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# New biodegradable fibres, yarn properties and their applications in textiles: a review

BANU OZGEN

REZUMAT – ABSTRACT

**Privire generală asupra fibrelor biodegradabile, proprietăților firelor şi aplicațiilor lor în domeniul textilelor**

*Creşterea exponențială a populației duce la o cerere crescândă de produse alimentare, energie, apă, resurse şi produse chimice şi determină măriri corespunzătoare ale nivelului de poluare a mediului şi de epuizare a resurselor finite. Polimerii biodegradabili şi fibrele produse pe baza acestora prezintă un mare interes, datorită faptului că oferă posibile soluții la problema eliminării deşeurilor. Cu toate acestea, într-o lume cu resurse limitate şi numeroase cazuri de impact asupra mediului este evident că stilul de viață durabil şi stilul industrial devin, de asemenea, importante. Având în vedere aceste preocupări, se face o trecere în revistă a noilor fibre biodegradabile – acidul polilactic (PLA), bambusul, fibrele Tencel® SUN şi a fibrelor din proteină de soia (SPF), precum şi a aplicațiilor acestora în domeniul textilelor. În acest studiu sunt analizate, de asemenea, efectele tipurilor de fibre asupra proprietăților firelor.*

*Cuvinte-cheie: biodegradabil, acid polilactic, bambus, fibre Tencel Sun, fibre din proteină de soia, textile*

**New biodegradable fibres, yarn properties and their applications in textiles: a review**

*The exponential increase in population increases the demand on food, energy, water, resources and chemicals, and affects a corresponding increase in environmental pollution and a depletion of finite resources. Biodegradable polymers and the fibres that can be produced from them are very attractive in offering a possible solution to waste-disposal problems. Nevertheless, in a world with limited resources and many environmental impacts, it is obvious that sustainable life and industrial styles are also becoming important. With these concerns, new biodegradable fibres: polylactic acid (PLA), bamboo, Tencel® SUN and soybean protein fibres (SPF) and their applications in textiles are reviewed. The effects of fibre types on yarn properties are also discussed in this review.*

*Key-words: biodegradable, polylactic acid, bamboo, Tencel Sun, soybean protein fibres, textile*

With increasing concerns regarding environment, rising oil prices and costumer demand, more textile researchers, producers and manufacturers are looking to biodegradable and sustainable fibres as an effective way of reducing the impact textiles have on the environment. Furthermore, these concerns drive research into ways to replace petrochemical products with bio-based materials. Global fibre supply in 2010 was 70.5 million tonnes, of which 44.1 million tonnes was synthetic [1]. These are fabrics or fibres that are manmade from petrochemicals. They are processed through a series of highly toxic chemical processes and will not decompose naturally. The only instance that synthetic fibres are considered sustainable is if they are recycled.

A further driver comes from consumer demand, with growth of the “eco-friendly” and “organic” markets in textiles. Surveys show environmental compatibility is increasing as a sales argument, as demonstrated by organic cotton fetching a premium price over the nonorganic fibre, even though they are physically indistinguishable. However, surveys also warn that consumers will not compromise product performance to have an eco-friendly product [2]. While there is no international standard to describe eco-friendly, a fibre made from renewable raw materials, using an environmentally friendly and commercially viable process, and having triggered biodegradability (i.e., is biodegradable in composting situations after disposal) or recycling capability can be considered eco-friendly.

The most commonly known novel type of regenerated fibre is Lyocell, which is produced from wood pulp by a viscose-like process but with a less hazardous environmental impact. Tencel is the brand name used for a type of Lyocell.

Fibres of regenerated protein were produced commercially in the 1930 – 1950 s and by today’s standards they would be considered natural, sustainable, renewable and biodegradable. Casein from milk was used by Courtaulds Ltd. to make Fibrolane and by Snia to make Lanital, groundnut (peanut) protein was used by ICI to make Ardil, Vicara was made by the Virginia-Carolina Chemical Corporation from zein (corn protein) and soybean protein fibre was developed by the Ford Motor Company [2].

Over recent years, fibres based on polylactic acid (PLA) have attracted increasing interest due to the fact that they lend themselves to manufacture from renewable resources, in particular, from corn-starch. One of the latest developments in new fibre researches is the use of bamboo fibre which is a sustainable material, capable of sustaining itself with minimal impact to the environment [3].

In this paper, the original research literature on the topic of new biodegradable materials to date was reviewed, with a particular emphasis on yarn properties made from biodegradable fibres and their application fields in textiles.

## BIODEGRADABLE MATERIALS

In the concern for a cleaner environment, new biodegradable materials, which would successfully replace or improve existing artificial and natural materials, are being searched for. New fibres are developed by using new technologies, such as genetic technology, biotechnology, nano-technology, microelectronics [3].

New fibres that are the result of new technologies and keep appearing on the market are nano-fibres made from several materials, i.e. genetically changed natural fibres such as regenerated cellulose fibres (Tencel), chemical fibres from naturally renewed sources (fibres from polylactic acid). Natural sources are also used for fibre making purposes, such as bamboo tree for bamboo fibres and soybean for soybean protein fibres.

### PLA fibres and their applications

Polylactic acid (PLA) is first manufactured by Cargill Dow in 2002. PLA fibres are synthetic but are derived from natural renewable resources. Thus, it is a biodegradable, bio-resorbable polymer that has good biocompatibility and excellent mechanical properties. Polylactic acid does not exist in nature and PLA fibres typically are made using lactic acid as the starting material for polymer manufacture. The lactic acid comes from fermenting various sources of natural sugars. These sugars can be provided from annually renewable agricultural crops such as corn or sugar beets. Two alternative chemical routes have been exploited in this respect. The first makes use of the polycondensation of appropriate monomers; the second entails so-called 'ring-opening polymerisation' [5], [6]. Attention has focused mainly on the ring-opening route, since it involves milder conditions than the polycondensation process.

Unlike other synthetic fibre materials with vegetable sources (e.g. cellulose), PLA is well suited for melt-spinning into fibres. Compared to the solvent-spinning process required for synthetic cellulose fibres, melt spinning allows PLA fibres to be made with both lower financial cost and lower environmental cost [3].

PLA fibres exhibit low moisture absorption and high wicking, offering benefits for sports and performance apparel and products. Other benefits of this fibre are low flammability and smoke generation, high resistance to ultra violet (UV) light that makes PLA suitable for performance apparel as well as outdoor furniture and furnishings applications. PLA fibres also have a low index of refraction, which provides excellent colour characteristics and lower specific gravity, making PLA lighter in weight than other fibres. Its mechanical properties are reported to be broadly similar to those of conventional PET [7], although its lower melting and softening temperatures clearly present a limitation on its use.

Notably, PLA is an important material in the medical industry and has been used for over 30 years. The mechanical properties and absorbability of PLA make it an ideal candidate for implants in bone and soft tissue, and for resorbable sutures [8, 9]. Ching-Wen Lou, et. al. [8] used twisted PLA multifilament and plied PLA yarns to fabricate an absorbable surgical suture that inhibits bacterial growth and promotes wound healing. Tensile strength and elongation properties were investigated for the twisted and plied PLA yarns with different twisting parameters. It was found that the breaking strength of twisted PLA plied yarn increased as the number of twists increased; however, after reaching the optimal strength twisted coefficient, the breaking strength started to decline. Elongation of untwisted PLA yarn was 28%, and that of twisted PLA yarn decreased to 26% as the PLA yarn was thinner in diameter than PLA plied yarn.

PLA is frequently used for biodegradable packing materials. However, numerous tests have shown that PLA is also suitable as matrix for the embedding of fibres in composites. Some products of natural fibre-reinforced PLA are already established in the market [10]. Beside plant fibres, man-made fibres based on renewable raw materials – e.g. viscose, rayon or Lyocell – can be used to reinforce PLA.

Zupin [11] investigated the mechanical properties of woven fabrics made from PLA, bamboo, soybean protein fibres (SPF) and cotton. It was found that biodegradable yarns differ from cotton yarns especially at tensile elongation that PLA has the highest tensile elongation. Comparison of fibre properties of biodegradable fibres were also presented in the study (table 1).

### Bamboo fibres and their applications

Regenerated bamboo fibre is obtained from the bamboo plant, which is an abundant and cheap natural resource. Regenerated cellulosic bamboo fibre was first manufactured in 2002 by Hebei Jigao Chemical Fibre Co. Ltd. in China [12]. Bamboo, as a regenerated cellulosic fibre, is being more widely used in the textile industry due to its features such as being antibacterial, soft feeling, easy dyeability, absorbancy, breathability and having a smooth texture. It's also the only 100% biodegradable textile material which does not cause any environmental pollution naturally recycling itself [13]. The thinness and whiteness degree of the fibre is similar to classic viscose.

In order to produce bamboo fibre, bamboo pulp is firstly refined from bamboo through a process of hydrolysis-alkalization and multi-phase bleaching. Then bamboo pulp is processed into bamboo fibre and impurities such as lignin and pectin are removed from bamboo. In order to improve the spinning properties of natural bamboo fibres, they are further subjected to a treatment by providing oil (emulsification oil) and then drying. Then the obtained fibres are treated by humidifying and providing oil [14]. Bamboo can be spun purely or blended with other materials such as cotton, hemp, silk, Lyocell (Tencel), Modal.

The most significant components in the bamboo's chemical constitution are those providing its extraordinary fungal and bacterial resistance. Thus, it has wide prospects in the field of hygiene products, medical suppliers, such as wet wipe, household wipes,

Table 1

| COMPARISON OF PHYSICAL AND MECHANICAL PROPERTIES OF BAMBOO FIBRES, PLA, SPF, COTTON, VISCOSE, WOOL AND PES [11] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Properties** | **Bamboo** | **Cotton** | **Viscose** | **PLA** | **PES** | **PA** | **SPF** | **Silk** | **Wool** |
| Length, mm | 38 - 76 | 25 - 45 | 30 - 180 | - | 32 - 150 | - | 38 - 76 | $3.5 \cdot 10^6$ - $9 \cdot 10^6$ | 50 - 200 |
| Fineness, dtex | 1.3 - 5.6 | 1.2 - 2.8 | 1.3 - 25 | - | 1.3 - 22 | - | 0.9 - 3 | 1 - 3.5 | 4 - 20 |
| Dry tenacity, cN/dtex | 2.33 | 1.9 - 3.1 | 1.5 - 3.0 | 3.2 - 5.5 | 3 - 7 | 3 - 6.8 | 3.8 - 4.0 | 2.4 - 5.1 | 1.1 - 1.4 |
| Wet tenacity, cN/dtex | 1.37 | 2.2 - 3.1 | 0.7 - 1.11 | - | 2.4 - 7 | 2.5 - 6.1 | 2.5 - 3.0 | 1.9 - 2.5 | 1.0 |
| Dry breaking extension, % | 23.8 | 7 - 10 | 8 - 24 | 20 - 35 | 20 - 50 | 26 - 40 | 18 - 21 | 10 - 25 | 20 - 40 |
| Moisture regan, % | 13.3 | 8.5 | 12.5 - 13.5 | 0.4 - 0.6 | 0.4 | 4.5 | 8.6 | 11.0 | 14.5 |
| Density, g/cm3 | 0.8 - 1.32 | 1.5 - 1.54 | 1.46 - 1.54 | 1.25 - 1.27 | 1.36 - 1.41 | 1.15 - 1.20 | 1.29 - 1.31 | 1.34 - 1.38 | 1.32 |

baby diaper, sanitary napkin, medical bandage, disposable sheet, inside lining, base cloth, nonwoven textiles, nano-technological products. Bamboo has been widely used in household products and extended to industrial applications due to advances in processing technology and increased market demand [15].

On the basis that there is uncountable lumen distribution on the cross-section of bamboo fibres bamboo fibres can absorb and evaporate moisture instantly. Therefore, "Breathing Fibre" is a name given to natural bamboo fibre. Thus, various downstream products are produced with bamboo fibres such as towel, bath towel, bed textile, sock, underwear, sport clothing since fabric made by bamboo yarn is quite breathable and cool and has great drape. The porous structure of bamboo fibres are presumed to be responsible for their high water absorption capacity. The micro pores and spaces in the cross-section of the bamboo fibre provide breathability and cool feeling to the bamboo fibre [13].

Bamboo fibres are also used in various textile products that have been used in construction materials, decorating items, furniture and high performance composite materials for years [12, 16, 17]. Bamboo fibres also attracted interest as a sustainable reinforcement fibre in (polymer) composite materials, due to specific mechanical properties which are comparable to glass fibres [18]. In this case (as opposed to bamboo fabrics for clothing) bamboo fibres are extracted through mechanical needling and scraping or through a steam explosion process where bamboo is injected with steam and placed under pressure and then exposed to the atmosphere where small explosions within the bamboo due to steam release allows for the collection of bamboo fibre.

Majumdar et. al. [19] investigated 100% bamboo, 50%:50% cotton:bamboo and 100% cotton yarn and knitted fabric properties. In the research, it was found that bamboo blended yarns are significantly less hairy than their cotton counterpart. It was also indicated that the yarns made from bamboo fibres have the lower values of diameter, initial modulus and bending rigidity than those of equivalent cotton yarns. The thermal conductivity of knitted fabrics reduces as the proportion of bamboo fibre increases in the yarn.

Guohe [20] investigated the tensile properties of bamboo pure yarn and bamboo-cotton blended yarns. It was indicated in the study that when the blending ratio of bamboo cotton bended yarn was about 50/50, the blended yarn had lower strength and worse tensile property, and with the increasing of bamboo fibre content, the breaking tenacity of blended yarn was enhanced. Sekerden [21] also investigated the effect of the bamboo fibre on performance properties of yarn and used ring-spun 19.68 tex 100% bamboo yarn, 100% cotton yarn and bamboo/cotton yard, blended in two different ratios for this purpose. It was indicated in the study that as the ratio of bamboo in the blend increased, unevenness of yarn decreased and that the ratio of bamboo fibre did not have an apparent significant on the yarn tenacity and elongation.

Blending wool fibre with polyester fibre and, in particular, wool fibre with regenerated bamboo fibre, produced fabrics with better moisture management properties than fabrics in wool fibre or regenerated bamboo fibre without blending [22].

## Tencel® Sun fibres and their applications

Lyocell is the first in a new generation of cellulosic fibres made by a solvent spinning process. The first samples were produced in 1984 and commercial production started in 1988 [23]. Lyocell is a man-made fibre produced in an environmentally-friendly process from wood pulp and Tencel is a brand name for Lyocell fibres.

Tencel® absorbs excess liquid and quickly releases it again into the atmosphere. Fibrils are tiny components (little "hairs") which make up the fibre. The controlled and regular arrangement of these tiny fibrils leads to new functional properties. The fibrils are hydrophilic and optimize the absorption of moisture with excellent cooling properties.

Lyocell is created through a process called solvent spinning. The wood pulp is dissolved in N-methylmorpholine N-oxide, creating a solution called

"dope", which is then pushed through a spinneret to form the individual fibres. After the dope has been spun into Lyocell fibres, the fibres are washed and the chemicals retrieved from the water are purified and recycled [24].
Lyocell blends well with other fibres, including cotton, viscose, linen, wool, silk, nylon and polyester. Lyocell adds strength to the yarn as well as enhancing the performance and aesthetic properties of the final fabrics [23].
Lenzing presented Tencel Sun, a new Tencel fibre that provides superior solar protection especially designed to meet the performance and sustainability demands of the outdoor apparel market in 2009. Tencel Sun is made from wood, a natural, renewable raw material making the fibre 100% bio-degradable. Additionally, the fibre's permanent solar protection cannot be washed out and it is manufactured with a process that is based on sustainable principles. Furthermore, Lenzing has won the 2011 Ispo (International Trade Fair for Sports Equipment and Fashion) Eco Responsibility Award in the "Fabrics and Fibres" category for its Tencel Sun fibres.
Tencel Sun is the outdoor fibre for the highest demands. It is by nature especially suited for clothing in which moisture absorption plays a big role. The fibre offers a wide range of important functions for sportswear, such as perfect moisture management, skin friendliness and temperature balance. Permanent pigment incorporation accounts for the functionality of Tencel Sun. The pigment comes from minerals and provides a long-term protection from solar radiation. Even after washing the clothing several times, Tencel Sun maintains its effectiveness. Tests show that a UV protection factor (UPF) of up to 110 can be reached. The fibre is therefore the perfect alternative to polyester fibres and conventionally finished fabrics with solar protection.

### Soybean protein fibres (SPF) and their applications

Developments in biodegradable fibres from renewable resources in the late twentieth century have revived interest in man-made fibre equivalent to wool. The development of a wool-like fibre from soya beans is a story of technological innovation [23].
A soy protein fibre (SPF) is the only plant protein fibre and a man-made fibre, manufactured in China. It is a liquefied soy protein that is extruded from soybean after extraction of oil, and processed mechanically to produce fibres by using new bioengineering technology. Fibres are produced by wet spinning, and stabilized by acetylating, and finally cut into short staples after curling and thermoforming [3, 23]. Reddy and Yang [26] obtained technical fibres from soybean straw by a simple alkaline extraction and studied the composition, structure and properties of the fibres. As a result of this study, the structure and properties of the technical fibres obtained from soybean straw indicates that the fibres could be suitable for use in textile, composite and other industrial applications.
SPF have cashmere like handle, good draping property, moisture absorption, good colour fastness and natural bacteria resistance. It can be blended with cashmere, wool, silk, cotton, polyester and synthetic fibres. SPF and its blends with various fibres are used in the production of sweater, underwear, towel, bedding, shirt, T-shirt and blanket.
Soybean protein fibre contains 18 amino acids necessary for the human body, is characterized by good affinity with skin, soft handle and excellent penetrability, and especially demonstrates obvious advantages in knitting garments. With the functions and effects of bacterial inhibition, far infrared, negative ions and resistance to ultraviolet, it is a super material to fabricate top-grade knitting underwear and household textiles.
Kavusturan et. al. [27] also used comfort fibres like Tencel, bamboo, modal, soybean, 50/50% soybean-Tencel and conventional fibres like viscose and cotton for the production of chenille yarns. In the study, the influence of chenille yarn parameters like pile and core fibre type on fabric abrasion and bending behaviour was investigated. It was indicated that fabrics produced using chenille yarns with soybean and 50/50% soybean-Tencel blend pile fibres showed moderate abrasion resistance compared with the other types.
The breaking strength of single filament of this fibre is over 3.0 cN/dtex, higher than the strength of wool, cotton and silk, and only slightly less than terylene and other commonly used high strength fibres [28].
Zupin [3] investigated tensile properties of fabrics with bamboo, PLA and SPF weft yarns and cotton warps. It was determined that among the fabrics woven in plain weave, the fabric with SPF yarn in weft distinguished with the highest tensile strength.

## CONCLUSIONS

The scale of human activity has become so large that it is altering ecosystems faster than the possible sustainability model. This fact threatens the integrity of ecosystems and their capacity to provide quality living for future generations [29]. Demand from consumers for eco-friendly products is growing stronger. Thus, the improvement of environmental performance of products is the main focus for many companies. While organic fibres are meeting part of this need, they are unlikely to be produced in sufficient quantities to meet all the demand for eco-friendly fibre [2].
New biodegradable fibres should compete well with organic and other eco-friendly fibres based on their environmental credentials. Once produced, they are able to be processed on conventional textile machinery. They can be used with blending various fibres types and have large application area. Potential product markets where they may have competitive advantage are in eco-friendly apparel as well as technical and industrial applications.

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# Relations for programming of beams revolutions at warp wrapping with constant variations of yarns tension

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**REZUMAT – ABSTRACT**

**Relații utilizate în programarea turației sulurilor la înfăşurarea urzelilor cu variații constante ale tensiunii firelor**

*În acest articol sunt prezentate principiile de stabilire a relațiilor de calcul utilizate în programarea calculatoarelor, care asigură reducerea ciclică a turației sulurilor, pe baza comenzilor date de cilindrul oscilant de tensionare. La înfăşurarea urzelii pe maşinile de încleiat sau de reunit urzeli, raza de înfăşurare creşte continuu. Pentru a evita supratensionarea în timpul creşterii vitezei sulului este necesară reducerea turației acestuia. La creşterea tensiunii cu o valoare constantă T, cilindrul oscilant de tensionare comandă, prin limitatorului de poziție, reducerea turației sulului la o valoare care asigură micşorarea tensiunii cu valoarea T. Comanda este transmisă variatoarelor de turație mecanice sau motoarelor controlate de către calculatorul de proces al maşinii. La fiecare ciclu de autoreglare, pe baza principiului prezentat în articol, este eliminată incertitudinea autoreglării turației prin stabilirea pozițiilor limită ale cilindrului oscilant de tensionare.*

*Cuvinte-cheie: reducere ciclică, program, turație, sul, urzeală, tensiune, autoreglare, relații tehnologice*

**Relations for programming of beams revolutions at warp wrapping with constant variations of yarns tension**

*In this paper is presented the principle of establishing calculus relations for the computer software that ensures the cyclic reduction of beam rotation speed, based on commands given by the cylinder oscillating tension. For wrapping the warp sizing machines or warp former, winding radius increases continuously. To avoid yarns overstressed due to increased wrapping speed, beam rotating speed reduction is required. The increased tension with a certain amount T, tension roller down and send a command position limiter for decrease beam rotating speed. The command to reduce rotating speed can be achieved by mechanical variable speed device or variable speed motors controlled by computer. At each cycle of self-regulation, the principle presented in the paper, remove the uncertainty of self-regulation of these rotating speed limits only on the positions of the oscillating cylinder measuring warp tension.*

*Key-words: cyclic reduction, software, rotation speed, beam, warp, tension, self-regulation, technological relationse*

In wrapping of the warps on sizing machines or warp former, winding radius $R_x$ (fig. 1) is increasing. To avoid yarns overstressed as a result of increased winding speed is required beam *5* rotation speed reduction. The warp *1* tension, on the area between drawing roller *2* and beam *5*, is followed by oscillating cylinder *3*, which is in equilibrium under the action of tension *T* and force *F* developed by mechanical and pneumatic systems of machines. The increased tension with a certain amount *T*, the tension roller *3* down and forward to position limiter *4* the reduction command of rotation speed *5*. The reduce command of rotation speed can be achieved by mechanical variable speed device or variable rotation speed motors controlled by computer machines.

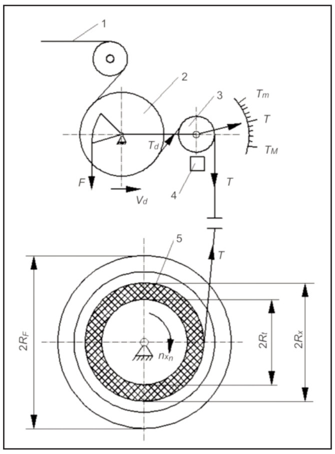

Fig. 1. Technological principle:
*1* – warp; *2* – drawing cylinder for warp delivery with speed $v_d$; *3* – oscillating cylinder for warp tension measurement; *4* – position limiter; *5* – warping beam; *T*, $T_m$ and $T_M$ – the position of oscillating cylinder *3* on the scale of warp tension in the moments to achieve minimum allowed tension and maximum allowed tension

Limiter position *4* (or the oscillation angle) is operated at all times in which the tension reaches maximum allowed wire $T_M = T_m + \Delta T$. In these moments, limiter position can transmit a command to record the number of cycles of self-regulating to a special counter for these cycles. Number *n* of these cycles of self-regulating recorded on their counter, the computer can be used to decrease cyclic machine rotating speed beam (beam engine) with the increase of wrapping diameter.

In this paper is shown the principle of establishing relations for computer software that provide the cyclic reduction of beam rotating speed based on commands given by the oscillating tension cylinder.

## TECHNOLOGICAL PRINCIPLE FOR ESTABLISHMENT OF CALCULUS RELATIONS

In the figure 2 are presented basical schemes for technological relations establishing which can be used in the computer software for cyclical commands used to reduce rotating speed wrapping beams, which ensures constants tension variations yarns, $\Delta T$ = constant.

