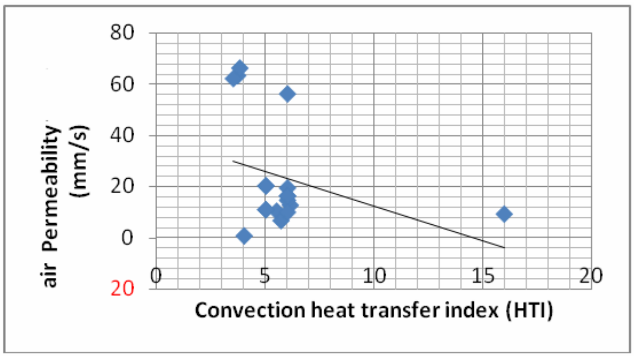

Fig. 2 − Variation of the radiant heat transfer index with air permeability.

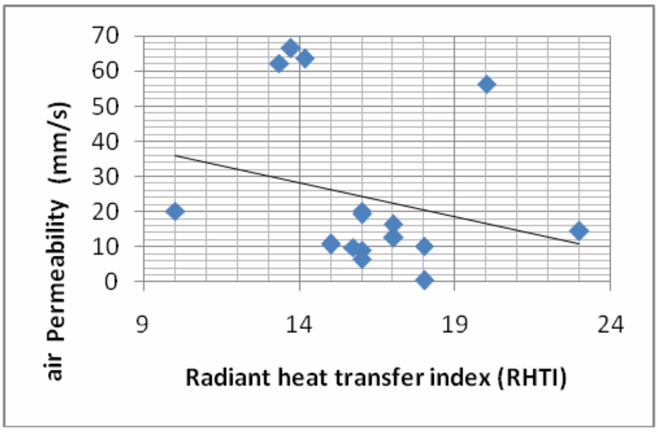

Fig. 3 – Variation of the radiant transfer index with air permeability.

4. Conclusions

The results from two graphics leads to the main conclusion that the transmission of the heat flux through a fabric or a set of fabrics depends on the structure and thickness of the fabric or the set, inclusively of the air strata contained, the air permeability of the material, and, in a smaller measure by the nature of fibres in the composition of the respective fabrics. Several conclusions are drawn:

− The air permeability, which currently has standardized values for thermal risk protective clothing is actually a parameter that has to be taken into consideration in the design of protective clothing with high performance against convection and radiant heat. In designing such models, ventilation of the protective clothing have to be carefully considered based on how they impact on these indices (*e.g.* ventilation slots, combinations of several fabrics, etc.).

− Special attention must be paid to the classic fabrics from cotton or wool. Although they have high performance with regard to the comfort provided during wear and have good protective performances for several indices, they are being replaced more and more by materials from several types of fibres due partially to a reduction in the production of natural fibres and partially due to their mechanical properties which impact the duration the protective clothing can have.

− Even fabrics such as Nomex or Kevlar have now been replaced with fabrics made from various ratios of cotton and PES fibres with a maximum of 2% antistatic fibres, for which the resistance of the fabric is increased to up to 100 cycles of maintenance by using currently available treatment technology. This spectacular evolution opens the door to innovations concerning the design of materials protecting against thermal risk.

− The results have shown that air permeability is very little influenced by the composition of the fabrics, respectively by the percentage of synthetic fibres. This leads to the implication for future research that in order to correctly evaluate the comfort parameters, other indicators have to be tested as well, such as the vapour permeability or evaporation resistance.

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PERMEABILITATEA LA AER ŞI PERFORMANȚELE DE PROTECȚIE TERMICĂ

(Rezumat)

Caracteristicile de protecție şi de confort ale îmbrăcămintei de protecție împotriva riscurilor termice sunt evaluate în conformitate cu standardele prevăzute în metodele de testare aplicabile. Performanța de protecție depinde în mare măsură de caracteristicile de performanță ale materialelor. Unul dintre cei mai importanți factori este permeabilitatea la aer, care are o influență majoră asupra performanțelor de confortul îmbrăcămintei de protecție. Lucrarea are ca scop prezentarea rezultatelor testelor pe diverse materiale utilizate pentru confecționarea îmbrăcămintei de protecție împotriva riscurilor termice, precum şi modul în care structura lor influențează permeabilitatea la aer.