Inside of each control cycle, in the growth phase tension from $T_m$ to $T_M$ (fig. 2), beam rotation speed remains constant at the values: $n_{x0}$ in the initially cycle 0, $n_{x1}$ in the cycle 1, $n_{x2}$ in the cycle 2 etc. (fig. 2*b*). At the end of each cycle at the time of contact with the limiter *7*, the tension drops from $T_M = T_m + \Delta T$ or $T_M = T_d + \Delta T_g$, to value $T_M = T_d + \Delta T_0$, due to a decrease rotation speeds from $n_{x0}$ to $n_{x1}$, from $n_{x1}$ to $n_{x2}$ etc. The increases of tensions in each cycle with the value $\Delta T$ (between $T_m$ and $T_M$ values – fig. 2*a*) is achieved due to increased wrapping speed on beam, providing the speed $v_m$ which ensure tension $T_M = T_d + \Delta T_0$ (*A, C, E* ...), to speed $v_M$ that determines the tension $T_M$ (*B, D, F* ...). It will consider yarns tension increases to wrapping on beam ($\Delta T_0$, $\Delta T$ and $\Delta T_g$) elongations proportional yarn this area (delivery cylinder and beam), i.e. with increasing speed from $v_d$ to $v_m$, from $v_m$ to $v_M$ and from $v_d$ to $v_M$. This calculation hypothesis is adopted, because yarns tension is far below the breaking strength, domain tensioning where the elastic component elongation is dominant. It also increases tension only occur in the restricted limits, which allow to narrow the field to be able to use the same coefficient of proportionality between tension and elongation, created only by the difference in speeds. It will use proportional relationships between $\Delta T_0$ and $\Delta T_g$ tension increases from $T_d$, respectively $\Delta T$ from $T_m$ (fig. 2*a*) and increases the speed that produced them: $\frac{v_m - v_d}{v_d}$ and $\frac{v_M - v_d}{v_d}$, respectively $\frac{v_M - v_m}{v_m}$. Proportionality relations will be written for pairs of points in each cycle of self regulating, that *A-B, C-D, E-F* etc. (fig. 2).

In all points *A, C, E* etc. occur the relations (1), (6):

$$\Delta T_0 = K_p \frac{v_M - v_d}{v_d} \qquad (1)$$

In all points *B, D, F* etc. occur the relations (2):

$$\Delta T = K_p \frac{v_M - v_m}{v_m} \quad \text{or} \quad \Delta T_g = K_p \frac{v_M - v_d}{v_d} \qquad (2)$$

where:

$K_p$ represents the proportional coefficient between yarn tensions and yarn elongation created by increasing the speed.

Through the reporting of increases in tension between points $A_0$ and *A, B* and *C, D* and *E, F* and *G* etc., it gets the same general relation to the ratio, for all cycles of self-regulating (3):

$$\frac{\Delta T}{\Delta T_0} = \frac{(v_M - v_m)v_d}{(v_m - v_d)v_m}; \qquad (3)$$

$$\Delta T_0 v_d (v_M - v_m) = \Delta T\, v_m (v_m - v_d)$$

Maximum speed $v_M$ is the speed which provides maximum tension $T_M$, i. e. the tension that made and the contact with the position limiter. Its value is known technological, could eventually be experimentally determined and displayed on the computer, at the beginning of the beam. Therefore, it must be calculated minimum speed $v_m$ which will meet the minimum tension $T_m$, and which ensure average tension $T$ = constant (fig. 2*a*).

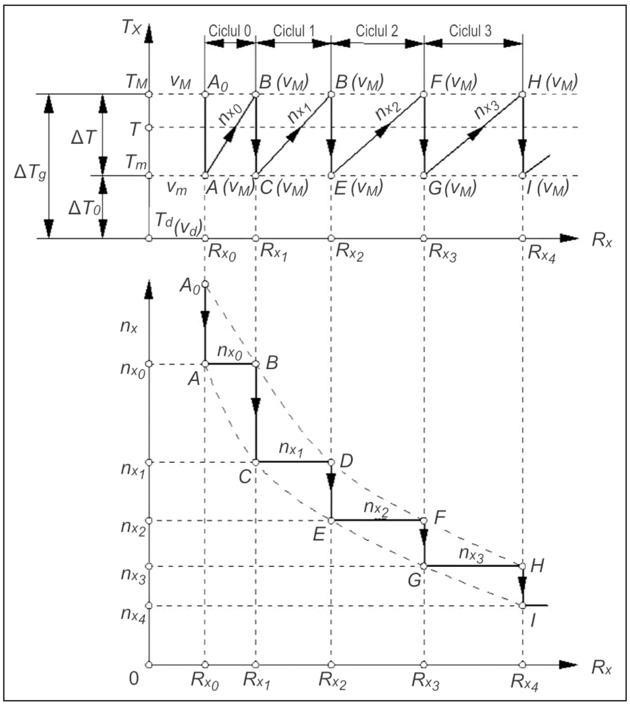


Fig. 2. The technological principle for the calculus relations:

$T$ – medium tension of yarns technological adopted (constant); $T_m$ – minimum allowable technological tension at each cycle; $T_M$ – maximum tension to each cycle; $T_d$ – constant yarns tension from the drawing cylinder and warp delivery cylinder; $\Delta T_0$ – increase the minimum allowable tension yarns to the $T_d$ value; $\Delta T$ – constant increase tensions between the minimum $T_m$ and maximum $T_M$ allowed within each cycle of self regulating; $\Delta T_g$ – maximum steady increase, tensions between $T_d$ and $T_M$; $R_{x0}$, $R_{x1}$, $R_{x2}$, $R_{x3}$, ... $R_{xn}$ – wrapping radius of the warp on beams in moments of starting self regulating cycles (cycle 0, cycle 1, cycle 2, cycle 3, cycle ... *n*); $n_{x0}$, $n_{x1}$, $n_{x2}$, $n_{x3}$, ... $n_{xn}$ – rotating speeds of wrapping beam remained constant during the wrapping cycle; $v_d$ – minimum delivery speed of warp in the wrapping zone (constant); $v_m$ – minimum speed of wound on beam at the beginning of each cycle of self regulating (points *A, C, E, G, I*); $v_M$ – maximum wrapping speed on beam at the end of each cycle of self regulating (points B, *D, F, H*)

Minimum speed $v_m$ can be determined by reporting tensions $\Delta T_g$ and $\Delta T_0$, resulting in equation (4):

$$\frac{\Delta T_g}{\Delta T_0} = \frac{v_M - v_d}{v_m - v_d} \qquad (4)$$

$$\Delta T_0 (v_M - v_d) = \Delta T_g v_m - \Delta T_g v_d$$

It obtains minimum wrapping speed on beam (5):

$$v_m = \frac{\Delta T_0 (v_M - v_d) + \Delta T_g v_d}{\Delta T_g} \qquad (5)$$

It can be calculated the minimum rotation speed of the first cycle of self-regulating, $n_{x0}$ as:

$$n_{x0} = \frac{v_m}{2\pi R_{x0}} \quad \text{if} \quad R_{x0} = R_t, \quad \text{then} \quad n_{x0} = \frac{v_m}{2\pi R_t} \qquad (6)$$

The wrapping radius at the end of some cycle $n - 1$ and the beginning of the next cycle $n$ is determined by relations (7) – (11):

Cycle 0:

$$R_x = R_{x0} \qquad (7)$$

Cycle 1:

$$R_x = R_{x1} = R_{x0}\frac{v_M}{v_m}$$

$$R_{x1} = R_{x0}\frac{v_M \Delta T_g}{\Delta T_0(v_M - v_d) + \Delta T_g v_d} \qquad (8)$$

Cycle 2:

$$R_x = R_{x2} = R_{x1}\frac{v_M}{v_m}$$

$$R_{x2} = R_{x0}\left(\frac{v_M}{v_m}\right)^2 \qquad (9)$$

$$R_{x2} = R_{x0}\left(\frac{v_M \Delta T_g}{\Delta T_0(v_M - v_d) + \Delta T_g v_d}\right)^2$$

Cycle 3:

$$R_x = R_{x3} = R_{x2}\frac{v_M}{v_m}$$

$$R_{x3} = R_{x0}\left(\frac{v_M}{v_m}\right)^3 \qquad (10)$$

$$R_{x3} = R_{x0}\left(\frac{v_M \Delta T_g}{\Delta T_0(v_M - v_d) + \Delta T_g v_d}\right)^3$$

Generally, in the cycle $n$, $R_{xn}$ will be:

$$R_{xn} = R_{x0}\left(\frac{v_M \Delta T_g}{\Delta T_0(v_M - v_d) + \Delta T_g v_d}\right)^n \qquad (11)$$

The beam revolution speed, inside of each cycle $n$, will be:

Cycle 0:

$$n_x = n_{x0} \qquad (12)$$

Cycle 1:

$$n_{x1} = n_{x0}\frac{\Delta T_0(v_M - v_d) + \Delta T_g v_d}{v_M \Delta T_g} \qquad (13)$$

Cycle 2:

$$C_{n_x} = n_{x2} = n_{x0}\frac{R_{x0}}{R_{x2}}$$

$$(14)$$

$$n_{x2} = n_{x0}\left[\frac{\Delta T_0(v_M - v_d) + \Delta T_g v_d}{v_M \Delta T_g}\right]^2$$

Cycle 3:

$$n_x = n_{x3} = n_{x0}\frac{R_{x0}}{R_{x3}}$$

$$(15)$$

$$n_{x3} = n_{x0}\left[\frac{\Delta T_0(v_M - v_d) + \Delta T_g v_d}{v_M \Delta T_g}\right]^3$$

..............................................................

Cycle $n$:

$$n_x = n_{xn} = n_{x0}\frac{R_{x0}}{R_{xn}}$$

$$(16)$$

$$n_{xn} = n_{x0}\left[\frac{\Delta T_0(v_M - v_d) + \Delta T_g v_d}{v_M \Delta T_g}\right]^n$$

It's obtained a new relationship for calculation and control of rotating speed of wrapping beam by computer in any cycle $n$ of self-regulating. This relationship will allow the use of computer software to maintain an average tension $T$ constant (on average between $T_M$ and $T_m$). The control variable component of the machine computer control will comprise the exponent $n$ from equation (16), which can be countdown by impulses received from the position limiter of the maximum tension $T_m$.

Total number of self-regulations from the beginning and end of a beam ($n = n_t$) is calculated according to the final radius ($R_{xn} = R_{xf}$) and support tube radius ($R_x = R_t = R_{x0}$) using equation (11).

Follows:

$$n_t = \frac{\ln \dfrac{R_{xf}}{R_{x0}}}{\ln\left[\dfrac{v_M \Delta T_g}{\Delta T_0(v_M - v_d) + \Delta T_g v_d}\right]} \qquad (17)$$

## WORKING STEPS FOR USE OF NEW TECHNOLOGICAL RELATIONS FOR ROTATING SPEED SELF REGULATION OF WRAPPING BEAM

### Introduction of constant technological and constructive set of characteristics in software

Constant technological and constructive set of characteristics in software are given by numerical example in table 1.

### Introduction in the software of technological relationship

Introduction in the software of technological relationship to determine the tensions of yarns, warp tensions and the limits of variation, respectively:

- Technological tensions of yarn (fig. 2) in zone of warp wrapping on beam at the sizing machine is determined by relations (2) and (3):

$$T_d = K_{td}T_t; \quad T_m = K_{tm}T_t; \quad T_M = K_{tM}T_t; \quad (18)$$

- Technological tensions of warp in wrapping zone, necessary to adjust the mechanical system of compensation and measurement of tension by

Table 1

| CONSTANT TECHNOLOGICAL AND CONSTRUCTIVE CHARACTERISTICS | | | |
|---|---|---|---|
| **Constant characteristics used in software** | **Adopted values for different warps** | | |
| | $U_1$ | $U_2$ | $U_3$ |
| Yarn density, $T_t$, in tex | 20 | 30 | 50 |
| Number of yarns on beam, $F_t$ | 4 000 | 3 400 | 2 700 |
| Adopted coefficient for yarn tension, specific tex in the delivery cylinder, $K_{td}$, în cN/tex ($K_{td}$ = 0,75 – 1.1 cN/tex) | 1 | 0.9 | 0.75 |
| Minimum tension coefficient adopted in the zone of wrapping on beam, $K_{tm}$, în cN/tex ($K_{tm}$ = 1 – 1.2 cN/tex) | 1.1 | 1 | 1 |
| Maximum tension coefficient adopted in the zone of wrapping on beam, $K_{tM}$, în cN/tex ($K_{tM}$ = 1,2 – 1.5 cN/tex) | 1.4 | 1.3 | 1.25 |
| Radius of support tubes on wrapping, $R_t$, in m | 0.06 | 0.06 | 0.06 |
| Final radius of wrapping beam, $R_{xf}$, or a beam flange, $R_F$, in m | 0.35 | 0.35 | 0.35 |
| Peripheral speed of drawing cylinder and delivery cylinder in test phase, at the begining of warp wrapping, $v_{dp}$, in m/min. ($v_{dp}$ = 0,5 – 5 m/min.) | 1 | 1 | 1 |
| Peripheral speed of drawing cylinder and delivery cylinder of warp, on duty of sizing machine, $v_d$, in m/min. | 60 | 50 | 40 |
| Initial wrapping radius on beam, $R_{x0}$; usually very close to $R_t$, in m | 0.0603 | 0.0604 | 0.0605 |

tensioning oscillating cylinder, will be determined with relationships:

$$T_d = T_d F_t; \quad T_{mu} = T_m F_t; \quad T_{Mu} = T_M F_t; \qquad T_u = \frac{T_{mu} + T_{Mu}}{2} \tag{19}$$

where:

$T_{du}$ is warps tension in drawing and delivery cylinders zone;

$T_{mu}$ – minimum tension of warp at beam wrapping;

$T_{Mu}$ – maximum tension of warp at beam wrapping;

$T_u$ – average tension of warp at beam wrapping;

$F_t$ – number of yarns in warp.

- Tension increasing $\Delta T_0$ and $\Delta T_g$ (fig. 2) of each yarn, will be determined with relations:

$$\Delta T_0 = T_m - T_d; \qquad \Delta T_0 = (K_{tm} - K_{td})T_t \tag{20}$$

$$\Delta T_g = T_M - T_d; \qquad \Delta T_g = (K_{tM} - K_{td})T_t \tag{21}$$

## Experimental detemination of speed and tension ratio

- Adjust the pressure value to balance the oscillating cylinder, corresponding to the tension value $T_u$ of warp, according to its characteristics and the manufacturer's recommendations.
- Start the machine to trial speed test $v_{dp}$, respectively initial test rotation speed of beam $n_{xp} = v_{dp}/R_t$, and the warp tension $T_u$.
- Slowly increase the rotation speed wrapping beam to the drawing and delivery cylinder ($v_{dp}$ remains constant) until the warp tension becomes equal with $T_{Mu}$, value determined by computer and displayed on the computer as a specific constant warp. Value $n_{xp} = n_{xpM}$ of beam rotating speed achieved when $T_u = T_{Mu}$ is recorded computer that in kinematic parameters sample.
- Value $T_{Mu}$, of warp tension reached should correspond with moment when the tensioning oscillating cylinder reaches the limiter position. To avoid excessive increases tension in warp is acting on the tension adjustment system (i.e. the pressure cylinder piston as opposed to descent oscillating cylinder). It can record initial wrapping radius value on roll $R_{x0}$, if is increased significantly from $R_t$.
- The computer will determine:
  - speed ratio which ensure maximum tension $T_M$, as: $i_{Mp} = v_{Mp}/v_{dp}$.
  - value $i_{Mp} = i_M$ must remain in the computer as a constant determined experimentally and to be used of the duty regime, i. e. at any speed $v_d$;
  - maximum speed on duty regime will be $v_M = v_d\, i_M$, which will provide same maximum tension of warp, $T_M$ and $T_{Mu}$, on duty;
  - minimum wrapping speed $v_m$ will be determined with relation (5) and will ensure the minimum warp tension $T_m$ and $T_{mu}$;
  - rotating speed, on duty, from cycle 0 of self-regulating is determined with classical relation, $n_{x0} = v_m/2\pi R_{x0}$;
  - value $n_{x0}$ will remain registered in the computer and will serve to determine self-regulation of beam rotating speeds in each cycle of self-regulating, $n_{xn}$.

Table 2

| TECHNOLOGICAL PARAMETERS DETERMINED BY PROCESS COMPUTER OF SIZING MACHINE AND SELF REGULATING ROTATING SPEED OF BEAM | | | | |
|---|---|---|---|---|
| **Calculated and self-regulating parameters by computer** | | **Determined and automatically adjusted values** | | |
| | | $U_1$ | $U_2$ | $U_3$ |
| Yarn tension in drawing and delivery cylinder zone, $T_d$, in cN | | 20 | 27 | 37.5 |
| Minimum allowed yarn tension in wrapping zone, $T_m$, in cN | | 22 | 30 | 50 |
| Maximum allowed yarn in wrapping zone, $T_M$, in cN | | 28 | 39 | 62.5 |
| Minimum allowable increasing of yarn tension in wrapping zone to $T_d$, $\Delta T_0$, in cN | | 2 | 3 | 12.5 |
| Maximum allowable increasing of yarn tension in wrapping zone to $T_d$, $\Delta T_g$, in cN | | 8 | 12 | 25 |
| Average allowable of yarn tension in wrapping zone, $T$, in cN | | 25 | 34,5 | 56.25 |
| Minimum tension of warp at wrapping, $T_{mu}$, in N | | 880 | 1020 | 1350 |
| Maximum tension of warp at wrapping, $T_{Mu}$, in N | | 1120 | 1326 | 1687.5 |
| Average tension of warp at wrapping, $T_u$, in N | | 1000 | 1173 | 1518.75 |
| Starting rotating speed of empty beam in trial test, $n_{xp}$, in rot./min. | | 2.65 | 2.65 | 2.65 |
| Maximum allowed rotating speed in trial test, $n_{xpM}$, in rot./min. (experimental) | | 2.68 | 2.69 | 2.7 |
| Maximum allowed speed in trial test, $v_{Mp}$, in m/min. (experimental) | | 1.0103 | 1.0141 | 1.0179 |
| Ratio between maximum wrapping speed in trial test, $v_{Mp}$ and speed of drawing and delivery cylinder, $v_{dp}$; $i_{Mp} = v_{Mp}/v_{dp}$ (may be adopted depending on yarns) | | 1.0103 | 1.0141 | 1.0179 |
| Maximum wrapping speed on duty, $v_M$, in m/min. | | 60.62 | 50.71 | 40.72 |
| Minimum wrapping speed on duty, $v_m$, in m/min. | | 60.16 | 50.18 | 40.36 |
| The calculated total number of self regulating cycles, $n_t$ | | 228.32 | 178.56 | 199.02 |
| The entire part of number $n_t$, calculated, $n_t^*$ | | 228 | 167 | 199 |
| The rotating speed of wrapping beam in initial self-regulating cycles, in rot./min. | $n_{x0}$ | 158.77 | 132.22 | 106.17 |
| | $n_{x1}$ | 157.55 | 130.84 | 105.23 |
| | $n_{x2}$ | 156.35 | 129.47 | 104.31 |
| The rotating speed of wrapping beam in final self-regulating cycles, in rot./min. | $n_{x \cdot n_t^* - 2}$ | 27.85 | 2343 | 18.68 |
| | $n_{x \cdot n_t^* - 1}$ | 27.63 | 23.19 | 18.52 |
| | $n_{x \cdot n_t^*}$ | 27.42 | 22.94 | 18.35 |
| Initial radius of self regulating in first cycles, in mm | $R_{x0}$ | 60.30 | 60.40 | 60.50 |
| | $R_{x1}$ | 60.77 | 61.04 | 61.04 |
| | $R_{x2}$ | 61.24 | 61.68 | 61.58 |
| Final radius of self regulating in last cycles, in mm | $R_{x \cdot n_t^* - 2}$ | 343.81 | 340.83 | 343.83 |
| | $R_{x \cdot n_t^* - 1}$ | 346.47 | 344.42 | 346.88 |
| | $R_{x \cdot n_t^*}$ | 349.14 | 348.05 | 349.95 |

## Cyclic self-regulation of wrapping beam rotating speed

Cyclic self-regulation of wrapping beam rotating speed based on commands of process computer:

- After turning the machine to duty speed $v_d$ and the beam rotation speed $n_{x0}$ start wrapping corresponding point *A* (fig. 2*a*), where tension yarns have adopted minimum value $T_m$;
- During the wrapping every time the yarn tension reaches $T_M$ and warp tension $T_{Mu}$, the oscillating cylinder down and contact the position limiter. At each contact of this limiter device, the self-regulating timer cycle will register a new value *n* self-regulating-cycle;
- Each new value *n* registered will be transmitted to machine computer, which based on relation (16) will determined a new value of rotating speed $n_{xn}$ that begun self-regulating cycle *n*. The command will effectively to beam motor which have variable rotation speed. In table 2 are presented the obtained results by computers which would use the technological formulas of calculus.

## CONCLUSIONS

- There have been established relationships for calculation wrapping radius where is necessary to command cyclic reduction of the beam's rotating speed, useful for computer software adjusting engine speed of beams rotation.

- There have been established relationships for calculation beam rotation speeds in all their self-regulating cycles, to ensure the maintenance of constant cyclical increases of yarns tension, $\Delta T = ct$.
- Effective calculation of wrapping beam rotating speed, at every cycle of self-regulating and using the computer to adjust of this, according to the principle presented in the paper, remove the uncertainty of self-regulation of these speed only on the limit positions of the oscillating cylinder, of measuring warp tension.
- Applying this principle of self-regulating, based on calculations requires accurate measurement of tension increases ($\Delta T_0$, $\Delta T$, $\Delta T_g$) and initial wrapping speed ($v_M$ and $v_m$), which be used as constant values, for a given warp, in programming system rotating speed.


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# DOCUMENTARE

## Materii prime

### TWARON BLACK – PRIMA FIBRĂ ARAMIDICĂ DE CULOARE NEAGRĂ

Compania ***Teijin Aramid***, cu sediul în Olanda, a lansat producția de fibre aramidice *Twaron Black*.
*Twaron Black* este prima fibră aramidică de culoare neagră, care posedă aceleaşi caracteristici ca şi fibra standard, produsă de compania Teijin.
De regulă, fibra Twaron este de culoare galben auriu, din cauza procesului chimic, iar aramida este, prin natura sa, dificil de vopsit.
La cererea clienților din industria articolelor pentru sport şi din industria navală, compania Teijin Aramid s-a implicat în dezvoltarea şi producerea acestor fibre şi în alte culori. Astfel, s-a investigat posibilitatea de a produce fibre aramidice de culoare neagră.
Pentru a produce fibre complet negre, compania Teijin Aramid a modificat procesul de producție, astfel încât fibra să poată fi injectată cu vopsea neagră. *„Au fost produse deja fibre aramidice de culoare neagră, însă acestea nu prezentau aceleaşi caracteristici ca şi fibrele aramidice Twaron standard... Fibrele aramidice sunt frecvent utilizate în domeniul sporturilor nautice şi al echipamentelor pentru sport, însă în combinație cu carbonul. De exemplu, se poate vedea, adesea, galbenul auriu al aramidei în navigația cu iahturi sau canoe. Folosind fibrele Twaron Black, acestea devin parte din ansamblu şi, astfel, îşi mențin aceleaşi caracteristici ca şi fibrele standard“* – a explicat Gert Frederiks, director general al companiei Teijin Aramid.
Fibra Twaron Black va fi lansată cu ocazia celei mai mari curse de navigație oceanică cu iahturi, Volvo Ocean Race.
Având trei spații de producție în Olanda, compania Teijin Aramid deține peste jumătate din producția de fibre aramidice din lume.

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# Combined effect of perspiration, rubbing and light over the fading of reactive dyed cotton fabrics

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**REZUMAT – ABSTRACT**

**Efectul combinat al transpirației, frecării şi luminii asupra decolorării țesăturilor din bumbac vopsite cu coloranți reactivi**

*Determinarea rezistenței la lumină este o problemă foarte importantă în testarea performanțelor materialelor textile din bumbac vopsite cu coloranți reactivi, în special în timpul verii şi în țările cu mult soare. Există unii factori care influențează rezistența la lumină, în afara sursei de lumină şi a tipului de colorant. Transpirația şi frecarea, împreună cu efectul luminii sporesc, de asemenea, procesul de decolorare, dar, din păcate, nu există suficiente cunoştințe despre efectele combinate ale luminii, transpirației şi frecării asupra modificării culorii. În prezentul studiu, toți aceşti factori care determină decolorarea țesăturilor din bumbac vopsite cu coloranți reactivi au fost analizați atât separat, cât şi împreună.*

*Cuvinte-cheie: rezistență la lumină, transpirație, frecare, coloranți reactivi, materiale textile din bumbac vopsite, decolorare*

**Combined effect of perspiration, rubbing and light over the fading of reactive dyed cotton fabrics**

*Determination of light fastness is a very important issue in the performance testing of reactive dyed cotton textile materials, especially in summer and in the countries that have more sunlight. There are some factors affecting to the light fastness besides the light source and kind of the dyestuff. Perspiration and rubbing together with the effect of light also increase fading problem, but unfortunately there is not satisfactory knowledge about the combined effects of light and perspiration and rubbing over color change. In this study, these factors affecting to the color fading of reactive dyed cotton fabrics were observed separately and in combination with each other.*

*Key-words: light fastness, perspiration, rubbing, reactive dyestuffs, dyed cotton textile materials, color fading*

Fading of dyed textile products in the sunlight, especially in the usage of cotton materials that are mostly preferred in summer is a major problem. Reactive dyestuffs give vivid colors; can be dyed with simple methods, give opportunities for level dyeing, high washing fastness and various combinations so today reactive dyestuffs are the most chosen dyestuff group in cotton dyeing. Some cotton products dyed with reactive dyestuffs do not fade by the light, but there is a significant fading by the light together with perspiration. Fading with the effect of light and perspiration reveals in the countries that take sunlight in long periods. Color fading by the effect of sunlight is observed especially in parts of textile materials that are exposed to rubbing and close to the perspired areas particularly on trousers and T-shirts.

Generally, the ratio of degradated dyestuff to the non-degradated dyestuff is greater in light colors, less in dark colors, so the light fastness of dark colors is higher [1].

There are many factors affecting the resistance of textile materials to light. These are spectral sources, moisture, atmosphere, temperature and kind of the textile material.

There are various light sources determining the light fastnesses. It was found out that blue wool scale that is used for a standard evaluation has a correlation with the light fastness tests made with xenon arc lamp. For this reason, today the light fastness of different dyestuffs is made by xenotest lightening sources and gives the best results.

The effect of atmospheric conditions is closely related with singlet oxygen. The singlet oxygen in the medium supports the photo oxidative fading and plays a key role. As the result of the photo oxidation reaction of the polymer, there are decompositions in the polymer and fading begins. The importance of moisture in the fading of dyestuffs with the light is another complicated subject. Generally, as the moisture increases, the light fastness decreases. The degree of the effect is related with the polymer structure of the dyestuff. The moisture in the atmosphere promotes the effect of the fading. The effect of fading increases as the temperature increases.

Normally, the dyestuffs show oxidation reaction by the effect of light. But in some cases the reaction can be reduction. Reduction occurs in the dyestuffs of protein fibers and in the systems that the oxidation of material is faster than the oxidation of dyestuff or in the cases that dyestuff has no contact with the oxygen.

Dyestuff aggregation (the dyestuff molecules are together) is an important parameter in order to keep fading with the effect of light under control. Studies indicated that the aggregated dyestuffs had significantly higher light fastness values compared with the monodisperse (standing alone) dyestuffs [2, 3]. The colors of colored materials come from one or more unsaturated bonds. These bonds or groups are called “Chromophore”. Unsaturated special states of them provide the visible parts of electromagnetic waves to absorb and reflect. In other words, the loose electrons in chromophores absorb light waves of particular wavelengths [2–5, 9].

The rubbing fastness of cotton dyed fabrics cause serious problems especially in dark tones. This problem is also evident in reactive dyeing group of cotton dyeing, especially in wet rubbing. In the study of Bredereck et al., many factors such as fabric type, pretreatment and dyeing (type and functionality of reactive dyestuff, color depth, dyeing method and washing processes), finishing and fiber damages in chemical treatments were taken into account.

Usually wet rubbing fastness values are significantly worse than dry rubbing fastness values although the unfixed dyestuff hydrolysates are washed thoroughly. In a study, the reason of low wet fastnesses was attributed to the swelling of fabrics rather than the level of wet rubbing forces. The water of rubbing fabric increased the sensitivity of cotton fibers to the rubbing in the opposite direction. Because the fibers in the rubbed surface swelled, the wet rubbing fastness values were low. The moisture in the rubbed surface increased the rubbing coefficient of the fabric approximately twice. Especially the cotton fiber swollen by water was very sensitive to rubbing in the opposite direction. Fiber parts that had dyed fibrillar structure were broken and formed flat fiber particles greater than 10–40 mm and stuck to rubbing fabric very well. These particles are responsible from the rubbing stain and could not be taken away by an efficient washing.

According to another approach, cotton fibers that do not have primary walls are very sensitive to rubbing forces in wet form. 3$^{rd}$ approach claims that in wet fastness tests, water in the medium causes the soluble dyes to bleed and stain the rubbing fabric. 1$^{st}$ and 2$^{nd}$ approaches depend on the dyestuff and are evaluated in manner of the fibers broken away from the fabrics, 3$^{rd}$ approach explains the situation as the desorption in washing tests. The different properties of reactive dyestuffs such as affinity, reactivity and diffusion do not have any negative effects over wet rubbing fastness. The dyeing method has also similar impacts. The most important parameter affecting wet rubbing fastness is the depth of dyeing.

In the study of Bredereck (2001), it was indicated that the cotton morphology changed after mercerization, big holes disappeared and fibrous structure tightened. Thus abrasion of the fibers decreases during wet rubbing. There is less need of dyestuff in mercerized cotton compared with the ordinary cotton of the same color because of the decrease in light scattering. That means as the result of wet rubbing, worn out fibers of mercerized cotton contained less dyestuffs and rubbing stain looks lighter. In a study by Yurdakul (2002), it was indicated that the processes before and after dyeing didn’t improve wet rubbing fastnesses, but additional mechanical processes (i. e. sueding, brushing) increased the breaking down of fibers and decreased wet rubbing fastness values significantly [6, 7].

Human sweat is defined in AATCC 15-1979 as “salty liquid secreted from perspiration glands”. Perspiration is composed of water, salt (mostly NaCl), urea, uric acid, amino acids, ammonia, sugar, lactic acid, ascorbic acid. Human sweat has an acidic character at the moment secreted from the body. But after a while as the result of bacterial activities, quantity of ammonia increases and the sweat turns into an alkaline character. So two *p*H values (5,5 and 8) are used in perspiration fastness tests [7].

Dyestuff of the fabric is affected from acidic or alkaline perspiration according to the dyestuff’s chemical structure sensitivity to the *p*H. Perspiration has an effect that promotes the color fading of the dyestuff.

One of the most important problems in the usage of dyed textile materials is the fading under the sunlight. Fading occurs either in usage or drying after washing by the sunlight. This situation is met mostly in cotton goods significantly.

Reactive dyestuffs are the most used dyestuffs in dyeing cotton products. Some of the cotton products dyed with reactive dyestuffs do not fade only by sunlight, but perspiration by sunlight fades significantly.

Significant fading especially in parts of textile materials that are exposed to rubbing and close to the perspired areas is observed. Fading by the light and perspiration problem is seen particularly on trousers and T-shirts in summer.

In this study, it is intended to observe the reasons of color fading of cotton textile products by the effect of light, perspiration and rubbing during usage in open air, especially in summer. As the result of reviewing the literature, it was determined that a detailed study about all the factors affecting the color fading wasn’t made, so it was concluded that a research about this subject would be necessary [8].

Table 1

| Chemical agents | Firm |
|---|---|
| L-histidine mono hydrochloride monohydrate ($C_6H_9O_2N_3.HCl.H_2O$) | MERCK |
| Disodium hydrogen orthophosphate ($Na_2HPO_4.2H_2O$) | MERCK |
| Sodium dihydrogen orthophosphate ($NaH_2PO_4.2H_2O$) | MERCK |
| Acetic acid ($CH_3COOH$) | MERCK |
| Sodium Carbonate ($Na_2CO_3$) | RIEDEL-DE-HAIDEN |
| Sodium Chloride (NaCl) | RIEDEL-DE-HAIDEN |

Table 2

| Dyestuffs | C.I. number | Reactive group |
|---|---|---|
| Procion Gelb HEXL | Reactive Yellow 138 | Monochlorotriazine |
| Procion Deep Red HEXL | Reactive Red 58 | Monochlorotriazine |
| Procion Brilliant Rot HE-GXL | Reactive Red 231 | Monochlorotriazine |
| Procion Gelb HE-6G | Reactive Yellow 135 | Monochlorotriazine |
| Remazol Turquoise G 133% | Reactive Blue 21 | Vinylsulpone |
| Remazol Gelb 3 GL | Reactive Yellow 168 B | Vinylsulpone |
| Remazol Blue BB 133% | Reactive Blue 220 | Vinylsulpone |
| Procion Blue HEXL | Reactive Blue 198 | Monochlorotriazine |
| Procion Blue HE-RD | Reactive Blue 160 | Monochlorotriazine |

Table 3

| Red | Dyestuff quantity, % |
|---|---|
| Procion Gelb HEXL | 0.408 |
| Procion Deep Red HEXL | 3.010 |
| Procion Brilliant Rot HE-GXL | 0.440 |
| **Yellow** | |
| Procion Gelb HE-6G | 5.150 |
| Procion Gelb HEXL | 0.110 |
| **Turquoise** | |
| Remazol Turquoise G 133% | 0.2370 |
| Remazol Gelb 3 GL | 0.0018 |
| Remazol Blue BB 133% | 0.011 |
| **Beige** | |
| Procion Gelb HEXL | 0.0123 |
| Procion Red HEXL | 0.0033 |
| Procion Blue HEXL | 0.0169 |
| **Blue** | |
| Procion Gelb HEXL | 0,1360 |
| Procion Red HEXL | 0.0265 |
| Procion Blue HE-RD | 2.8600 |
| **Khaki** | |
| Procion Gelb HEXL | 0.71 |
| Procion Red HE-GXL | 0.30 |
| Procion Blue HE-RD | 1.28 |
| **Navy** | |
| Procion Gelb HEXL | 1.050 |
| Procion Red HEXL | 0.600 |
| Procion Blue HE-RD | 4.840 |

## MATERIALS AND METHODS

100% cotton knitted fabrics of 170 g/m$^2$ were used in the study. The chemical agents used in the experiments are given in table 1. Reactive dyestuffs with different reactivities are used in the experiments are given in table 2.

Dyeings were made by all- in method with the dyestuffs determined in table 2 at a liquor ratio of 1:40. Reactive dyestuffs of this study were applied by the recipe below (table 3). Remazol type of the dyestuffs had low and medium level of substantivities.

Determination of Light Fastness was made according to ISO 105 B02 by Xenotest Alpha Light Fastness Tester and under the sunlight. Blue Scale was used to evaluate the results. Rubbing fastness test is made to according to TS 717 EN ISO 105 X12.

Table 4

| Samples | Light fastness | |
|---|---|---|
| | *Sunlight* | *Xenotest* |
| Yellow | 6 – 7 | 6 – 7 |
| Red | 4 | 4 |
| Blue | 4 | 4 |
| Turquoise | 3 | 4 |
| Beige | 5 | 5 |
| Navy | 3 – 4 | 4 |
| Khaki | 3 | 4 |

Perspiration fastness test of dyed fabrics were made according to ISO 105 E04 standard.

In the determination of color fastness to light and perspiration, an internationally valid standard hasn't been developed yet. For this reason the firms apply their in-house methods. In the study, a method developed by ourselves was used. The fabrics were wetted by acidic and alkaline perspiration solutions and water in every 30 minutes and subjected to light in Xenotest for 20 hours. The evaluation was made by blue scale.

Similar experiments were made by sunlight in open-air in July and August in order to provide the hard conditions of summer heat and intensive sunlight. In the experiments dry fabrics were subjected to sunlight and wetted by distilled water, acidic perspiration solution and alkaline perspiration solution in every 30 minutes. After wetting, rubbing process was applied to the same part of the fabrics in order to see the effect of rubbing over wetted fabric in manner of color change.

Determination of color fastness to light-water was made by subjecting the fabrics to light in xenotest for 20 hours and wetting the fabrics by distilled water in Xenotest in every hour. The evaluations were made by blue scale. Similar tests were made by sunlight in open-air.

## RESULTS AND DISCUSSIONS

Light fastness (by Xenotest), perspiration fastness and rubbing fastness values of all the dyed fabrics were evaluated separately.

Different colors were dyed by 9 different reactive dyestuffs. The colors were chosen as the most problematic fading colors in sunlight with the additional

Table 5

| Samples | | Acetate | Cotton | Polyamide | Polyester | Polyacrylnitrile | Wool |
|---|---|---|---|---|---|---|---|
| Yellow | Acidic | 5 | 5 | 5 | 5 | 5 | 5 |
| | Alkaline | 5 | 5 | 5 | 5 | 5 | 5 |
| Red | Acidic | 4 – 5 | 4 | 4 – 5 | 4 – 5 | 4 – 5 | 4 – 5 |
| | Alkaline | 4 – 5 | 4 | 4 – 5 | 4 – 5 | 4 – 5 | 4 – 5 |
| Blue | Acidic | 4 – 5 | 4 | 4 – 5 | 4 – 5 | 4 – 5 | 4 – 5 |
| | Alkaline | 4 – 5 | 4 | 4 – 5 | 4 – 5 | 4 – 5 | 4 – 5 |
| Turquoise | Acidic | 4 – 5 | 4 – 5 | 4 – 5 | 4 – 5 | 4 – 5 | 4 – 5 |
| | Alkaline | 4 – 5 | 4 – 5 | 4 – 5 | 4 – 5 | 4 – 5 | 4 – 5 |
| Beige | Acidic | 5 | 5 | 5 | 5 | 5 | 5 |
| | Alkaline | 5 | 5 | 5 | 5 | 5 | 5 |
| Navy | Acidic | 5 | 4 – 5 | 4 – 5 | 5 | 5 | 5 |
| | Alkaline | 5 | 4 – 5 | 4 – 5 | 5 | 5 | 5 |
| Khaki | Acidic | 5 | 5 | 5 | 5 | 5 | 5 |
| | Alkaline | 5 | 5 | 5 | 5 | 5 | 5 |

effect of perspiration and rubbing such as navy, khaki and beige, besides main colors such as red, yellow and blue.

The studies are performed in two parts; under sunlight and artificial daylight. Sunlight related studies are very important to represent the conditions of the countries which are under the effect of long periods of sunlight, so there is significant color fading in most of the colored textile products. Artificial daylight studies are made in order to provide standard conditions. The results are given in table 4. Similar results were obtained by yellow, red, blue and beige colors under sunlight and artificial daylight. Turquoise, navy and khaki colors gave different results, lower light fastness values under the sunlight. The results of perspiration fastness values are given in table 5. The lowest perspiration fastness value in table 5 is 4 and the other results are between 4 and 5, generally high values were obtained. Dry and wet rubbing fastness test results of dyed fabrics are given in table 6. When table 6 is examined, it is found out that navy and khaki colors have the lowest rubbing fastness values. The wet rubbing fastness values are about 0,5 or 1 point lower than dry rubbing fastness values. The wet rubbing fastness values of blue, navy and khaki are significantly low. After the evaluations of all the dyed fabrics in manners of light fastness under two lights (sunlight and xenon lamp), perspiration fastness and rubbing fastness separately, the next step of the study was made by the combined effect of these fastnesses under different conditions.

### Perspiration and light fastness results under sunlight and artificial daylight

In this part of the study, the combined effect of light and perspiration were examined. For this aim, first the effect of sunlight and perspiration and then artificial daylight and perspiration were searched and the results are give in figure 1 and figure 2.

The light fastness values of the samples which were wetted by water, artificial acidic and alkaline perspiration solutions were applied 1,5–2 degrees lower than only light fastness values as seen in figure 1. The results of the tests made by alkaline perspiration solutions were significantly lower especially in some colors.

Table 6

| Samples | Rubbing fastness | |
|---|---|---|
| | *Dry* | *Wet* |
| Yellow | 5 | 4 – 5 |
| Red | 4 – 5 | 3 – 4 |
| Blue | 4 | 3 |
| Turquoise | 4 | 3 – 4 |
| Beige | 4 – 5 | 4 |
| Navy | 3 | 2 |
| Khaki | 3 – 4 | 2 – 3 |

The light fastness values of the samples which were wetted by water, artificial acidic and alkaline perspiration solutions were lower than only light fastness values as seen in figure 2. The light fastness value of the sample that was wetted by water was higher than the ones wetted by perspiration solutions.

### Perspiration and light and rubbing fastness results under sunlight

In this part of the study, the combined effect of light, perspiration and rubbing were examined. In order to determine the effect of sunlight, two different experiments were made, in open-air conditions under the sunlight and in laboratory conditions without exposing to light. The fabrics that were wetted by water and perspiration solutions in some periods, then they were rubbed and evaluated and the procedures of exposing to light or leaving without exposing to light were continued. The color-change results were evaluated by gray-scale by taking rubbing fastness into consideration.

The results of rubbing fastness values after exposing to sunlight and wetting by water or perspiration solutions are given in figure 3.

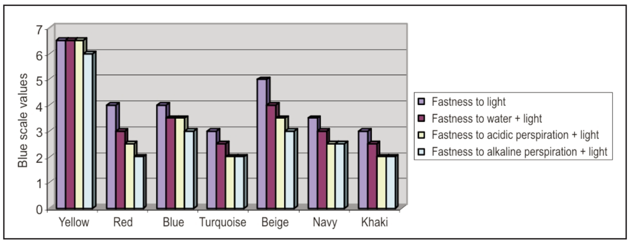


Fig. 1. The results of sunlight + Perspiration fastness tests

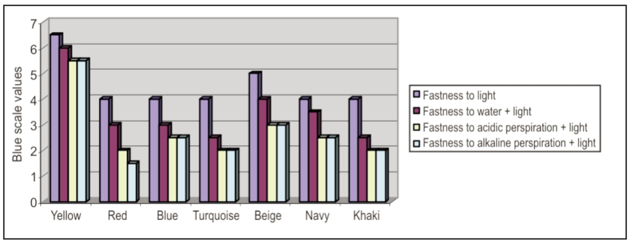


Fig. 2. The results of artificial daylight + Perspiration fastness tests

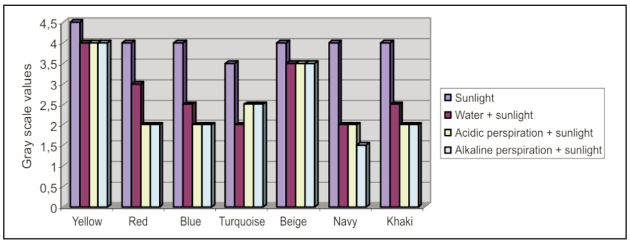


Fig. 3. The results of rubbing fastness values after exposing to sunlight and wetting by water or perspiration solutions

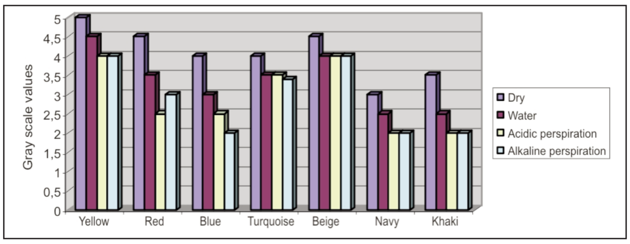


Fig. 4. The results of rubbing fastness values in the laboratory conditions without exposing to sunlight, but wetting by water or perspiration solutions

The rubbing fastness tests made under the of sunlight with water or perspiration solutions are significantly lower except yellow and beige colors than the ones of sunlight + rubbing fastness tests without wetting by the solutions.

The results of rubbing fastness values in the laboratory conditions without exposing to sunlight, but wetting by water or perspiration solutions are given in figure 4.

As the result of the experiments made in laboratory conditions without sunlight, the decrease in wet fastnesses was not as much as the ones under the sunlight. The sunlight increased the fading effect. In most of the dyed fabrics, the rubbing effect was more significant with water or perspiration solutions than dry conditions under the sunlight.

## CONCLUSIONS

In this study, the fading of reactive dyed cellulosic materials during usage by the effects of rubbing, perspiration and light was examined.

For this aim, trichromy colors of yellow, red and blue and some combination colors such as turquoise, navy, khaki and beige were used. In order to see the single effects of light, perspiration and rubbing, their fastness tests were made separately and then their combined effects under different conditions were examined. Fabric samples dyed with all these dyestuffs were exposed to sunlight and artificial sunlight.

The similar light fastness test results were obtained by beige, yellow, red and blue colors. The results of turquoise, navy and khaki were lower in the sunlight experiments. Perspiration fastness test results were generally between 4 and 5. Dry rubbing fastness values of navy and khaki were lower than the others. Wet rubbing fastness values were app. 0.5 to 1 point lower than dry rubbing fastness values.

The light fastness values of the fabrics which were wetted by acidic and alkaline perspiration solutions and water were 1.5 to 2 degrees lower than dry conditions. This decrease was more with the experiments made by perspiration solutions and using alkaline perspiration solutions gave more evident decreases. Experiments with water resulted higher light fastness values than the ones made with perspiration solutions.

The rubbing fastness values after exposing to sunlight and wetting by water or perspiration solutions gave significantly lower values except than yellow and beige colors. The decrease of the wet fastness values without the effect of light, in the laboratory conditions were less. The light increased fading effect. The combined effect of perspiration, water and rubbing were more apparent in the presence of the light. Generally reactive dyestuffs showed low stability to the combined conditions of light, perspiration and rubbing. As the conditions become harder, the fading effect increases.

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# DOCUMENTARE

## *Noi tehnologii*

### FIBRE COMPOZITE PENTRU CONSTRUCȚII UŞOARE

***Cetex Institut für Textil-und Verarbeitungs-maschinen gemmeinnützige GmbH***, din Germania, este renumit atât pentru cercetările privind dezvoltarea construcției de maşini, cât şi pentru producția de textile tehnice şi de diverse structuri din fibre compozite pentru construcții uşoare.

Fabrica hibrid pentru materiale *Ce-Preg* realizează o producție eficientă de fibre de sticlă termoplastice, consolidate cu fibre continue, care sunt prelucrate, ulterior, în produse semifinite, destinate producerii de fibre compozite. Materialele se caracterizează prin dispunerea paralelă a tuturor fibrelor de consolidare şi realizarea unei inserții de protecție a fibrelor între două pelicule matriceale termoplastice. Prin noul mod de dispunere a fibrelor, se obține o greutate pe unitatea de suprafață precis definită, pentru fiecare strat, şi o distribuție uniformă a semitorturilor de ranforsare.

În prezent, accentul se pune pe folosirea unor amestecuri din fibre de sticlă cu polipropilenă sau cu poliamidă, ori din fibre de carbon cu poliamidă.

Prin modificarea componentei matriceale termoplastice, se pot obține materiale hibride personalizate, cu o înaltă rezistență mecanică şi la impact, pentru o gamă largă de aplicații, în special în ingineria mecanică şi în construcțiile de automobile.

Materialele țesute 3D interspațiate sunt solicitate pentru diverse aplicații tehnice, cum ar fi protecția împotriva zgomotului sau structurile de ranforsare 3D, destinate construcțiilor.

Pe lângă materialele clasice din poliester, pentru producerea lor sunt utilizate fibre de sticlă şi de bazalt.

Realizările viitoare ale companiei includ maşinile destinate producției de benzi uscate unidirecționale din fibre de carbon, fibre de sticlă, fibre aramidice şi fibre de bazalt.

În domeniul producției de țesături multidirecționale, accentul se pune pe structurile biomimetice consolidate cu fibre, fabricate printr-un proces NCF, compatibil cu volume mari şi cu o dispunere variabilă a filamentelor în material.

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# A facile method for anti-bacterial finishing of cotton fabrics using silver nanoparticles

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**REZUMAT – ABSTRACT**

**Metodă simplă de finisare antibacteriană a țesăturilor din bumbac cu nanoparticule de argint**

*Studiul se concentrează pe finisarea antimicrobiană a țesăturilor din bumbac cu o soluție coloidală de nanoparticule de argint. În acest scop, au fost experimentate, pe țesături din bumbac, procesul de hidrofobizare cu fluorocarburi şi cel de finisare antişifonare folosind diferite substanțe chimice. Mostrele au fost testate din punct de vedere al proprietății antibacteriene, al unghiului de revenire din şifonare, al caracterului hidrofug, al tenacității, abraziunii şi rezistenței la spălare. Deşi la mostrele tratate prin metoda de fulardare-uscare s-a constatat cel mai bun efect antibacterian, rezistențele la spălare şi abraziune nu au atins un nivel acceptabil. În consecință, aplicarea soluției coloidale cu nanoparticule de argint pe materiale hidrofobe şi rezistente la şifonare a dus la îmbunătățirea proprietăților de rezistență, în timp ce proprietățile antibacteriene s-au înrăutățit din cauza limitării contactului direct dintre nanoparticule şi bacterii. Prin urmare, metoda de finisare antibacteriană trebuie selectată în conformitate cu utilizările finale. În plus, tratamentul antibacterian ar putea deveni una dintre finisările multifuncționale ale țesăturilor din bumbac.*

*Cuvinte-cheie: țesătură din bumbac, nanoparticule din argint, antibacterian, hidrofob, antişifonare*

**A facile method for anti-bacterial finishing of cotton fabrics using silver nanoparticles**

*This research focuses on the anti-microbial finishing of cotton fabrics using colloidal solution of silver nanoparticles. For this purpose, water repellent finishing process using a fluorocarbon and anti-crease finishing using different chemicals on cotton fabrics were experimented. The properties of samples have been investigated by measuring bacteria reduction, wrinkle recovery angle, water repellency, tenacity, abrasion and washing fastness. Although treated samples by pad-dry method have the best anti-bacterial effect, the washing and abrasion fastness were not at the acceptable level. Consequently, co-application of the colloidal solution of silver nanoparticles with the water repellent and crease resistant materials improved the fastness properties, while at the same time the anti-bacterial properties were reduced because of the limited direct contact between the nanoparticles and the bacteria. Therefore, it was concluded that the anti-bacterial finishing method should be selected according to the end uses. In addition, anti-bacterial treatment could be one of the multi-functional finishes for cotton fabric.*

*Key-words: cotton fabric, silver nanoparticles, anti-bacterial, water repellent, crease resistant finishes*

Invisible wastes from the human body such as sweat and sebum cause microorganisms to adhere to cloths and grow easily, causing unpleasant odor along with altering the shade of fabric and lowering the strength. Applying anti-microbial finishes decreases the growth of microorganisms and prevent the above mentioned problems. The textiles used in healthcare should have antimicrobial properties to limit the propagation of diseases. In consequence, various anti-microbial finishes and sterilization methods have been developed for different textiles. Generally, the anti-bacterial agents can be applied to the textile substrates by exhaustion, pad-dry-cure, coating, spray and foam techniques. The substances can also be applied directly by adding into the fiber spinning melt or dope. A number of methods for incorporating anti-bacterial agents into textile materials have been developed for improving the durability of the chemical anti-bacterial finishing process [1–4].

The application of nanotechnology to the development of functional textiles has been growing. Using nanotechnology to improve existing material performances and developing unrivaled functions on textile materials are flourishing. The development of anti-microbial textiles in every aspect of life based on the immobilization of nanoparticles on textile fibers has recently received a growing interest from both the academic and industrial sectors [6–7]. Silver nanoparticles [8], titanium dioxide [9–10] and zinc oxide [11] are used to impart anti-microbial properties. The number of particles per unit area is increased by applying nano-sized particles, so the anti-microbial effects can be maximized.

The silver nanoparticles with their unique chemical and physical properties are proving as an alternative for the development of new anti-bacterial agents. Large surface area of silver nanoparticles increases their contact with bacteria or fungi and improves the germicidal and bactericidal efficacy. Additionally, it prevents the growth of bacteria which cause odor, infection and sores, so it can be widely used in socks, and other healthcare products such as dressings for burns, scald, skin donor and recipient sites [12–14].

Recently, new techniques for the modification of textile fibers using anti-bacterial nano-sized silver particles were introduced [7, 13–19]. Ki et al imparted anti-bacterial properties to the wool fabrics using sulfur nano-silver ethanol based colloid with the particle size of average 4.2 nm [16]. The fibers were treated with nano-silver colloid by a conventional pad-dry-cure method. Lee at al developed a method to incorporate colloidal silver nanoparticles into polyester nonwovens [19].

Dubas at al. described a new method where anti-microbial silver nanoparticles were immobilized on nylon or silk fibers by following the layer-by-layer deposition method [14]. Potiyaraj at al synthesized silver chloride nanocrystals on silk fiber [15]. The growth of the nanocrystal was achieved by sequential dipping of the silk fibers in alternating solution of either silver nitrate or sodium chloride followed by a rinsing step.
In another study, Lee et al produced anti-bacterial woven cotton and polyester fabrics using colloidal silver nanoparticles. They demonstrated that anti-bacterial efficacy on textile fabrics can be easily achieved with nanosized silver colloidal solution through padding process [7] .
It can be seen that in all previous researches, having a separate process for anti-bacterial finishing of the textiles was crucial, because it is difficult for textile industries to use a new procedure in industrial scale because adding one stage to the process means more costs for them. Previously we reported co-application of silver nanoparticles and textile finishing chemicals simultaneous co-application used in crease resist finishing was reported [20]. This study is based on multifunctional finishing of the cotton fabrics by using the colloidal solution of silver nanoparticles and water repellent finishing together. In addition, the effects of combination of the anti-bacterial agent with crease resistant chemicals or fluorochemical on the anti-microbial efficacy and the cotton fabric properties are compared.

## EXPERIMENTAL PART

### Materials used

Desized, scoured, bleached and mercerized cotton fabric (plain weave, 98 g/m$^2$), was supplied by Broojerd Textile Co., Iran. The chemicals used in this study were 2 000 ppm colloidal solution of silver nanoparticles (Pars Nano Nasb Co., Iran), nonionic detergent of Sera wet C-NR (DyStar Co., Germany), sodium carbonate for washing fabric before treatment, acetic acid (Merck, Germany), fluorochemical (Rucostar EEE, Rudolf Chemie Co., Germany), nutrient broth and nutrient agar (Becton Dickinson and Company Sparks, MD).

### Fabric preparation

All samples prior to any treatments were washed to remove any possible impurities which could adversely affect the fabric treatment using Roaches Dyeing machine (Pyrotec S). The samples were washed at *p*H 8-9 (sodium carbonate) using 0.5 g/L non-ionic detergent at 100ºC for 30 minutes and the liquor-to-fabric ratio was 40:1. Then, fabrics were washed off at 35–40ºC for 45 minutes and cooled gradually and finally cold rinsed and air dried without any tension.

### Fabric treatment

First we obtained the optimum concentration of silver nanoparticles not allowing bacteria to grow on the fabric. Silver nanoparticles were added to fabric by the pad-dry process, without any chemicals. In this process we have used a padder (HVF 53800, Werner Mathis, Switzerland) and the wet pickup was 80%. For obtaining the optimum concentration, different concentration of nanoparticles from 25 until 300 ppm were used and experiments showed that at the concentration of 100 ppm for gram-positive bacterium and 300 ppm for gram-negative bacterium, no growing of bacteria were attained.
Silver nanoparticles were applied on fabric by using 2 methods, pad-dry process and co-application with the chemicals, which have already been reported [20]. In the second method, the crosslinking agent, Fixapret ECO, with two different concentrations of 40 and 60 g/L and the resin former agent, Cellofix ME, with the concentration of 50 g/L with silver nanoparticles were used. Also in second method, the optimum concentrations of silver nanoparticles, 100 ppm and 300 ppm, were added to the solution containing two different concentration of 30 and 50 g/L water repellent agent, Rucostar EEE, 1 ml/L acetic acid, 5 ml/L propan-2-ol. This solution was applied to the samples by the pad-dry-cure process and wet pick-up of 80%. After drying (2 minute, 110ºC) the fabric was cured for 2 minute, at 140ºC, in a lab dryer (Warner Mathis AG, Niederhasli/Zürich).

### Evaluation methods

The bacterial properties were quantitatively evaluated with the gram-positive bacterium, Staphylococcus aureus (A. aureus), ATCC 1337, gram-negative bacterium of Escherichia coli (E. coli), ATCC 1330 and Pseudomonas aeruginosa (P. aeruginosa), ATCC 1074, according to AATCC test method 100. The bacteriostatic ratio (%) was calculated using the equation (1):

$$R\ (\%) = (A - B)/A \times 100 \qquad (1)$$

where:
*R* is the reduction rate;
*A* – the number of bacterial colonies from untreated fabrics;
*B* – the number of bacterial colonies from treated fabrics.
The washing fastness was measured according to the ISO 105 – Col: 1989 test method. Different samples were washed in detergent solution of 5 g/l with *L* : *R* of 50:1 and *p*H of 7 at 40ºC, using Polymath (Ahiba, Data color, Switzerland).
The abrasion resistance of finished fabrics was measured according to BS 12947-2: 1999, on a Martindale Wear & Abrasion tester (1994) by rubbing the circular samples against a standard cotton fabric and the anti-bacterial properties evaluated after 3 000 cycles, and 4 samples for every test.
The samples were tested for water repellency using the water/ alcohol drop test. The samples are placed flat on a smooth, horizontal surface. Beginning with the lowest numbered test liquid, 3 small droplets (approximately 5 mm in diameter) are placed onto the sample using a pipette.
The droplets are observed for 10 seconds. If after 10 seconds, 2 of the 3 droplets are still visible as

Table 1

| ANTI-BACTERIAL PROPERTIES OF FLUOROCHEMICAL AND SILVER NANOPARTICLE TREATED COTTON FABRICS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Treatment** | | **Bacterium reduction, %** | | | | | | | | |
| **Fluoro-chemical,** g/l | **Silver nano-particle,** ppm | ***E. coli*** | | | ***S. aureus*** | | | ***P. aeruginosa*** | | |
| | | *Before wash or abrasion* | *After wash* | *After abrasion* | *Before wash or abrasion* | *After wash* | *After abrasion* | *Before wash or abrasion* | *After wash* | *After abrasion* |
| 30 | 100 | 56.7 | 52.4 | 50.0 | 64.5 | 60.4 | 57.9 | 54.8 | 50.6 | 48.4 |
| | 300 | 60.4 | 56.4 | 53.9 | 68.3 | 64.3 | 61.8 | 57.8 | 57.2 | 50.1 |
| 50 | 100 | 52.3 | 48.7 | 45.9 | 60.1 | 56.1 | 54.0 | 52.1 | 48.9 | 46.5 |
| | 300 | 56.9 | 53.5 | 51.7 | 63.2 | 58.6 | 56.2 | 53.2 | 49.7 | 47.1 |

spherical to hemispherical, the fabric passes the test. Samples are rated as pass or fail of the appropriate test liquid, W–10. The rating given to a sample is for the highest test liquid remaining visible after 15 seconds. In general, water repellency rating of 2 or greater is desirable.

Determination of fabric tensile properties were carried out according to BS 13934-1:1999 test method on an Instron model 5564, with gauge length of 0.1 m, crosshead speed of 0.050 m/minute, and 10 tests for each sample.

## RESULTS AND DISCUSSIONS

### Treatment of fabrics with the water repellent agent and silver nanoparticles

Previously, we have demonstrated that the antimicrobial behavior is directly related to the silver nanoparticle concentration [20]. Accordingly, the optimum nanoparticle concentration of 100 ppm to 150 ppm for gram-positive bacterium (S. aureus) and 300 ppm for gram-negative bacteria (E. coli and P. aeruginosa) was chosen for further experiments. Metallic ions and compounds like silver nanoparticles show certain degrees of anti-bacterial effects. Silver nanoparticles have high reactivity with proteins. They adversely affect cellular metabolism of bacteria and fungi, and restrain cell growth, along with decrease in respiration, basal metabolism of the electron transfer and the transport of the substrate into the microbial cell membrane[12–14]. However, the act of the antimicrobial agent is affected by the kind of bacterium. The differences between gram-positive and gram-negative bacteria essentially rest in the structure of their respective cell walls. Gram-negative bacterium has an outer layer, lipopolysaccharide, preventing silver nanoparticles penetration through the cell wall; hence, higher concentrations of silver nanoparticles are needed to destroy gram-negative bacterium [5].

This paper deals with the application of silver nanoparticles to the cotton fabrics during water repellent finishing via fluorochemicals with imparted high water and oil repellency that aided the anti-bacterial finishing. In addition, all three methods are compared to find out the best treatment procedure. As already mentioned, in this new method the samples were impregnated by padding with optimum concentrations of silver nanoparticles along with two different amount of the fluorochemical, and then dried and cured according to the manufacturer recommended conditions.

Fluorochemical or fluorocarbon finishes has been applied to textile goods to impart easy care properties such as water, oil, and stain repellency in addition to soil and stain release properties. Table 1 shows the anti-bacterial properties of the fluorochemical and silver nanoparticle finished fabrics. As can be seen, samples showed the best results of anti-bacterial properties versus S. aureus bacteria, followed by E. coli and then P. aeruginosa bacteria. Another important feature that was obviously observed is that anti-bacterial properties decreased when the concentration of fluorochemical increased from 30 g/l to 50 g/l. This effect could be due to the possible thicker layer of the fluorocarbon film on the topmost layer of the fibres which hindered the direct contact between the silver nanoparticles and the bacteria, because these particles are only effective when they come into contact with the microorganisms [2]. In addition, this effect could be due to the decreased in water activity after fluorocarbon finishing with a reduction in available water amount for bacterial growth. The results also indicate the direct relation between silver nanoparticles concentration and the anti-bacterial efficacy. In other word, the higher the silver nanoparticles concentration, the better anti-bacterial effect could be obtained. Subsequently, with the higher amount of nanoparticles and the minimum level of the fluorochemical that form a continuous film on the fibres, the better anti-bacterial characteristics were achieved (table 1).

Evaluation of the results of durability indicated that laundering and abrasion tests decreased the samples anti-microbial properties. During pad-dry process, presented in table 2, the silver nanoparticles are just being physically absorbed and kept amongst fibers; therefore, the durability is not high enough against laundering and abrasion tests. Poor wash and abrasion fastness led the authors to find another procedure that had long lasting anti-bacterial effect. Subsequently, durable press treatment and repellent finishes were chosen.

Table 2

| ANTI-BACTERIAL PROPERTIES OF SILVER NANOPARTICLES TREATED COTTON FABRICS BY THE PAD-DRY METHOD | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pad-dry treatment** | | **Bacterium reduction, %** | | | | | | | | |
| **Silver nano-particle,** ppm | ***Dry temperature,*** °C | ***E. coli*** | | | ***S. aureus*** | | | ***P. aeruginosa*** | | |
| | | *Before wash or abrasion* | *After wash* | *After abrasion* | *Before wash or abrasion* | *After wash* | *After abrasion* | *Before wash or abrasion* | *After wash* | *After abrasion* |
| 100 | 80 | 84.3 | 77.5 | 70.3 | 84.3 | 67.5 | 64.3 | 80.3 | 62.7 | 59.6 |
| | 100 | 94.2 | 84.1 | 75.6 | 91.2 | 79.0 | 75.6 | 87.5 | 74.0 | 71.2 |
| | 120 | 98.6 | 90.3 | 86.5 | 98.6 | 90.3 | 86.5 | 91.2 | 80.7 | 76.5 |
| | 140 | 99.3 | 92.4 | 85.0 | 97.0 | 92.4 | 85.0 | 96.0 | 88.5 | 83.2 |
| 300 | 80 | 89.0 | 72.0 | 67.5 | 87.0 | 70.8 | 65.2 | 89.6 | 74.3 | 62.6 |
| | 100 | 95.2 | 80.7 | 76.7 | 96.6 | 79.6 | 74.5 | 94.5 | 84.0 | 74.2 |
| | 120 | 98.5 | 90.3 | 87.5 | 98.9 | 86.8 | 80.0 | 98.2 | 90.2 | 87.9 |
| | 140 | 100 | 92.4 | 89.0 | 100 | 92.5 | 87.3 | 100 | 90.0 | 92.3 |

When the durability of the finishing process after co-application of the silver nanoparticles with the fluorochemical is compared, it is verified that there is a negligible decrease in anti-microbial properties of samples after washing or abrasion tests, declining by roughly 4% and 6% for washed and abraded samples, respectively, due to the possible gradual release of the silver nanoparticles from the fabric surface. Therefore, the washing fastness of samples was better than abrasion fastness due to the lower resistance of the deposited nanoparticles on the fiber surface to high level of mechanical action. Although the anti-bacterial properties of these samples are not high enough at that level of those other samples treated by pad-dry method (table 2) or co-application with the anti-crease finishes (table 3) it is worth mentioning that better wash and abrasion durability was obtained, particularly as compared with the pad-dry method.

The applied fluorochemical by itself without any silver nanoparticles, impart certain intensity of the anti-bacterial effect, about 6 to 8 percent, possibly due to the protection that is provided to the textile fibre surface against both aqueous and oily liquids due to the low reactivity of the fluorochemical finish in which the scaffold carbon is shielded by fluorine atoms with provided high degree of protection with subsequent lower water activity.

Moreover, it must be ensured that the silver nano-particles not only are permanently effective, but also are compatible with the finishing agents. Consequently, the effect of addition of the silver nanoparticles to the formulation of the water repellent finish on hydrophobic properties of samples was

Table 3

| ANTI-BACTERIAL PROPERTIES OF ANTI-CREASE AND SILVER NANOPARTICLES TREATED COTTON FABRICS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Anti-crease finishing treatment** | | **Bacterium reduction, %** | | | | | | | | |
| **Silver nano-particle,** ppm | ***Anti-crease agent*** | ***E. coli*** | | | ***S. aureus*** | | | ***P. aeruginosa*** | | |
| | | *Before wash or abrasion* | *After wash* | *After abrasion* | *Before wash or abrasion* | *After wash* | *After abrasion* | *Before wash or abrasion* | *After wash* | *After abrasion* |
| 100 | 40 g/lit of Fixapret ECO | 78.3 | 68.1 | 65.2 | 85.0 | 79.0 | 72.8 | 75.5 | 65.3 | 62.1 |
| | 60 g/lit of Fixapret ECO | 82.5 | 74.9 | 71.8 | 87.6 | 80.3 | 73.0 | 79.6 | 70.4 | 67.8 |
| | 50 g/lit of Cellofix ME | 70.0 | 63.9 | 60.1 | 75.6 | 68.4 | 65.0 | 65.3 | 59.9 | 54.3 |
| 300 | 40 g/lit of Fixapret ECO | 85.6 | 76.3 | 73.9 | 93.3 | 86.5 | 79.5 | 70.2 | 73.6 | 82.7 |
| | 60 g/lit of Fixapret ECO | 88.8 | 82.4 | 78.9 | 95.6 | 89.9 | 81.0 | 72.5 | 76.1 | 85.5 |
| | 50 g/lit of Cellofix ME | 78.3 | 72.3 | 68.8 | 83.0 | 76.7 | 80.0 | 70.1 | 65.7 | 63.5 |

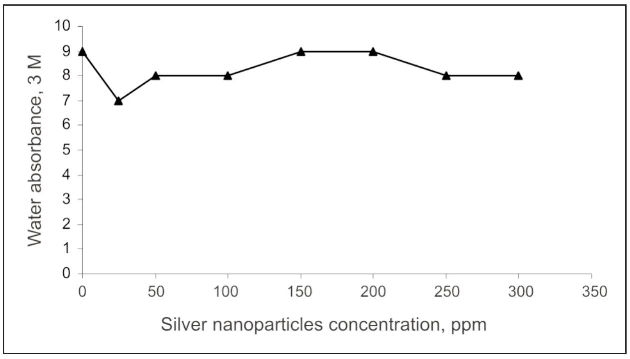

Fig. 1. Water repellency of the fluorochemical and silver nanoparticles treated cotton fabrics

evaluated. According to figure 1, fluorocarbon finishing regardless of the applied silver nanoparticles leads to 3M water repellency of 8–9 for approximately all samples. Therefore, it can be concluded that the addition of silver nanoparticles does not have any adverse effect on the repellent properties of the fluorochemical finished fabric.

## Comparison of the anti-microbial properties of samples using different method

The bacterium reduction of samples treated by different methods and with optimum concentrations of silver nanoparticles are compared in tables 1–3. In pad-dry method, the samples were padded with optimum concentrations of silver nanoparticles and dried at different temperatures from 80 to 140ºC. Table 2 shows the effects of different drying temperatures on the bacterium reduction in which the best results were obtained at 140ºC. In other words, the results demonstrated that the higher the drying temperature, the better anti-bacterial properties with 100% bacteria reduction. This effect could possibly be due to the higher thermal energy that each particle received during drying at higher temperature causing deeper penetration of silver nanoparticles inside the cotton fibre with better durability. In addition, it is possible that, at higher temperatures, the chemical structure of the dispersing agent used in colloidal solution of silver nanoparticles was decomposed in which the dispersing agent acted as a surfactant that could help washing off the deposited nanoparticles. Also, due to the removal of the dispersing agent, this could possibly cause better contact between the nanoparticles and the bacteria with subsequent higher anti-bacterial efficiency, because direct contact between these particles and the microorganisms is crucial for their effectiveness [2]. However, more investigation in this respect is necessary.

Studying the results of durability indicated that washing and abrasion tests decreased the samples anti-microbial properties. During pad-dry process, the silver nanoparticles are only kept amongst the fibers due to physical absorption, therefore, the durability is not fast enough against repeated laundering and abrasion processes. The acquired poor wash and abrasion fastness results make it necessary to find another procedure that has long lasting anti-bacterial effect.

Subsequently, durable press treatment as a popular finishing process was considered. Two types of general anti-crease finishes of Fixapret ECO and Cellofix ME have been investigated as a crosslinking agent and resin former, respectively. The results presented in table 3 show that co-application of these finishing agents could help improving the durability and fastness properties of the anti-bacterial finish with the silver nanoparticles. These agents react directly with the hydroxyl groups on the cellulose and cross link the cellulose chains, Fixapret ECO, or introduce a thermoset resin which produce a network within the fibres, Cellofix ME, and lock the structure together conferring an improved degree of elasticity to the fibre structure [19] by which the fastness properties of the anti-microbial finish was improved.

Thus, it can be concluded that, applying silver nanoparticles by the pad-dry method showed the maximum bacterium reduction, followed by samples treated with anti-crease finishes, Fixapret ECO and Cellofix ME, and finished samples with the water repellent agent yield the least anti-bacterial effect.

The undesirable effects of washing and abrasion tests on the obtained anti-bacterial effect of the tested method indicate the lost effect of the silver nanoparticles for 15 to 20% which is higher than that level of the other methods. Subsequently, the pad-dry method appeared to be appropriate for those cases that do need to be washed like disposable dresses. Results shown in tables 1 to 3 indicate that binding the nanoparticles as compared with the pad dried samples. Accordingly, the bacterium reduction of the samples treated with Rucostar EEE after washing and abrasion tests is very low. This phenomenon is possibly due to the effects of finishing chemicals on the fiber and fabric structures in which anti-crease agents crosslink the cellulose chains and lock the structure together [21], and water repellent agents cover the surface by the hydrophobic layer and prevent release of nanoparticles. Samples treated with Cellofix ME showed better performance against washing and abrasion tests with lower bacterium reduction than Fixapret ECO. Fixapret ECO is a reactant chemical which improves the wrinkle recovery by crosslinking between adjacent polymer chains while Cellofix ME is a polymerizing agent and forms a network between the fibres which keep the nanoparticles far from the reach of the tested bacteria. Subsequently, before washing and abrasion tests, the anti-bacterial effect of the reactant resin is better than the resin former polymers, which is capable of self-crosslinking to form resinous, three-dimensional polymers as well as crosslinking the cellulose chains. As a result, the formed resin creates better durability in this way. Moreover, similar to pad dried samples, for all samples, the wash fastness results is much better than abrasion fastness. Consequently, due to the necessity of direct contact of the anti-bacterial agent with bacteria, it is

Table 4

TENACITY OF SAMPLES TREATED WITH PAD-DRY, ANTI-CREASE AND WATER REPELLENT FINISHING PROCESSES

| Used methods | Silver nanoparticles concentration, ppm | Conditions | Tenacity, $N/cm^2$ |
|---|---|---|---|
| Pad-dry process | - | - | 115.2 |
| | 100 | 80°C | 115.5 |
| | | 100°C | 114.9 |
| | | 120°C | 114.6 |
| | | 140°C | 115.1 |
| | 300 | 80°C | 114.8 |
| | | 100°C | 116.1 |
| | | 120°C | 115.6 |
| | | 140°C | 115.9 |
| Anti-crease of Fixapret ECO | - | - | 108.9 |
| | 100 | 40 g/lit | 108.3 |
| | | 60 g/lit | 108.0 |
| Anti-crease of Cellofix ME | | 50 g/lit | 107.6 |
| Anti-crease of Fixapret ECO | 300 | 40 g/lit | 109.2 |
| | | 60 g/lit | 110.1 |
| Anti-crease of Cellofix ME | | 50 g/lit | 110.7 |
| Water repellent finishing with Rucostar EEE | - | - | 112.6 |
| | 100 | 30 g/lit | 112.1 |
| | | 50 g/lit | 111.9 |
| | 300 | 30 g/lit | 112.3 |
| | | 50 g/lit | 111.2 |

crucial to choose the suitable finishing agent that does not limit silver nanoparticles accessibility to the surface of textile goods and also create enough fastness required for the end uses.

The compatibility of the silver nanoparticles with different finishing agent formulations was also studied. As can be seen in figure 1 no adverse effect of the anti-microbial agent on Rucostar EEE was observed. Also it was already reported that [20] co-application of silver nanoparticles and used anti-crease finishing agents including Fixapret ECO and Cellofix ME did not have objectionable results on wrinkle recovery angle while an improvement in the fastness properties with higher effect for the resin former polymer, Cellofix ME was obtained. In addition, inevitable release of formaldehyde from this finishing agent improved the anti-microbial effect. Therefore, it can be concluded that the addition of silver nanoparticles does not have any adverse effect on wrinkle recovery angle and repellent properties. The reason for this phenomenon is that some properties like strength, recovery power, hydrophobic properties, are not directly affected by fiber properties alone but they are related to several fiber properties as well as to the yarn and fabric construction.

### The effects of different finishing methods on the samples' tenacity

Evaluation of the tensile properties of samples, presented in table 4, illustrates that in most cases there is no significant differences among samples' tenacities indicating any negative impact of the applied process on the samples' strength which is very important for industrial applications. This effect could be possibly due to the more adhesion between fibers that resulted in better force distribution.

## CONCLUSIONS

This research focuses on the anti-microbial finishing of cotton fabric using silver nanoparticles. The results indicated that the optimum concentration of nano particles depends on the kind of bacteria cell wall component with, 100 ppm to 150 ppm for gram-positive bacterium (S. aureus) and 300 ppm for gram negative bacteria (E. coli and P. aeruginosa).

The results of different finishing indicated that binding the nanoparticles by the chemical products improved wash and abrasion fastness as compared to the pad dried samples because of crosslinking the cellulose chains by anti-crease agents, or covering the fibres surface via the hydrophobic layer by the water repellent agents and preventing the release of nanoparticles. Subsequently, due to the low washing and abrasion fastness, pad-dry process presents a facile method for temporary anti-bacterial finishing for specific purposes where washing the textiles are not necessary. Consequently, due to the necessity of direct contact of the anti-bacterial agent with bacteria, it is crucial to choose the suitable finishing agent that does not limit silver nanoparticles accessibility to the surface of textile goods and also create enough fastness required for the end uses.

In addition, co-application of silver nanoparticles with anti-crease finishing agents or the water repellent fluorochemicals did not have any adverse effect on wrinkle recovery angle and repellent properties.

Overall, the results of this research showed that by co-applying silver nanoparticle and the finishing agents, acceptable anti-microbial effect with proper fastness properties could be achieved, accordingly there is no necessity to add another step to the general finishing layout for cotton fabric.

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# Preparation of antibacterial sheepskin with silver nanoparticles, potential for use as a mattress for pressure ulcer prevention

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**REZUMAT – ABSTRACT**

**Tratarea pieilor de ovine cu blană, destinate saltelelor pentru prevenirea ulcerului ischemic de presiune, cu o soluție antibacteriană pe bază de nanoparticule de argint**

*În cadrul acestui studiu, pieile de ovine cu blană au fost tratate cu nanoparticule de argint, cu o concentrație de 2.4 × 10$^{-2}$ g · L$^{-1}$ şi o dimensiune medie a particulei de 26 nm. S-au investigat absorbția nanoparticulelor de argint, morfologia şi efectul antibacterian al pieilor tratate. Spectroscopia UV-VIS a indicat o absorbție aproape totală a nanoparticulelor de argint în pieile cu blană tratate. Analiza de microscopie electronică de baleiaj (SEM) a confirmat faptul că nanoparticulele de argint aderă la suprafața acestora. Proprietățile antibacteriene ale pieilor cu blană tratate au fost evaluate după aplicarea unor tratamente repetate cu soluție artificială de transpirație. Rezultatele studiului au arătat că proprietățile de inhibiție antibacteriană a pieilor cu blană tratate sunt de 99,9% față de Escherichia coli şi Staphylococcus aureus şi că, după şase cicluri de tratare cu soluție de transpirație, acestea se mențin la nivelul de 79.4% pentru dermă şi 67.1% pentru lână. Astfel, comparativ cu tratamentele tradiționale, care utilizează agenți antibacterieni fenolici, toxici, în lucrare este prezentată o alternativă ecologică de obținere a pieilor cu blană utilizate ca saltele antiescară.*

*Cuvinte-cheie: piei de ovine cu blană, acțiune antibacteriană, nanoparticule de argint, prevenirea escarelor, saltele*

**Preparation of antibacterial sheepskin with silver nanoparticles, potential for use as a mattress for pressure ulcer prevention**

*In the study, sheepskin was treated with silver nanoparticles, which were prepared at the concentration of 2.4 × 10$^{-2}$ g·L$^{-1}$ with average particles size about 26 nm. The absorption of the silver nanoparticles by the sheepskin, as well as the morphology and the antibacterial effect of the treated sheepskin were investigated. The UV-VIS absorption spectroscopy indicated nearly all of the silver nanoparticles were absorbed by the sheepskin in this method. From scanning electron microscopy (SEM) observations, it was confirmed that the nanoparticles attached on the surface of the sheepskin. The antibacterial effect of the treated sheepskin was evaluated after repeated perspiration treatments. The results of antibacterial study showed that the treated sheepskin had an antibacterial inhibition ratio of 99.9% against Escherichia coli and Staphylococcus aureus, even after 6 cycles of perspiration treatment, the sheepskin still exhibited a durable antibacterial effect with the inhibition rate above 79.4% and 67.1% respective to the leather and the wool. Thus, comparing with traditional treatments which use toxic antibacterial agents such as phenolic active ingredients, this study has provided an eco-friendly alternative for the preparation of antibacterial sheepskin without nocuous organics, which would be potentially used as a mattress for pressure ulcer prevention.*

*Key-words: sheepskin, antibacterial activity, silver nanoparticles, pressure ulcer prevention, mattress*

Pressure ulcers are very prevalent, especially among elderly people residing in nursing homes and immobile patients [1, 2]. They develop when blood circulation in capillaries is obstructed by prolonged pressure. Shear and friction are the main factors contributed for the development of pressure ulcers [3]. So, there are many interventions used to minimize pressure on bony prominences for the prevention of pressure ulcers [4–6], in which, the usage of sheepskin has been a successful nursing aid since the early 1960's [7]. The high density pile of soft, springy resilient wool fibers provide a cushion to distribute the patient's weight and pressure points over a large area [8]. Each fiber acts as a "mini-spring" that deforms to the body contours. Meanwhile, the wool fibers are able to absorb 33% of their weight of moisture without damp feeling [9]. These properties of sheepskins result in improved comfort for the patients and reduction in the primary causes of pressure ulcers.

Because sheepskin is a natural biomaterial, it easily acts as media for the growth of microorganisms such as pathogenic or odor-generating bacteria and fungi [10–12]. When in contact with the patient's body, such material offers an ideal environment for microbial growth because of their large surface area and ability to retain oxygen, moisture and warmth, as well as nutrients from body spillages and exudates. With a rising interest in health and hygiene, sheepskin with antimicrobial properties is becoming an increasingly desirable aim for pressure ulcer prevention. However, the antibacterial agents used in sheepskin treatment currently are toxic organics, such as phenolic active ingredients, which would harm the safety of the patients. In addition, the organics are also lack of antibacterial efficiency and durability. Thus, an ideal antibacterial treatment for sheepskin should be safe and environmentally benign besides killing undesirable micro-organisms.

Herein, we report the usage of silver nanoparticles as a new material to prepare antibacterial sheepskin. Silver nanoparticles have attracted considerable interest from the chemical industry and medical field due to their unique properties, such as high electric conductivity [13], high catalytic effect [14] and high antibacterial activity [15–16]. Various inorganic antibacterial materials containing silver nanoparticles have been developed and some are in commercial use. The antimicrobial activity of silver nanoparticles is comparable or better than the broad spectrum of most prominent antibiotics used worldwide [17]. Moreover, the biological safety of silver nanoparticles has been widely proved in many researches [18–21]. These advantageous properties of the silver nanoparticles might be potentially useful for their applications to the sheepskin as an alternative antimicrobial agent. In this study, sheepskin was treated with silver nanoparticles for the potential use of pressure ulcer prevention. The absorption of the sheepskin with silver nanoparticles, as well as the morphology and the antibacterial effect of the treated sheepskin were investigated in detail.

## EXPERIMENTAL PART

### Materials used

Silver nitrate, sodium borohydride, sodium citrate and butylparaben were analytical grade and used as received. Benzalkonium bromide (5% solution, w/w) was purchased from Baiyun Pharmaceutical Company (China). Isothiazolinone (industrial grade) was bought from Huibang Chemical Company (China). Glutaraldehyde tanned sheepskin was bought from Chengdu (China).

### Preparation of silver nanoparticles

A $1.5 \times 10^{-2}$ g of $AgNO_3$ was dissolved in a 100 mL of distilled water and placed in water bath at 30ºC for 15 minute. A 100 mL of benzalkonium bromide ($2 \times 10^{-2}$ g) solution was added dropwise to the $AgNO_3$ solution with intense stirring for 30 minute to form a combined solution. Subsequently, a 200 mL of solution containing $NaBH_4$ ($7.4 \times 10^{-3}$ g) and benzalkonium bromide ($4 \times 10^{-2}$ g) was added dropwise for 1.5 hour to get silver nanoparticles. Then, the prepared silver nanoparticles were conserved at 30ºC. Image of the silver nanoparticles was obtained using a transmission electron microscopy on copper grids (JEM-100CXII, Japan). Size distribution of the silver nanoparticles was measured by DLS (Dynamic Light Scattering) technique using a nanoparticle size analyzer (Zetasizer NanoS90, Malvern, England).

### Antimicrobial activity of the silver nanoparticles

Various strains of bacteria including gram-negative bacteria Escherichia coli, Enterobacter hough, Acinetobacter, gram-positive bacteria Staphylococcus aureus, Bacillus subtilis, Bacillus cereus were used to evaluate the antibacterial activity of the prepared silver nanoparticles. Both butylparaben and isothiazolinone were used to compare the antimicrobial effect with the silver nanoparticles. Firstly, a 10 mL of beef extract peptone medium and a 1 mL of the bacteria suspension ($1.0 \times 10^5$ cfu · mL$^{-1}$) were added in a culture dish. Then, the prepared antimicrobial agents were serially diluted in the culture dishes [22]. The minimum inhibitory concentration (MIC) was read after the culture dishes were incubated in a Mould Incubation Chamber at 37ºC and 90% relative humidity for 24 hours.

### Treatment of sheepskin with silver nanoparticles

Each sheepskin sample (3 cm × 3 cm) was washed in 200 ml water with 0.5 g · L$^{-1}$ sodium dodecyl sulfate (SDS), and dried at 30ºC. Then, the sheepskin was rewetted in a conical beaker with a 1 200% float (based on the weight of the sheepskin) at 30ºC overnight. Next, the sample was squeezed lightly to remove the excess water, soaked in the prepared silver nanoparticles solution ($2.4 \times 10^{-2}$ g · L$^{-1}$) and shaked in a shaker bath at 30ºC for 3 hours. After this time period, the sheepskin was picked out, squeezed lightly to remove the excess water, and then dried at 30ºC in an oven.

### Characterization of the treated sheepskin

The absorption of silver nanoparticles was analyzed with a UV-vis absorption spectroscopy (UV-2501PC, Shimadzu, Japan). Images of the treated sheepskin were obtained using a scanning electron microscopy (S-480, Hitachi, Japan). The surfaces of the wool and the leather were coated with a layer of gold before SEM characterization. Energy dispersive spectroscopy analysis (EDS) was used to confirm the presence of silver particles.

### Antimicrobial activity of the treated sheepskin

#### *Antibacterial test*

The antibacterial activity of the wool and the leather of the sheepskin were evaluated separately, using a shake flask method [23]. A typical procedure was as follows: 2 g of the treated leather or wool, was cut into small pieces of approximately 1 cm × 1 cm (the wool was 1 cm long), and 0.2 mL bacterial spore suspension at the concentration of $1.0 \times 10^5$ cfu · mL$^{-1}$ were added to a triangular flask containing 20 mL sterilized physiological saline solution. Then, the flask was shaken for 8 hours at 200 rot./minute in a water-bath oscillator. The colony forming units (*cfu*) of the remained solution before and after oscillation were determined. The inhibition ratio (*IR*) of the antibacterial sheepskin was calculated using the following formula:

$$IR = \frac{C_0 - C_t}{C_0} \times 100\% \qquad (1)$$

where:

$C_0$ and $C_t$ are the colony forming units of the solution before and after oscillation, respectively.

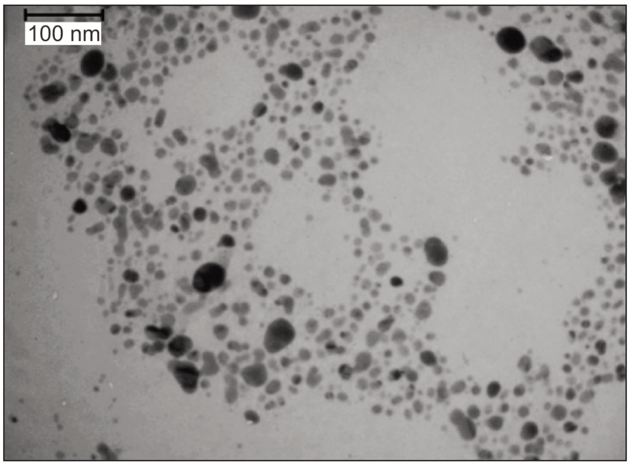


Fig. 1. TEM image of the silver nanoparticles

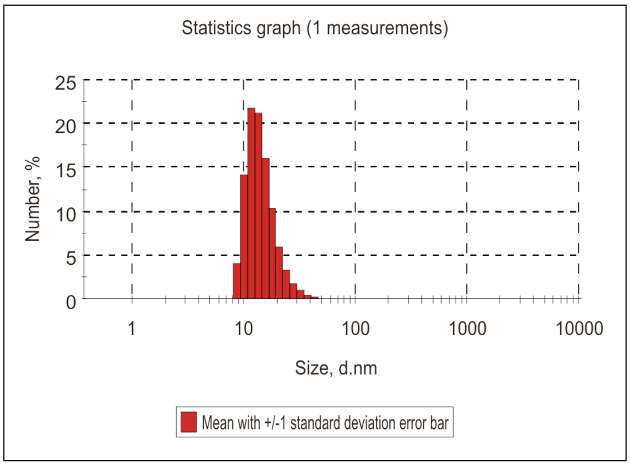


Fig. 2. Size distribution of the silver nanoparticles

Table 1

| *MIC* (μg · mL$^{-1}$) OF THE ANTIBACTERIAL AGENTS | | | | | | |
|---|---|---|---|---|---|---|
| **Sample** | **Gram-negative bacteria** | | | **Gram-positive bacteria** | | |
| | ***Escherichia coli*** | ***Enterobacter hough*** | ***Acinetobacter*** | ***Staphylo-coccus aureus*** | ***Bacillus subtilis*** | ***Bacillus cereus*** |
| $A^{a*}$ | 50 | 100 | 200 | 50 | 50 | 25 |
| $B^{b*}$ | 4 | 4 | 15 | 2 | 4 | 4 |
| $C^{c*}$ | 1 | 4 | 6 | 4 | 6 | 2 |

* $^a$ is butylparaben, $^b$ is isothiazolintone, $^c$ is silver nanoparticles.

### *Perspiration treatment*

The artificial sweat was prepared containing 5 g/L hydroxylamine hydrochloride monohydrate, 5 g/L sodium chloride and 2.5 g/L disodium hydrogen phosphate dihydrate. The *p*H of the artificial sweat was adjusted to 8.0 with 0.1 mol/L sodium hydroxide. The treated sheepskin sample (3 cm × 3 cm) was completely immersed in the artificial sweat (100 ml) and placed at 35ºC for 24 hours. After this time period, the sheepskin was picked out and dried at 30ºC for the antibacterial test.

## RESULTS AND DISCUSSIONS

### Dispersity and particle size analysis of silver nanoparticles

The morphology and the dispersity of the silver nanoparticles were analyzed by TEM observation. The TEM image showed the silver nanoparticles were spherical in shape, and dispersed well in the solution, without agglomeration (fig. 1). As further analysis from the dynamic light scattering (*DLS*) method, the average particles size of the silver nanoparticles was about 26 nm (fig. 2).

### Antibacterial study of the silver nanoparticles

The dilution micromethod [22] was applied to study the antibacterial activity of silver nanoparticles on the agar plates. Both butylparaben and isothiazolin-ketone, which are the antibacterial agents commonly used in leather industry, were subjected to the antibacterial tests. MIC of the tested samples is summarized in table 1.

As can be seen in table 1, the silver nanoparticles had excellent antibacterial effect on all tested specimens against gram-positive and gram-negative bacteria. And also, the MIC of the silver nanoparticles was much less than butylparaben, and less than isothiazolinone overall. The antibacterial tests showed that the MIC of the silver nanoparticles against Escherichia coli was the least as to the six bacteria strains, which was 50 times less than butylparaben and 4 times less than isothiazolinone, respectively. That is to say, to inhibit a same Escherichia coli strain, only a fewer dosage of the silver nanoparticles is needed than that of butyl-paraben and isothiazolinone.

The effective antibacterial activity of silver nano-particles may be owing to the silver nanoparticles react to the bacterial cell membrane and weaken it firstly, then invade into the bacteria and cause damage by interacting with phosphorus- and sulfur-containing compounds such as DNA, which lead to the cell death [24]. This active property showed a promising prospect of the utilization of silver nanoparticles instead of organic antibacterial agents for the treatment of sheepskins.

### Antibacterial results of the treated sheepskin

The antimicrobial properties of the sheepskin treated with different dosages of silver nanoparticles were quantitatively evaluated against Escherichia coli. The antibacterial effect of the wool and the leather of the

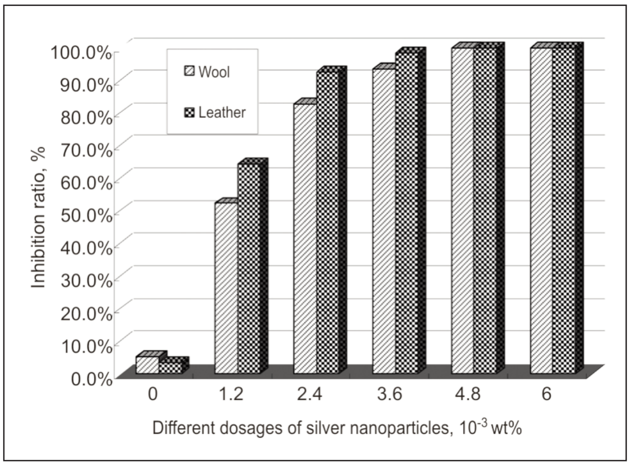


Fig. 3. Inhibition ratio of the treated sheepskin with different dosages of silver nanoparticles against Escherichia coli

sheepskin was tested separately. As expected, the wool and the leather without silver nanoparticles gave a negligible antibacterial activity of less than 6% (fig. 3). The antibacterial activity of the wool and the leather increased with increasing dosage of silver nanoparticles from 1.2 × $10^{-3}$ wt% to 4.8 × $10^{-3}$ wt%, base on the weight of the sheepskin. As the dosage was 4.8 × $10^{-3}$ wt%, the inhibition ratio reached 99.9% for both the leather and the wool, indicating the treated sheepskin had a better antibacterial activity against Escherichia coli, so, the sheepskin was treated with silver nanoparticles of this dosage for the further analysis.

## Absorption of the treated sheepskin

The absorption of the silver nanoparticles in the sheepskin was determined by a UV-VIS absorption spectroscopy, which is a very useful technique for the analysis of nanoparticles [25]. Figure 4 shows the UV-VIS absorption spectroscopy of the silver nanoparticles before and after antibacterial treatment at the dosage of silver nanoparticles of 4.8 × $10^{-3}$ wt%. The absorption peak around 400 nm is the charac-

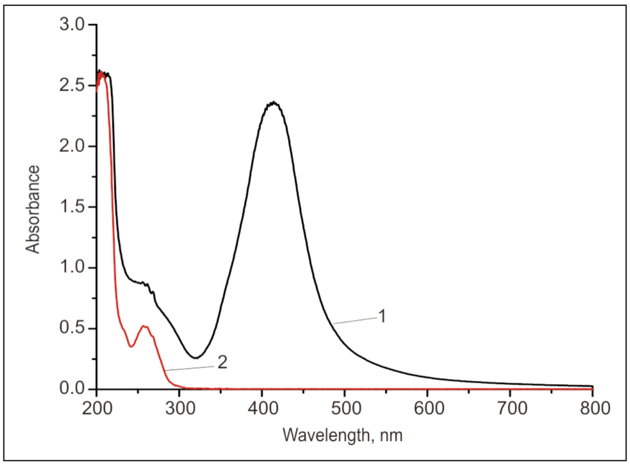


Fig. 4. UV-VIS spectroscopy of the silver nanoparticles concentration:
***1*** – before antibacterial treatment of sheepskin;
***2*** – after antibacterial treatment of sheepskin

teristic absorption peak of silver nanoparticles [26]. It can be seen the absorption peak at 406 nm was vanished completely after treatment, indicating that nearly all of the silver nanoparticles were absorbed by the sheepskin and there are few nanoparticles in the solution. The same absorption was observed when we used lower silver nanoparticles dosage of 1.8 × $10^{-2}$ wt% to treat the sheepskin. This interesting phenomenon may be owing to the high activity of the silver nanoparticles, which would impel the adhesion of the silver nanoparticles on the sheepskin to reduce the particle surface energy.

## Morphology of the treated sheepskin

Samples of sheepskin treated with silver nanoparticles at the dosage of 4.8 × $10^{-3}$ wt%, as well as their controls were investigated by SEM (fig. 5). Representative images of the micrographs of the investigated wool are shown at different magnifications, both treated and control samples. The scale layer of the wool is clearly shown at low magnification (× 10 000). When comparing the treated samples with the control, it can be seen the surface of treated

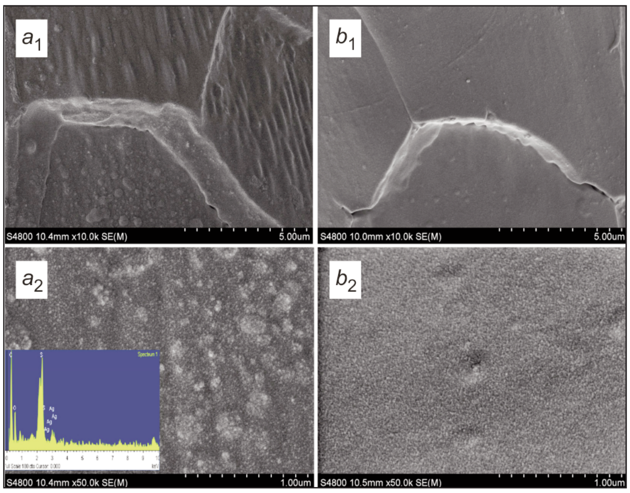


Fig. 5. ***$a_1$, $a_2$*** – SEM images of the wool with silver nanoparticles; ***$b_1$, $b_2$*** – control samples
EDS analysis shows peaks of silver (small panel)

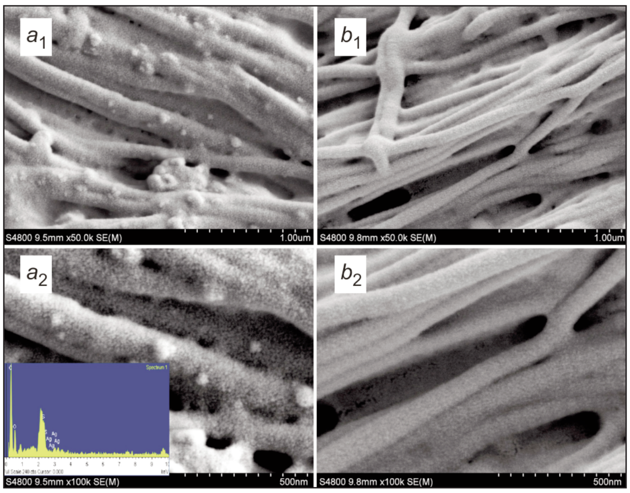


Fig. 6. ***$a_1$, $a_2$*** – SEM images of the leather treated with silver nanoparticles; ***$b_1$, $b_2$*** – control samples
EDS analysis shows peaks of silver (small panel)

Table 2

| ANTIBACTERIAL INHIBITION RATIO (%) OF THE SHEEPSKIN TREATED WITH SLIVER NANOPARTICLES AFTER DIFFERENT CYCLES OF PERSPIRATION TREATMENT | | | |
|---|---|---|---|
| **Sample** | **Perspiration treatment** | **Bacterial strains** | |
| | | ***Escherichia coli*** | ***Staphylococcus aureus*** |
| Wool | 0 cycles | 99.9 | 99.9 |
| | 3 cycles | 88.1 | 74.7 |
| | 6 cycles | 83.2 | 67.1 |
| Leather | 0 cycles | 99.9 | 99.9 |
| | 3 cycles | 90.6 | 81.3 |
| | 6 cycles | 87.5 | 79.4 |

wool was obviously coarser than that of the control, indicating the attachment of the silver nanoparticles on the surface of the wool. Also, the EDS analysis showed the presence of the silver particles with content of 3.01% on the surface.

The SEM images of the leather samples, both treated and control, were also presented at different magnifications (fig. 6).

It can be easily observed that silver nanoparticles attached on the surface of the collagen fibrils in the case of the treated sample in comparison with the control.

The EDS analysis showed the silver content of the surface of the treated leather was 6.43%. We also observed the cross section of the treated leather, but no silver particles were detected, showing the silver nanoparticles were rather attached on the surface of the leather than penetrated the fibrils.

### Perspiration durability of bacteriostasis of the treated sheepskin

The antibacterial activity of the treated sheepskin could potentially be reduced when contacted with patients' perspiration. Thus, the durability of antibacterial activity to perspiration is a major consideration. To evaluate the durability of antibacterial property, the antibacterial efficacy of the treated samples after repeated perspiration treatment was examined. Table 2 shows the effect of repeated perspiration treatment on the antibacterial activity of the sheepskin treated with silver nanoparticles at the dosage of $4.8 \times 10^{-3}$ wt%. It is found that the treated sheepskin had an antibacterial inhibition ratio of 99.9% against the two tested bacteria without perspiration treatment. As cycles of perspiration treatment increased, the antibacterial effect decreased gradually. However, even after 6 cycles of perspiration treatment, the sheepskin still exhibited a good antibacterial effect with the inhibition ratio above 79.4% and 67.1%, respectivelly to the leather and the wool. The good perspiration durability demonstrated the stable adhesion of the silver nanoparticles on the surface of sheepskin, which may prolong the service life of the antibacterial sheepskin.

## CONCLUSIONS

This study has shown a novel way to prepare antibacterial sheepskin with silver nanoparticles as a new antibacterial agent. The UV-VIS absorption spectroscopy indicated that nearly all of the silver nanoparticles were absorbed by the sheepskin. The SEM images confirmed that the silver particles attached on the surface of the sheepskin. The results of antibacterial study showed that the treated sheepskin had an antibacterial inhibition ratio of 99.9% against Escherichia coli and Staphylococcus aureus, even after 6 cycles of perspiration treatment, the sheepskin still exhibited a durable antibacterial effect with the inhibition rate above 79.4% and 67.1% respective to the leather and the wool. Thus, comparing with traditional treatments which use toxic antibacterial agents such as phenolic active ingredients, this study has presented an eco-friendly alternative for the antibacterial treatment of sheepskin which would be potentially used as a mattress for pressure ulcer prevention.

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# Using Gemini-Cad sofware for pattern nesting on textile-based leather substitutes

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LILIANA INDRIE
SABINA GHERGHEL
LILIANA DOBLE

**REZUMAT – ABSTRACT**

**Utilizarea programului Gemini-Cad la încadrarea tiparelor pe suprafața înlocuitorilor cu suport textil**

*În lucrare sunt prezentate rezultatele cercetărilor privind încadrarea optimă a tiparelor pentru fețe de încălțăminte pe suprafața materialelor de tip înlocuitori de piele pe un suport textil, utilizând programul de lucru Gemini Cad. În acest program se vor face aşezări practice tipar cu tipar, sau aşezări practice în care să se încadreze toate tiparele din componența unui produs de încălțăminte pe suprafața materialului. În vederea obținerii unor indici superiori de utilizare a materialului, în porțiunile de deşeu se vor încadra tipare de curea, care, ulterior, vor fi utilizate la confecționarea unor articole de marochinărie, de tip curele pentru femei. Prin utilizarea acestui program este posibilă aşezarea combinată a tiparelor într-un timp scurt, respectând direcțiile de întindere minimă a materialului respectiv, precum şi direcția de solicitare maximă a tiparului, atât în procesul de purtare, cât şi în procesul de utilizare.*

*Cuvinte-cheie: înlocuitori de piele, suport textil, tipar, produs de încălțăminte, curea, încadrare optimă, model, aşezare practică, Gemini Cad*

**Using Gemini-Cad sofware for pattern nesting on textile-based leather substitutes**

*In this paper are shown the research results regarding the optimal placement of patterns of footwear exterior part on the surface of leather substitute materials on textile support, using the Gemini Cad program. In this program are positioned pattern by pattern or practical placements are realized in which all the patterns that make up a footwear product are placed on the surface of the material. In order to obtain superior usage indices of material, in waste material parts will be placed belt patters, which consequently will be used as leather goods, such as belts for women. By using this program it is possible to realize a combined placement of patterns in a short time, taking into consideration though the directions of minimum stretch of material, respectively the direction of the maximum stretch of the pattern both for wearing as well as for exploitation.*

*Key-words: leather substitute on textile support, pattern, footwear, belt, optimal placement, model, practical placement, Gemini Cad*

Leather substitutes on textile support are more and more used in the leather garment industry, due to its reduced cost, but also due to some superior proprieties specific to leather. The physical-mechanical characteristics of these materials are given by the textile support, which constitutes the basic layer of leather substitutes, this being a woven, unwoven or knitted material [4].

The hygienic proprieties of leather substitutes are influenced by the porosity of these materials, thus the leather substitutes are superior to leather form the pint of view of desorption and thermal conductivity.

From the point of view of material saving when cutting the patterns for footwear exteriors, we notice the uniform aspect of leather substitutes, without flaws, which leads to a rational use of leather substitutes when cutting the flexible patterns for footwear exteriors [2].

The ratio between pattern pieces and waste when cutting the material is influenced by a number of factors [9], [10]:

- the configuration of pattern shapes and the possibility of interpenetration;
- the size of the material form which the patterns are being cut;
- the shape and the size of the patterns, as well as their arrangement;
- the quality of the material;
- the working method: cutting a single pattern or cutting all the component patterns on the same surface;
- the skill of the worker.

The positioning of the patterns on the surface of the leather substitutes is done in compliance with the general rule of cutting, respectively the direction of the minimum stretch of the material should coincide with the direction of the maximum stretch of the patterns [8].

The usage coefficient value for the leather substitutes patterns positioning will depend on the way they cover the surface of the substitute, the width of the substitute and also the length that is adopted [6].

In technological practice, the main objective regarding the optimal use of materials surfaces in the process of manufacturing footwear products, is represented by cutting through modern techniques

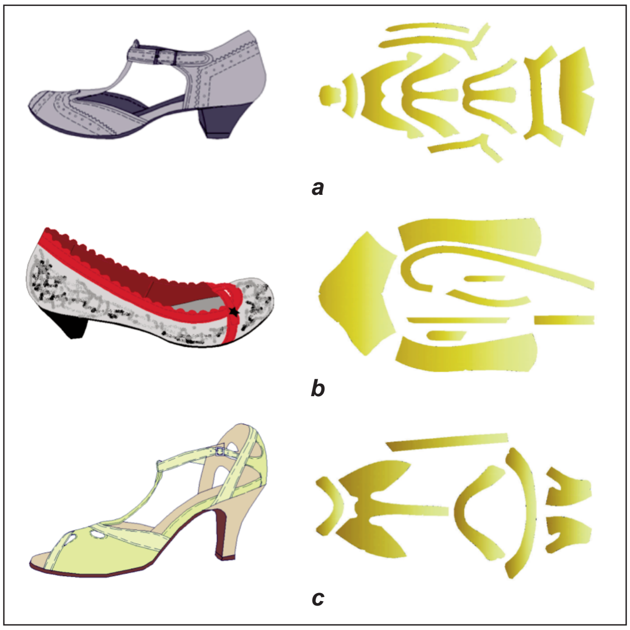


Fig. 1. Model versions:
***a*** – model $M_1$ and pattern; ***b*** – model $M_2$ and pattern; ***c*** – model $M_3$ and pattern

and that is the automated cutting of the patterns used for footwear exteriors [4].
This techniques uses the Gemini Cad program, with the help of which optimal arrangements are done on the surface of leather substitutes, in order to obtain superior usage indices. Gemini Cad is the absolute solution for textile and leather garment industry, offering a quick and precise support for the whole technological flux of preparing the textile products starting from basic design up to cutting and optimizing the placement of patterns.
The present paper shows the research results regarding the optimal placement of leather substitute patterns using the Gemini Cad program, with the help of which the arrangement is done on the whole surface of the material, both for one single pattern [5], [7], and also for all patterns that are component part of a product pair. Also in order to put to good use the waste material pieces there will be placed also the component patterns of some leather products such as belts.

## THE EXPERIMENTAL PART

In the case of the three shoe models obtained from "S.C. Tricostar S.R.L." Oradea, different arrangements using the Gemini Cad program were made, in order to increase the usage index. Thus practical arrangements will be done [1], pattern by pattern but also arrangements where, on the surface of the material, component patterns of a footwear product are placed, and in order to obtain a superior usage index [3] belt patterns will be inserted [2] in the waste material parts on the surface of the material.
The model versions as well as the component patterns which make up each model are presented in figure 1.
The windows of the Gemini Cad program are shown in the figure 2 and figure 3.

## RESULTS AND DISCUSSIONS

To exemplify this with help of Gemini Cad program, the practical arrangement pattern by pattern combined with the belt patterns, from the composition of three models, taken while still in the working process, is shown in figure 4.
The optimum arrangement values, using Gemini Cad for the cut patterns made of leather substitutes, arrangements where all the component parts of a product pair were positioned and in which were intercalated also belt patterns, is shown in figure 5.
By combining a component pattern of a footwear product with belt patterns, a significant improvement of usage indices values is obtained, in the case of practical arrangements pattern by pattern.
The values of these indices, for the patterns taken while still in work are presented in figure 6.
For model *1* (fig. 6) arrangements for the toe cap *2* are made, where we get a usage coefficient of 50.05%, then for toe cap *3*, a coefficient of 43.87%, and for the back strap *2*, we get a value of 55.83% of the coefficient of material usage.
For model *2* (fig. 7) we obtained values of 52.12% for the collar 1.85,5% for the interior top banc 84.3% for the exterior top band.
For model *3* (fig. 8), we obtained values of 72.89% for toe cap and 66.18% for the strap shoe rist.
From the above graphs we notice an increase in the usage indices for the patterns where the arrangement allowed the insertion of belt patterns in the areas with normal waste material, edges and moulds, which appear when cutting the flexible patterns on the leather substitute surface.

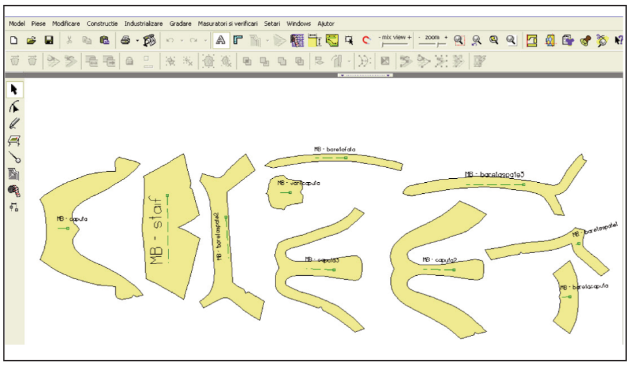

Fig. 2. Pattern editor module with imported models

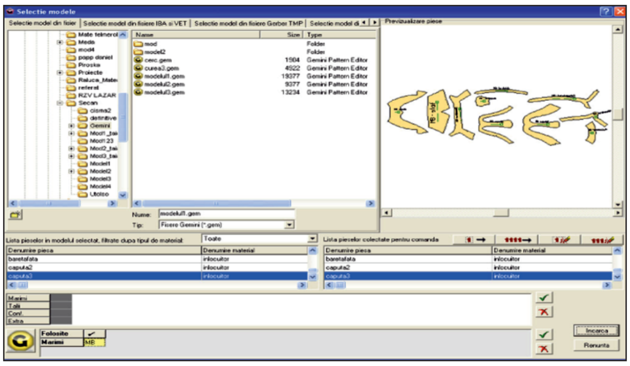

Fig. 3. Cut-plan module with the selected model

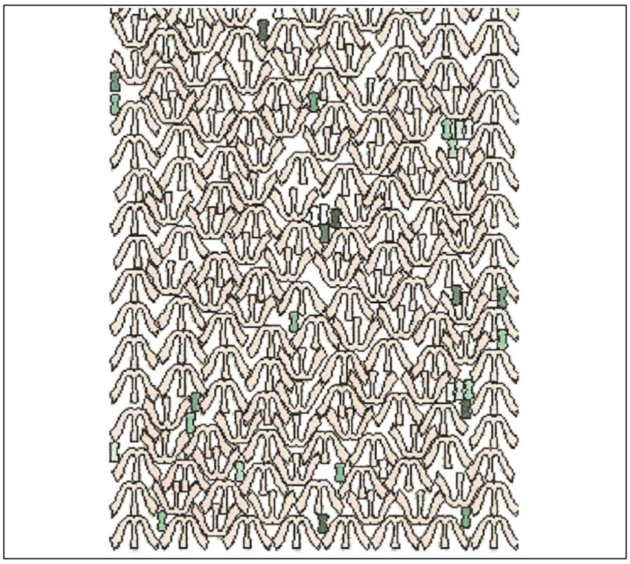

Fig. 4. Combined practical arrangement, toe cap 2, model *1*

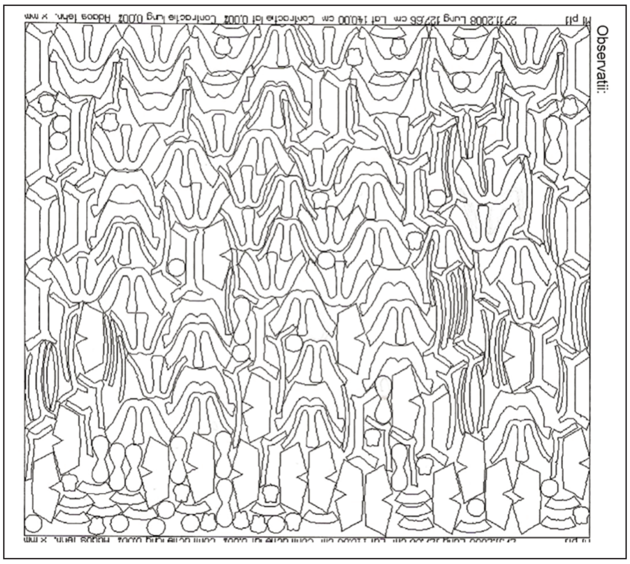


Fig. 5. Combined practical arrangement model *1*

For a more suggestive exemplification of usage indices variation, in figure 9 are presented for the 3 models analyzed, the values of these indices, for both variants in which the patterns arrangement was done.

From this graph we notice an increase of usage index in the case of the second variant, in which the arrangement of all the patterns from a footwear product on the surface of the material, the waste material pieces being put to good use by placing some belt patterns in the Gemini-Cad program.

By the practical placement of patterns for model *1* we obtain a usage coefficient $I_u$ = 55.73%, for model *2* we get $I_u$ = 73.03%, and for the third model we obtain a usage index of $I_u$ = 70.86%.

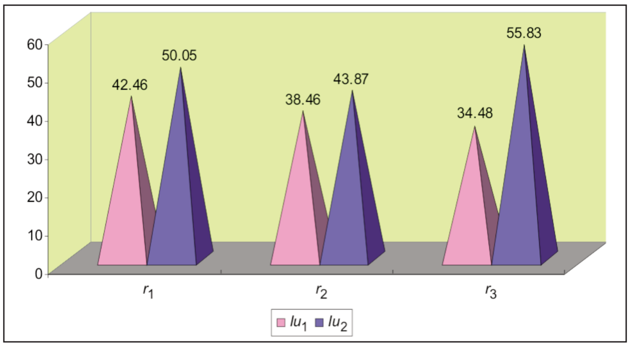


Fig. 6. Optimizing the usage indices for model *1*: $Iu_1$ – usage indices of the surface for the pattern by pattern arrangement; $Iu_2$ – usage indices of the surface for the combined arrangement of the patterns with the belt pattern; $r_1$, $r_2$, $r_3$ – patterns

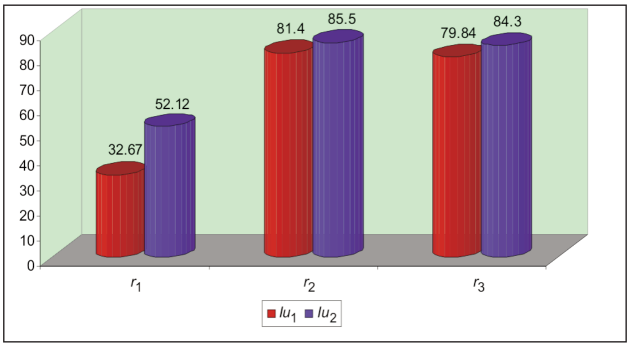


Fig. 7. Optimizing the usage indices for model *2*: $Iu_1$ – usage indices of the surface for the pattern by pattern arrangement; $Iu_2$ – usage indices of the surface for the combined arrangement of the patterns with the belt pattern; $r_1$, $r_2$, $r_3$ – patterns

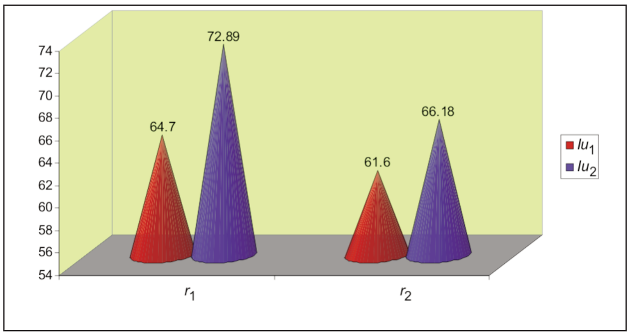


Fig. 8. Optimizing the usage indices for model *3*: $Iu_1$ – usage indices of the surface for the pattern by pattern arrangement; $Iu_2$ – usage indices of the surface for the combined arrangement of the patterns with the belt pattern; $r_1$, $r_2$, $r_3$ – patterns

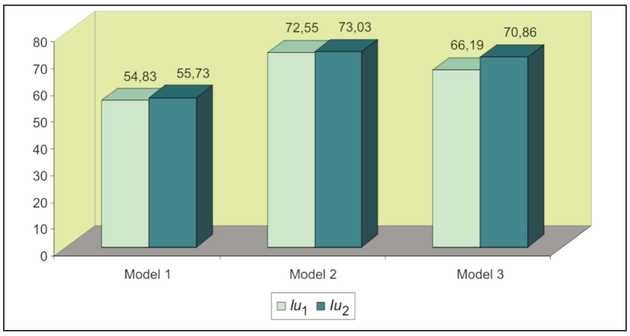


Fig. 9. Usage indices variant for models *1, 2* and *3*: $Iu_1$ – usage indices of the surface for the pattern by pattern arrangement; $Iu_2$ – usage indices of the surface for the combined arrangement, of all patterns from a product pair, with belt patters

In the case of model *1*, we obtained a significant increase of the usage index, just by combining its patterns with the ones form model *2*, thus obtaining a value of 70.02%.

The $I_u$ increase in the case of the models that we have analyzed is higher for model *2*, respectively of 73,03%.

## CONCLUSIONS

By using the Gemini Cad program we get better values of the usage index for patterns arrangement on the surface of leather substitutes, due to its possibility to make a combined arrangement of all the patterns for a footwear product, in a short time, considering the material's directions of minimum stretch, respectively the direction of maximum demand of the patterns both for wearing and also for exploitation. Reducing the material expenditure will have a positive influence upon the increase of the usage coefficient. This expenditure decrease can be done by a rational design of moulds, but also by putting to good use the technological waste materials resulted from the cutting process.

The resulted waste material from the cutting process of leather and leather substitutes can be used for obtaining some smaller details that can be part of footwear or leather goods products.

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# Predicting pull-out force of loop pile of woven terry fabrics usingartificial neural network algorithm

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**REZUMAT – ABSTRACT**

**Evaluarea forței de smulgere a firelor de pluş din țesăturile flauşate, pe baza algoritmului rețelei neurale artificiale**

*În acest studiu, s-a analizat capacitatea metodei rețelei neurale artificiale, bazată pe algoritmul de învățare cu gradient conjugat, de modelare a forței de smulgere a firului de pluş din prosoapele flauşate. Prin urmare, au fost selectate 24 de mostre diferite, din care 21 de mostre ca set de instruire şi 3 mostre ca set de testare. Modelele dezvoltate au fost evaluate prin verificarea erorii pătratice medii de predicție a datelor de testare. Rezultatele obținute evidențiază faptul că modelul rețelei neurale artificiale este foarte eficient pentru predicția forței de smulgere a firului de pluş din țesăturile pluşate pe baza parametrilor procesului. Valoarea lui $R^2$ a modelului rețelei neurale artificiale a fost de 0,998. De asemenea, a fost investigată importanța relativă a parametrilor procesului asupra forței de smulgere a firului de pluş. S-a descoperit că finețea firului de pluş este principalul parametru care influențează acest proces.*

*Cuvinte-cheie: țesătură pluşată, forță de smulgere, rețea neurală artificială, gradient conjugat*

**Predicting pull-out force of loop pile of woven terry fabrics using artificial neural network algorithm**

*In this study, the capability of artificial neural network (ANN) method based on scale conjugate gradient learning algorithm for modeling the pull-out force of pile yarn in terry towel was investigated. Accordingly, 24 different samples were produced. 21 samples were selected as training set and 3 ones as testing set. The developed models were assessed by verifying mean square error (MSE) of prediction of testing data. The obtained results reveal that the artificial neural network model is very effective for predicting the pull-out force of pile yarn of terry fabrics based on process parameters. The $R^2$ value of artificial neural network model was 0.998. The relative importance of process parameters on pull-out force of pile loop has also been investigated. The count of pile yarn was found as the major contributing parameter.*

*Key-words: terry fabric, pull-out force, artificial neural network, scale conjugate gradient*

## TERRY FABRICS

A terry woven described as a textile product that is made with loop pile on one or both sides generally covering the entire surface or forming strips, checks or other patterns. A woven terry consists of five parts namely pile area, fringes beginning and end part, selvage and borders. The pile area is considered the toweling part of the towel [1].

The functionality of the pile area is very important and the users consider this part precisely. A terry woven fabric should be characterized by some characteristics such as high water absorption ability, heat insulation, crease resistance, friction coefficient and bulky handle. In the literature, there are some studies about the terry towels [2–10]. In this filed the work of Karahan [2] that studied the effect of fabric construction of terry woven fabrics on dynamic water absorption could be mentioned. It was shown that around 26% to 40% of water was absorbed during the first 10 seconds. Van der meeren et.al quantified wetting and wicking phenomena in cotton terry [3]. Performance of open-end and ring spun yarns in terry toweling were investigated by a variety of methods by lord [4]. Effect of pile height on static water absorption was also studied [5]. Wetting phenomenon of terry fabrics was studied by Petrulyte and Baltakyte [6].

One of the main problems in the terry fabrics is the poor resistance of pile yarns against pull-out which not only effect the functionality, but also the appearance of woven terry towel. Therefore, the structure and weaving parameters of terry fabrics should also be selected in ways, which improve the resistant of pile yarns against pull-out.

## ARTIFICIAL NEURAL NETWORK ALGORITHM

An artificial neural network (ANN) is one of the intelligence technologies for data analysis, which has been employed extensively in various textile disciplines ranging from yarn manufacturing, fabric formation and fabric properties. This technique is useful when there are a large number of effective factors on the specific process.

The artificial neural network technique imitates the behavior of biological neural networks to learn a subject from the data provided to it. An Artificial Neural Network (ANN) is composed of simple elements, called neuron or processing elements, operating in parallel by biological nervous systems. There are different kinds of structure and learning algorithms, but the feed forward neural network with back-propagation (BP) learning algorithms is more popular. In this structure, the neurons are located in layers and from one layer to another one connected with each other with links to carry the signals between them. There is a weight for each connection link, which acts as a multiplication factor to the transmitted signal. An activation function is applied to each neuron's input to determine the output signal [11].

In this study, the back-propagation algorithm was based on scaled conjugate gradient (S.C.G) learning algorithm. The initial evaluations performed, clearly showed the advantages of this algorithm compared with the conventional gradient descent with momentum and gradient descent with variable learning rate algorithms. This algorithm does not perform a line search at each iteration. Scaled conjugate gradient (S.C.G) substitutes the line search by a scaling of the step that depends on success in error reduction and goodness of the quadratic approximation to the error. It is motivated by the desire to accelerate the typically slow convergence associated with the gradient descent method while avoiding the information requirements associated with the evaluation, storage and inversion of the Hessian matrix as required by the Newton method. Hestenes and Stiefel originally developed the standard conjugate gradient method and Moller developed the scale conjugate gradient [12].

In the literature, three are many researches using the artificial neural network algorithm such as the research of Koc and Yurek on tensile strength of polyester/viscose blended open end rotor spun yarns [13]. A study was carried out by Hasani et al. for optimizing the production parameters of elastic core-spun yarns produced by siro spinning [14]. Kumar et al. proposed an ANN model to predict the drape profile of cotton woven fabrics [15]. Majumdar et al. compared three modeling methodologies based on mathematical, statistical, ANN models on predicting the breaking elongation of ring and rotor spun yarns [16, 17]. Neural network was used to predict the properties of melt spun fibers [18]. Intelligent model to predict the tensile properties of needle-punched nonwovens was also proposed by Debnath et al. [19].

The main object of this research was to predict and modeling the pull-out force of loop pile of terry woven fabrics, which is one of the main critical parameters of terry towels. Pull-out force of pile yarn was predicted based on some of the main process parameters namely, count of pile yarn, count of weft yarn, weft density, and the kind of weft yarn by using artificial neural network (ANN) algorithm based on scale conjugate gradient (SCG) learning algorithm. Finally, the effectiveness of each independent parameter was evaluated.

## MATERIALS AND METHODS

### Experimental part

To study the effect of count of pile yarn (Ne), count of weft yarn (Ne), weft density (picks/cm) and kind of weft yarn on the loop pile pull-out force, 24 terry woven fabrics with classical three-weft weaves (fig. 1) were woven on Dornier Air-jet weaving machine. The produced samples had the same warp parameters, i.e. 20/2 Ne (100% cotton) with 11 ends per cm, 220cm width, and the 11 pile per cm of 100% cotton yarns. Two kinds of weft yarns i.e. cotton and polyester with 15, 16 and 20 Ne were used. Weft density varied in three levels 16, 18 and 20 per cm and count of pile yarn was 10 and 20 Ne.

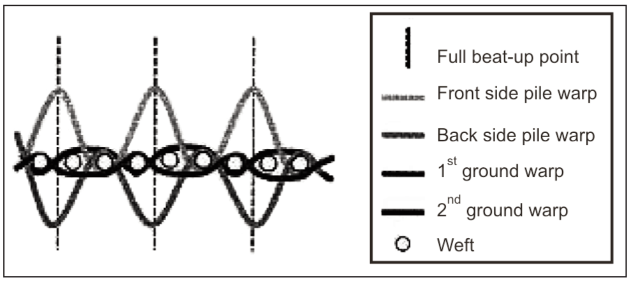
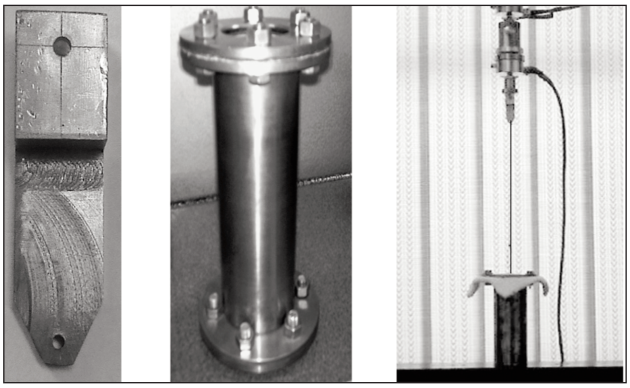



Fig. 1. Basic 3-picks terry weave [1]

For devising a method for estimation of pull-out force of pile yarn, we modified the Zwick tensile tester instrument that works based on CRE method. So, specific clamp was installed on fixed jaw to pull-out the pile yarn using a hook (fig. 2*a*). The hook was linked to the specific clamp using a copper wire with 0.2 mm diameter. As shown in figure 2*b*, each sample was mounted on purpose-built circle shaped holder, which was installed on movable jaw. In figure 2*c*, the overall view of testing method has been illustrated.



***a*** ***b*** ***c***

Fig. 2: ***a*** – special tools installed on fixed jaw; ***b*** – sample holder on movable jaw; ***c*** – general view of proposed method

The speed of movable jaw was 1 mm/ minute and the amount of movement was 4 cm. Each sample was tested five times. The pull-out curves of pile yarn of sample 24 has been shown in figure 3. As shown, each peak of curve belongs to the beginning of pulling out two loop pile in both sides of pull-out point from the terry fabric. So first peak of four successive loop piles were extracted from the stress-strain curves as pull-out force of first two loop pile from the surface of woven terry towel. In table1, the extracted results from the pull-out curves which were for the

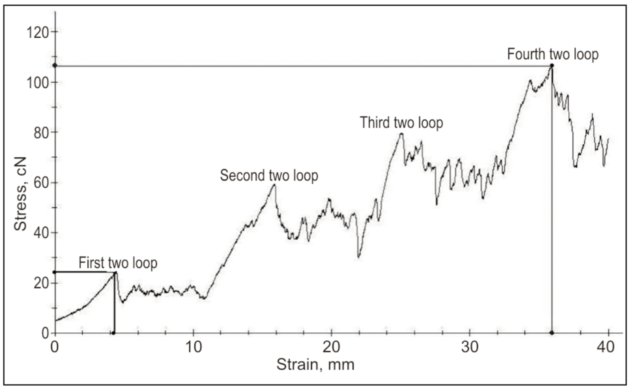



Fig. 3. The pull-out curve of pile yarn of sample 24

first two loop pile of samples and also the process parameters of all samples have been presented.

The pull-out force of first two loop pile (cN) was applied as output and the mentioned parameters as input to the artificial neural network models. For artificial neural network modeling the Matlab software was used.

### Artificial neural network parameters

The network parameters were adapted through the presentation of 21 training and 3 testing data. Batch mode of back-propagation learning weight updating was used. The number of hidden neurons and the number of hidden layers are usually adjusted by trail and error. Studies by various researchers have shown that neural networks with one hidden layer are suitable for the majority of applications, however, some works have reported using more than one hidden layer and have obtained better results. Therefore, we have used ten different network structures with one and two hidden layer(s) consisting of 4–6 neurons. All the designed networks have four input units and one output neuron in output layer, which was pull-out force of loop pile. The input parameters were count of weft yarn (Ne), count of pile yarn (Ne), weft density (picks/cm), and kind of weft yarn. All of these parameters were expressed in a vector form. Regards the qualitative input parameter, namely kind of weft yarn, input were encoded as 1, and 2.1 referred to cotton, and 2 referred to polyester weft yarn.

The back-propagation learning algorithm was based on scaled conjugate gradient (S.C.G) learning algorithm.

To prevent over fitting of networks, weight decay technique based on the mean square error regularization (MSEREG) performance function as shown in equation (1) was used instead of common mean square error function. Based on neural network toolbox of Matlab software, weight decay generally provides better generalization performance network compare with cross-validation technique. This is due to the fact that, weight decay dose not requires a validation data set to be separated out of the training data set. It uses all of the data and this advantage is especially noticeable when the size of the data set is small [20].

$$msereg = \gamma(mse) + (1 - \gamma)msw \qquad (1)$$

Table 1

GENERAL PROPERTIES OF SAMPLES AND PULL-OUT FORCE OF FIRST TWO LOOP PILE

| Count of pile yarn, Ne | Kind of weft yarn | Weft density, picks/cm | Count of weft, Ne | Pull-out force, cN |
|---|---|---|---|---|
| 10 | cotton | 20 | 15 | 116.619 |
| 10 | cotton | 18 | 15 | 91.832 |
| 10 | cotton | 16 | 15 | 91.708 |
| 10 | cotton | 20 | 16 | 105.962 |
| 10 | cotton | 18 | 16 | 94.858 |
| 10 | cotton | 16 | 16 | 86.321 |
| 10 | cotton | 20 | 20 | 76.709 |
| 10 | cotton | 18 | 20 | 79.242 |
| 10 | cotton | 16 | 20 | 65.269 |
| 10 | polyester | 20 | 20 | 64.543 |
| 10 | polyester | 18 | 20 | 66.807 |
| 10 | polyester | 16 | 20 | 56.518 |
| 15 | cotton | 20 | 15 | 55.544 |
| 15 | cotton | 18 | 15 | 62.276 |
| 15 | cotton | 16 | 15 | 40.804 |
| 15 | cotton | 20 | 16 | 48.114 |
| 15 | cotton | 18 | 16 | 36.463 |
| 15 | cotton | 16 | 16 | 42.011 |
| 15 | cotton | 20 | 20 | 33.032 |
| 15 | cotton | 18 | 20 | 39.139 |
| 15 | cotton | 16 | 20 | 42.086 |
| 15 | polyester | 20 | 20 | 41.005 |
| 15 | polyester | 18 | 20 | 32.924 |
| 15 | polyester | 16 | 20 | 24.456 |

where:

$\gamma$ is the performance ratio;

$$msw = \frac{1}{n}\sum_{j=1}^{n} w_j^2 \qquad (2)$$

where:

$n$ is the number of weighted connections [20].

Data normalizing was carried out in such a way that they have zero mean and unit standard deviation. After some trials the sigmoid and linear function were applied for hidden neurons and output neuron respectively. The mean square error (MSE) as shown in equation (3) was used to judge the performance of different models.

$$MSE = \frac{1}{N}\sum_{i=1}^{N} (y_i - x_i)^2 \qquad (3)$$

where:

$N$ is the number of data sets;

$y_i$ – the desired output for its data set;

$x_i$ – the predicted value for its data set.

## RESULTS AND DISCUSSIONS

### Prediction performance of ANN methodology

By comparing the mean square error of neural network models in predicting the testing data reported in

Table 2

| THE PREDICTIVE POWER OF DIFFERENT ARCHITECTURES ON TRAINING AND TESTING DATA SET | | | |
|---|---|---|---|
| **Model no.** | **Architecture** | **MSE** | |
| | | **Testing data** | **Training data** |
| 1 | 4-4-1 | 5.7706 | 7.5610 |
| 2 | 4-5-1 | 76.1968 | 7.5321 |
| 3 | 4-6-1 | 44.1436 | 7.1027 |
| 4 | 4-7-1 | 72.4900 | 7.3100 |
| 5 | 4-8-1 | 40.1824 | 6.9288 |
| **6** | **4-4-4-1** | **0.9784** | **7.5610** |
| 7 | 4-4-5-1 | 15.5429 | 7.5583 |
| 8 | 4-5-5-1 | 14.5280 | 7.5789 |
| 9 | 4-6-5-1 | 48.4320 | 5.882 |
| 10 | 4-6-6-1 | 61.4693 | 7.5866 |

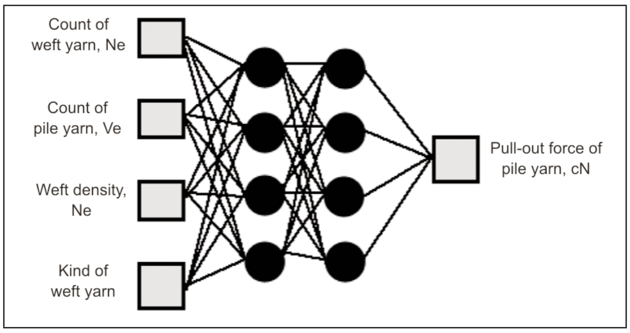



Fig. 4. The schematic of best arhitecture

table 2, it could be concluded that the neural network model with two hidden layers and four neurons in the hidden layers had the best prediction result in the testing data after 1 000 epochs. The schematic of best architecture has been illustrated in figure 4. As shown in table 2, the mean square error of testing and training data was 0.9784 and, respectively, 7.5610. By considering table 3, the average error for prediction the testing data set in selected neural network model was 1.546%. The best ANN model exhibited a maximum error as high as 9.71% and a minimum error as low as 0.746% in predicting training data. These results showed the good capability of neural network algorithm for modeling this process. The $R^2$ – value of the best model was 0.988.

### Analyzing the relative importance of input parameters

According to proposed method by Majumdar et. al [16, 17], to analyze the relative importance of various input parameters each of them was eliminated from the optimized ANN model. The increase in mean

Table 3

| PREDICTION OF PULL-OUT FORCE OF LOOP PILE BY THE NEURAL NETWORK WITH 4-4-4-1 ARCHITECTURE | | | |
|---|---|---|---|
| **Sample no.** | **Pull-out force of loop pile** | **Predicted value** | **Error, %** |
| 6 | 86.321 | 87.622 | 1.507 |
| 11 | 66.807 | 67.384 | 0.864 |
| 18 | 42.011 | 41.058 | 2.268 |
| Mean error | - | - | 1.546 |

Table 4

| RELATIVE IMPORTANCE OF INPUT PARAMETERS | | | |
|---|---|---|---|
| **Input parameter** | **MSE** | **% increase in MSE** | **Ranking** |
| Weft density | 2.666 | 172.533 | 2 |
| Count of weft yarn | 0.983 | 0.478 | 4 |
| Count of pile yarn | 3.474 | 255.023 | 1 |
| Kind of weft yarn | 1.141 | 16.641 | 3 |

square error value in the testing set compared to the optimized ANN model was considered as the indicator of importance of the eliminated input. According to table 4 count of pile yarn was the major contributing parameter on pull-out force. The increase of MSE after eliminating this independent parameter was 255.023%. Weft density and kind of weft yarn were the next two parameters, which affect the pull-out force of loop pile. The least effective parameter on pull-out force was count of weft yarn.

## CONCLUSIONS

In this study, the feed forward neural network based on scale conjugate learning algorithm was utilized to create one predictive model for pull-out force of pile of terry woven fabrics. The production parameters of terry fabric namely, weft density, type of weft yarn, count of weft yarn and count of pile yarn were applied as input parameters for predictive models and pull-out force was used as output parameter.

The obtained ANN model with 4-4-4-1 architecture, i. e. 4 input unit, 4 neurons in first and second hidden layer and one output neuron was found as the best model for prediction pull-out force of pile of terry towel. The mean square error (MSE) for predicting the testing data was 0.9784. The ANN model has been found to be accurate for prediction the pull-out force of loop pile, despite the availability of only a small data set for training this process.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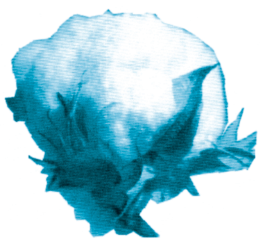

# Study of structural parameters of weft knitted fabrics on luster and gloss via image processing

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ZARY REYHANI

**REZUMAT – ABSTRACT**

**Studiul unor parametri structurali ai materialelor tricotate din bătătură – luciul şi strălucirea, prin procesarea imaginilor**

*Analiza parametrilor structurali ai materialelor tricotate a evidențiat faptul că luciul este unul dintre factorii importanți şi eficienți care influențează aspectul. Definiția subiectivă a luciului țesăturilor duce la o inexactitate. În acest studiu, a fost studiat luciul a 27 de mostre din materiale tricotate din bătătură, prin metoda de procesare a imaginii. De asemenea, au fost studiate efectele diferitelor variabile structurale, cum ar fi desimea ochiurilor şi tipul de legătură, asupra luciului tricotului. Rezultatul a stabilit că valoarea luciului scade odată cu creşterea desimii ochiurilor. S-a constatat că structura tricotului glat şi toate structurile cu ochiuri lipsă au avut influențe maxime asupra luciului, iar structurile interloc şi toate structurile cu ochiuri tricotate au avut influențe minime asupra luciului. Comparația dintre luciu şi strălucire prezintă o corelație inversă. Proprietățile fizice ale țesăturii nu au un efect important asupra luciului sau strălucirii țesăturii.*

*Cuvinte-cheie: material tricotat, variabile structurale, desimea ochiurilor, tip de legătură, luciu, proprietăți fizice*

**Study of structural parameters of weft knitted fabrics on luster and gloss via image processing**

*The analysis of fabrics structural parameters has shown that luster is one of important and effective factors that influence the appearance. Subjective definition of the fabric luster leads to its inaccuracy. In this study, luster of twenty seven weft knitted fabric samples was measured by image processing method. After that, effects of different structural fabric variables (such as the stitch density and the type of texture) on luster were studied. The result presented that the value of luster decreased by increasing stitch density. Single jersey textures and all of textures with missed loops had the maximum luster values. Interlock textures and all of textures with knitted loops had the minimum luster values. Comparison between luster and gloss had reverse correlation. Physical properties of fabric did not present any meaningful effect on fabric luster or gloss.*

*Key-words: knitted fabric, structural variables, stitch density, type of texture, luster, physical properties*

Luster and gloss have been studied for many years by researchers [1–8]. Study on luster was significantly increased as a result of its important role in fashion. Various conflict definitions have been presented about the luster hence nature of the luster is objective.

Many terms have been used to describe the characteristic of light reflection from surfaces [9]. Attempts have been made to obtain a quantitative parameter in order to describe the visual impression of object luster [10]. ASTM [11] defined luster or contrast gloss as: *"Luster – the appearance characteristics of a surface that reflects more in some directions than it does in other directions, but not of such gloss as to form clear mirror images".* There are several devices which were designed to measure luster and gloss [9]. ASTM standardized some of the methods of measurements of gloss and luster [12]. In analyzing the light reflection from a surface the best method is use of goniophotometry [9]. A new technique based on image analysis was utilized to characterize the luster of carpets [13]. The method was based on light reflectance of fabric according to goniophotometric principles. Also, there is a patent by Schwarz which has been concerned with luster measurement of fabric as gloss of surface in various lightening angles [14]. An image processing method was used for investigating luster and determining critical factors on appearance of fabrics made from modified cross-section fibers [15]. In Hadjianfar et al. [9], the determination of luster index was attempted by a novel method based on image processing.

In presented study the image processing method provided by Hadjianfar et al. was also used to measure weft knitted fabric luster index, then fabrics were compared based on their luster indexes.

A capture device used for taking photographs consists of a high-resolution digital camera and an even diffused regular non-polarized lighting system. Fabric Pictures are taken in constant lightening conditions for different angles. The *RGB* color images were converted to the *YCbCr* color space in the computer for analysis and image luminance was obtained by extraction of the *y* component, which represents luminance from the *YCbCr* format, and was used to calculate an index for the fabric luster [9]. The *YCbCr* color space has been used widely in digital video, where this format represents luminance information by a single component *y* and color information is stored as two color-difference components *Cb* (difference between the blue component and a reference value) and *Cr* (difference between the red component and a reference value) [16]. Luminance gives a measure of amount of energy an observer perceives from a light source [16]. Thus an object image luminance is the amount of specular and diffused reflection from the object. By measuring and analyzing the value of fabric image luminance an index for luster of fabric can be calculated [9].

Regarding to various functions of weft-knit fabrics, effective structural and physical properties on luster and gloss may have great importance. In this research, effects of structural and physical parameters of commonly used knitted fabrics on those of luster and gloss was studied.

## EXPERIMENTAL PART AND METHOD USED

Cotton – polyester (50/50) 20 Ne-S800 rotor spinning yarn was used for knitting fabric samples. Nine different textures with three different stitch densities were designed. Mayer and Cie double knit jacquard circular knitting machine with positive yarn feeder was used to produce fabric samples. Gauge 18 and feeder density 12, were selected for fabric producing. Different textures and stitch density with their acronyms have been presented in table 1.

Table 1

TEXTURES AND STITCH DENSITY OF FABRIC SAMPLES WITH THEIR ACRONYMS

| Textures | Stitch density, $S/in^2$ | | Acronyms |
|---|---|---|---|
| Plain | First | 262 | P1 |
| | Second | 302 | P2 |
| | Third | 354 | P3 |
| Cross-tuck single jersey | First | 152 | CTS1 |
| | Second | 182 | CTS2 |
| | Third | 234 | CTS3 |
| Cross-missed single jersey | First | 168 | CMS1 |
| | Second | 206 | CMS2 |
| | Third | 238 | CMS3 |
| Interlock | First | 288 | I1 |
| | Second | 306 | I2 |
| | Third | 352 | I3 |
| Cross-missed double jersey | First | 285 | CTD1 |
| | Second | 315 | CTD2 |
| | Third | 375 | CTD3 |
| Cross-missed double jersey | First | 298 | CMD1 |
| | Second | 362 | CMD2 |
| | Third | 412 | CMD3 |
| Rib | First | 216 | R1 |
| | Second | 247 | R2 |
| | Third | 357 | R3 |
| Full-cardigan | First | 102 | FC1 |
| | Second | 142 | FC2 |
| | Third | 178 | FC3 |
| Full-milano | First | 228 | FM1 |
| | Second | 247 | FM2 |
| | Third | 266 | FM3 |

Finally twenty seven samples from different fabric in 20 × 20 cm were put in the texture capture device. The texture capture device had a dark room in order to prevent the surrounding light to enter the capturing area, the possible light intensity have been changed during capturing, and must be stabilized light condition when taking picture of samples. It also had a uniform light source system in various angles. The holder plate could be rotated around the perpendicular axis respect to the fabric normal vector. Four images from four different angles respect to the fabric normal vector were taken (0°, 22.5°, 45° and 67.5°). In each of them, five images were taken. In each angle, fabric rotated around own perpendicular axis in the angles of 0°, 22.5°, 45°, 67.5° and 90°. The images in different angles were sent to computer and were changed from *RGB* to *YCbCr* by MATLAB software. Finally, *Y* component which represent luminance [17] is extracted. The experiments were repeated for five specimens per each sample.

Based on image luminance analysis method which is presented in [9] a luster index was calculated for each capturing condition and were saved into a matrix, in which the rows were capturing angles and the columns were fabric rotation angles, as the primary luster indexes. The luster indexes for different capturing conditions were analyzed by ANOVA and efficacy coefficient of capturing conditions in luster index was measured as each conditions weight. Different weights were saved in a 4 × 5 matrix as weight matrix in which the rows presented capturing angles and columns presented samples rotation angles. Different capturing weights have been shown in table 2. Final fabric luster index has been calculated by equation (1):

$$Luster = \sum_{i=1}^{4} \sum_{j=1}^{5} W_{ij} \times L_{ij} \qquad (3)$$

where:

$W_{ij}$ is weight matrix element;

$L_{ij}$ – primary luster index element.

After that, the relationship between the values of luster index of fabrics with different texture patterns have been investigated with fabric parameters. The parameters included: texture type, stitch density, thickness, air permeability, friction coefficient and mass per area of fabrics. Thicknesses of samples were measured by Thickness Tester-Baer 674 with a precision of 0.01 mm and were measured ten times for each specimen and the mean value was reported as the thickness value. Air permeability of fabrics was measured by Air Permeability SDL-MO21S with

Table 2

DIFFERENT CAPTURING WEIGHTS

| Capturing angle, degree | Fabric rotation angle, degree | | | | |
|---|---|---|---|---|---|
| | 0 | 22.5 | 45 | 67.5 | 90 |
| 0 | 0.0620 | 0.0495 | 0.0658 | 0.0440 | 0.0287 |
| 22.5 | 0.0428 | 0.0649 | 0.0524 | 0.0473 | 0.0427 |
| 45 | 0.0639 | 0.0473 | 0.0494 | 0.0476 | 0.0419 |
| 67.5 | 0.0314 | 0.0384 | 0.0324 | 0.0611 | 0.0868 |

precision of 1 ml/cm$^2$ per second and each specimen was measured five times and the mean value was reported in the final report. Coefficient of friction was measured for four times in four main directions by Zwick Universal Testing Machine 1446-60 with a normal load of 144 cN according to ASTM D1894 standard then the mean value was reported as coefficient of friction. Mass per area of fabrics was measured for three times with an accuracy 2 g/m$^2$ and the mean value was reported as final mass per area. Finally, for measuring fabric gloss, glossmeter has been used which has shown light specular reflection from fabric surface. Gloss of fabrics was considered in wale and course direction and mean gloss of these two directions has presented the fabric total gloss.

## RESULTS AND DISCUSSIONS

Luster and gloss values and also cover factor and porosity for different fabrics have been illustrated in table 3.

Figure 1 shows the luster change by stitch density and texture type. In interlock and cross-tuck double jersey, by increasing stitch density, loops become closer to each other and space between them decreases, and consequently contact surface between indicated light and fabric increases and more light is reflected. In plain fabric by decreasing stitch density and increasing loop length, yarns become more relaxed and their diameters increase, there for light contact surface with yarn increases and reflection and luster increase [18].

By considering a 3D loop, the third dimension which is thickness and is formed through imposing twisting torque in knitting, increases by an increase in stitch density which decrease luster. In most textures, thickness increases by increasing stitch density. If yarn is used more in face side, luster and reflection increase. It is considered in simple interlock and cross-tuck double jersey, yarn is used more in face side. In Full-Milano contact area increases by the first increasing in stitch density, in the second increasing of stitch density, the vector in thickness ward increases. Hence, its luster increases first and then decreases. Figure 2 shows luster index mean value for different textures in three stitch densities.

As it is shown in figure 2, single jersey and interlock textures with missed loop have the most luster and single jersey and interlock textures with knitted loop have the least luster. In rib textures tuck loops are completely apparent in fabric concaves and increase the reflected light in different directions which cause an increase in luster. Figure 3 shows a general trend for luster change based on gating type. Single jersey has the most and interlock has the least luster. The value luster of rib gating is less than single jersey gating but close to it. However the luster of interlock is very different with the luster of the other two gating.

Figure 4 shows gloss change based on texture and density. Increasing gloss by increasing stitch density is expected which happens in most texture. The gloss of cross-tuck single jersey and full-cardigan decreases first and then increases. The structures of these two textures justify this treatment. Due to the structure of tuck stitch, it decreases specular reflection so if tuck stitches lay in stretched form in fabric structure or hide because of excess of loop density, the fabric structure is altered and gloss increases. By first increasing in stitch density of cross-tuck single jersey and full-cardigan wales become closer but

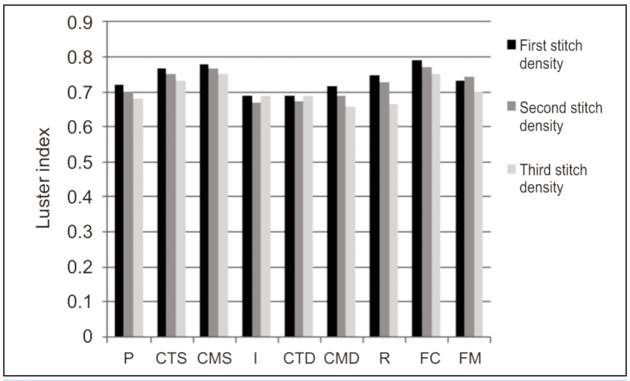



Fig. 1. Luster change based on texture type and stitch density

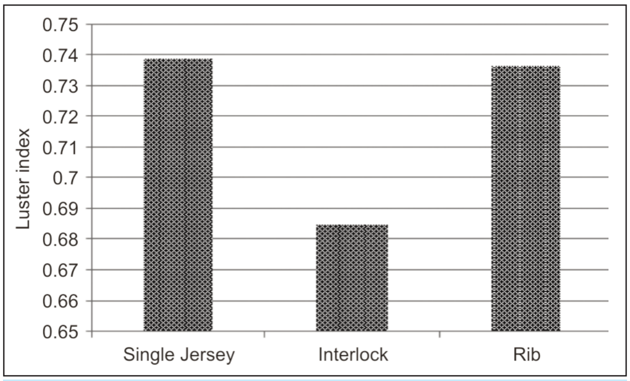



Fig. 3. Luster change based on gating

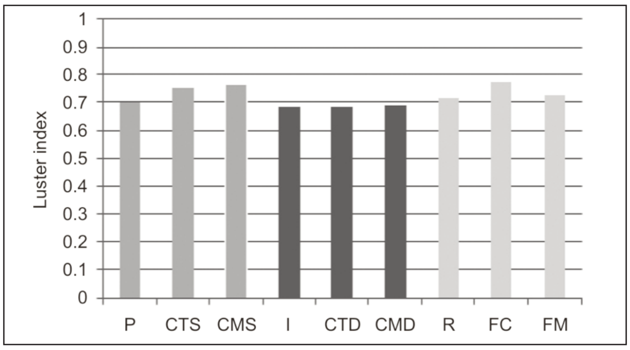



Fig. 2. Luster change by texture

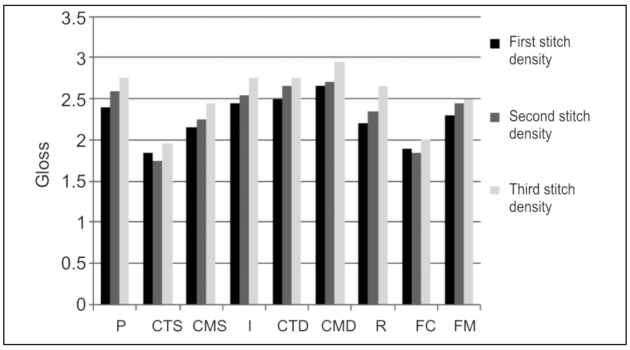



Fig. 4. Gloss change based on texture and stitch density

Table 3

| VALUES OF COVER FACTOR, POROSITY, SPECULAR REFLECTIONS AND LUSTER | | | | |
|---|---|---|---|---|
| Fabric texture | Cover factor | Porosity | Luster index | Specular reflections, % |
| P1 | 0.812635 | 21.09133 | 0.7203 | 2.4 |
| P2 | 0.96547 | 22.84987 | 0.7022 | 2.6 |
| P3 | 0.933518 | 21.31774 | 0.6798 | 2.75 |
| CTS1 | 0.745537 | 15.96278 | 0.7682 | 1.9 |
| CTS2 | 0.770033 | 16.63139 | 0.7502 | 1.85 |
| CTS3 | 0.915945 | 18.48985 | 0.7302 | 2.05 |
| CMS1 | 0.883994 | 19.53677 | 0.7801 | 2.15 |
| CMS2 | 0.876538 | 21.57161 | 0.7668 | 2.25 |
| CMS3 | 0.937246 | 21.24577 | 0.7513 | 2.45 |
| I1 | 0.868018 | 26.41302 | 0.6872 | 2.6 |
| I2 | 0.878668 | 27.72736 | 0.6702 | 2.65 |
| I3 | 0.990499 | 29.17006 | 0.6893 | 2.75 |
| CTD1 | 0.846717 | 22.88955 | 0.6872 | 2.5 |
| CTD2 | 0.905295 | 24.36647 | 0.6748 | 2.6 |
| CTD3 | 0.985174 | 26.80849 | 0.6878 | 2.7 |
| CMD1 | 0.873343 | 24.24601 | 0.7158 | 2.55 |
| CMD2 | 0.97186 | 26.12966 | 0.6901 | 2.6 |
| CMD3 | 0.872278 | 22.10526 | 0.6581 | 2.85 |
| R1 | 0.501373 | 18.29861 | 0.7466 | 2.2 |
| R2 | 0.484599 | 17.22832 | 0.7269 | 2.35 |
| R3 | 0.553827 | 18.74549 | 0.6672 | 2.65 |
| FC1 | 0.372768 | 14.64313 | 0.7901 | 1.9 |
| FC2 | 0.374366 | 13.42525 | 0.7713 | 1.85 |
| FC3 | 0.380756 | 13.0123 | 0.7497 | 2 |
| FM1 | 0.764175 | 21.25107 | 0.7311 | 2.3 |
| FM2 | 0.786275 | 21.85335 | 0.7431 | 2.45 |
| FM3 | 0.772163 | 21.42498 | 0.7013 | 2.5 |

Table 4

| THE PARAMETERS OF DIFFERENT FABRICS | | | | |
|---|---|---|---|---|
| Fabric texture | Thick-ness, mm | Air perme-ability, $ml/cm^2/sec.$ | Coefficient of friction | Mass per area, $g/m^2$ |
| P1 | 0.476 | 210 | 0.5898 | 152.6 |
| P2 | 0.522 | 171.6 | 0.5337 | 181.3 |
| P3 | 0.541 | 155.4 | 0.6162 | 175.3 |
| CTS1 | 0.577 | 280.4 | 0.6728 | 140 |
| CTS2 | 0.572 | 295.2 | 0.6426 | 144.6 |
| CTS3 | 0.612 | 207 | 0.6672 | 172 |
| CMS1 | 0.559 | 202 | 0.5085 | 166 |
| CMS2 | 0.502 | 141.4 | 0.6409 | 164.6 |
| CMS3 | 0.545 | 153 | 0.6007 | 176 |
| I1 | 0.812 | 66.2 | 0.3735 | 326 |
| I2 | 0.783 | 58.6 | 0.5426 | 330 |
| I3 | 0.839 | 46 | 0.3370 | 372 |
| CTD1 | 0.914 | 90.8 | 0.4203 | 318 |
| CTD2 | 0.918 | 73.8 | 0.3322 | 340 |
| CTD3 | 0.908 | 64.2 | 0.4291 | 370 |
| CMD1 | 0.890 | 71.2 | 0.4347 | 328 |
| CMD2 | 0.919 | 56.8 | 0.5490 | 365 |
| CMD3 | 0.975 | 44 | 0.3853 | 327.6 |
| R1 | 0.677 | 234 | 0.5423 | 188.3 |
| R2 | 0.695 | 240 | 0.7849 | 182 |
| R3 | 0.730 | 211.6 | 0.6257 | 208 |
| FC1 | 0.629 | 319 | 0.6679 | 140 |
| FC2 | 0.689 | 345.4 | 0.5670 | 140.6 |
| FC3 | 0.723 | 332.8 | 0.5373 | 143 |
| FM1 | 0.8885 | 170.2 | 0.3167 | 287 |
| FM2 | 0.889 | 150.4 | 0.3166 | 295.3 |
| FM3 | 0.8905 | 153.4 | 0.5599 | 290 |

tuck stitches change from stretched and smooth state and contract which causes more unevenness on the surface and decrease specular reflection. By second increasing in stitch density, the above mentioned procedure repeats, however more contraction between wales because of tuck stitches unevenness overcomes and by hiding tuck stitches, specular reflection increases.

Figure 5 shows gloss change for different textures. As it is shown in figure 5, single jersey textures with knitted loop have most gloss. Rib and interlock textures with missed loop have the most gloss approximately. Tuck textures with have the least gloss in all texture type.

Figure 6 shows a general trend for gloss change based on gating type. Interlock has the most and rib has the least gloss. The specular reflection from interlock textures is most than rib and single jersey textures because of compactness and smoothness of interlock texture surface. The value gloss of rib gating is less than single jersey gating but close to it. However the gloss of interlock is very different with the gloss of the other two gating. Figure 7 shows gloss and luster change by loop type.

As it is shown in figure 7, knitted textures have least luster and tuck textures have most luster. Knitted and missed textures have the most value of gloss and tuck textures due to tuck loop nature have least gloss value.

Table 4 shows thickness, air permeability, coefficient of friction and mass per area for different fabrics. Figure 8 and 9 show correlation between luster index and stitch density and correlation between gloss and stitch density respectively.

According to figure 8 and 9, increasing in stitch density lead to increase luster index and decrease gloss. The $R^2$ values of luster and gloss between stitch densities show an acceptable linear correlation between them. Table 5 presents regression line of luster and gloss between structural parameters. However, $R^2$ air permeability and porosity show an approximate effect on luster and gloss but $R^2$ values of each parameters show these parameters does not have remarkable meaningful effect on luster and gloss. As it is shown in figure 8 and 9 and also

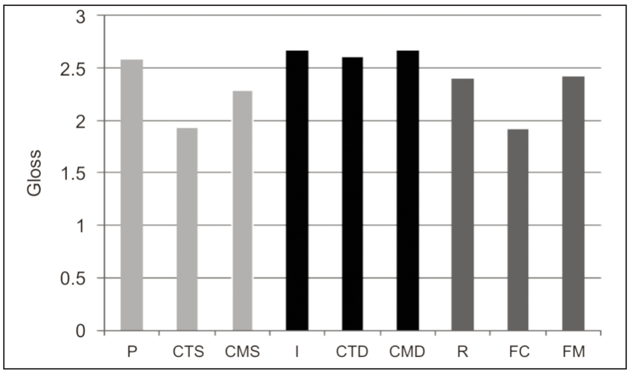



Fig. 5. Gloss change by texture change

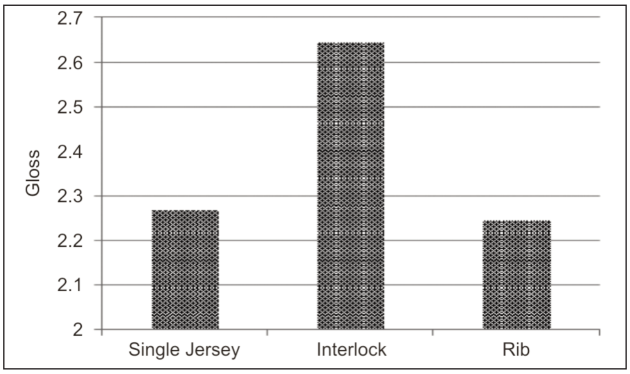
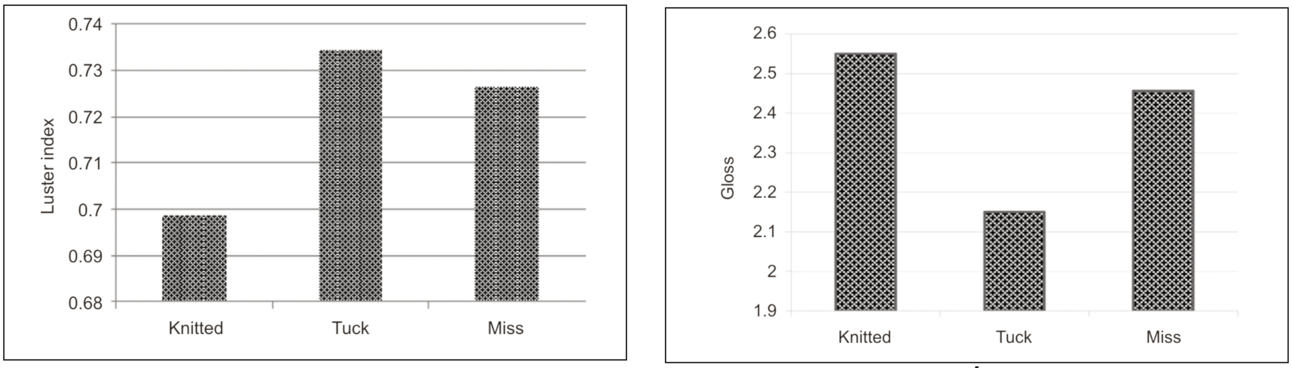



Fig. 6. Gloss change based on gating




***a*** ***b***

Fig. 7: ***a*** – luster change by loop type; ***b*** – gloss change by loop type

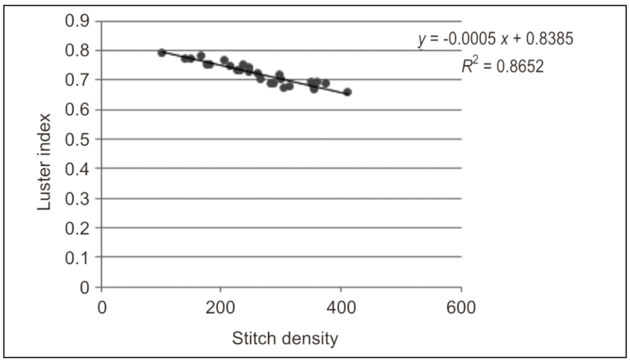



Fig. 8. Correlation between luster index and stitch density and their regression line

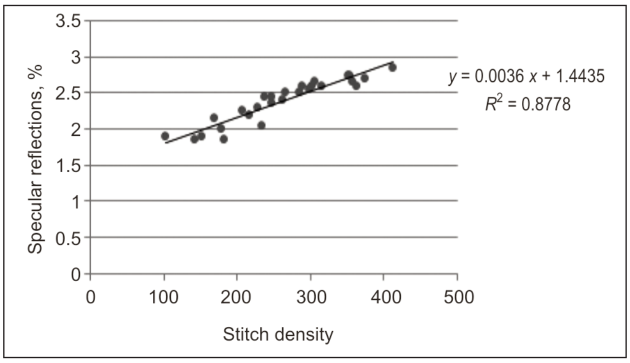



Fig. 9. Correlation between gloss and stitch density and their regression line

table 5, each of parameters has reverse effect on luster and gloss. Physical properties have not presented powerful relation to luster or gloss lonely. This matter does not mean that they are not effective on apparent properties because these physical properties have depended effects of luster or gloss. Physical properties are affected by structural features of knitted fabric. For example, Cover factor and porosity are very affected by stitch density (related to loop length) and texture. Thickness is depended of texture widely. Air permeability is depended to porosity which is affected by the fabric structure. Therefore, physical properties have not alone confirmed regression to luster or gloss. One and two ways ANOVA tests were applied to physical parameters data but no significant effect could be observed because all of physical parameters might be depended together and more depended to structural parameters.

## CONCLUSIONS

Regarding the broad function of weft knitted fabrics, especially in the ones that fashion is of great importance, the effective study of physical and structural parameters on their appearance is essential. The mentioned physical properties do not have remarkable meaningful effect on luster and gloss lonely. Generally these properties are affected by structural parameters. Texture and stitch density have a meaningful impact on luster and gloss which is more on gloss factor. By increasing stitch density for any texture, gloss increases and luster decreases. Texture has a reverse impact on luster and gloss. Interlock textures have the most gloss and the least luster, single jersey textures have the most luster and rib texture have the least gloss and also the textures with knitted loop have the most gloss and the least luster. Thus, gloss and luster represent two separate

Table 5

| $R^2$ VALUES AND REGRESSION LINES OF LUSTER AND GLOSS BETWEEN STRUCTURAL PARAMETERS | | | | |
|---|---|---|---|---|
| **Independent variables** | **Dependent variables** | | | |
| | ***Luster*** | | ***Gloss*** | |
| | Regression line | $R^2$ | Regression line | $R^2$ |
| Cover factor | $Y = -0.0928\ x + 0.7921$ | 0.226 | $Y = 0.9301\ x + 1.6610$ | 0.365 |
| Porosity | $Y = -0.0062\ x + 0.8503$ | 0.473 | $Y = 0.0582\ x + 1.1592$ | 0.673 |
| Thickness | $Y = -0.1338\ x + 0.8174$ | 0.306 | $Y = 0.9281\ x + 1.7089$ | 0.237 |
| Air permeability | $Y = 0.0003\ x + 0.6689$ | 0.543 | $Y = -0.0028\ x + 2.8559$ | 0.745 |
| Coefficient of friction | $Y = 0.1195\ x + 0.6571$ | 0.156 | $Y = -1.1460\ x + 2.9877$ | 0.231 |
| Mass per area | $Y = -0.0003\ x + 0.7944$ | 0.498 | $Y = 0.0026\ x + 1.7761$ | 0.536 |

different visual characteristics which are different because of different effective factors on them. Smoothness and evenness of fabric surface, contact area and loop vector in the direction of thickness are effective on luster. Full-cardigan and simple interlock represents maximum and minimum luster values, consequently. Simple interlock and cross-tuck single jersey has the most and the least gloss, consequently.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# Method and algorithm for mass modification of the check pattern fabrics from weave

GEORGETA ȚUGULEA DANIEL CHINCIU

**REZUMAT – ABSTRACT**

**Metodă şi algoritm pentru modificarea masei țesăturilor cu efect de caro, obținut din legătură**

*Țesăturile cu efect de caro dețin un loc important în sortimentul de țesături pentru îmbrăcăminte sau alte destinații, dintre care importante sunt țesăturile dimensionate: batiste, fețe de masă, şervețele etc. Efectul de caro al acestor țesături se obține în procesul de țesere, prin combinarea simultană de dungi longitudinale şi transversale, din grupe de fire ale căror densitate de lungime, desime şi legătură cu flotare medie sunt semnificativ diferite. Astfel, se obține un contrast de aspect, care poate fi evidențiat mult mai bine dacă se asociază cu efectul de culoare. Țesăturile cu efect de caro, obținut din legătură, au o structură complexă, de aceea pentru a obține o țesătură echilibrată şi stabilă este necesar ca dimensionarea componentelor să se facă prin metode specifice de proiectare, iar tehnologia să fie adaptată caracteristicilor de structură ale acestor țesături. Metoda şi algoritmul utilizate pentru modificarea masei sunt în totalitate originale şi au fost stabilite în urma unor studii şi cercetări, prin care au fost analizate componentele structurale în interdependența şi interacțiunea lor cu influențele asupra masei țesăturii.*

*Cuvinte-cheie: țesătură, legătură, dungi longitudinale, dungi transversale, densitate de lungime, masă*

**Method and algorithm for mass modification of the check pattern fabrics from weave**

*The check pattern fabrics hold an important place in the fabric assortment for both clothing and other destinations, among which sized fabrics: handkerchiefs or table-linens etc. The check effect at these fabrics is obtained during the weaving, through the simultaneous association of lengthwise and cross stripes made of groups of yarns with fineness, set and weave with significantly different mean float, a contrasting aspect being thus obtained, which can be shown off by combining it with color effect. The fabrics with check pattern from weave have a complex structure, and in order to obtain a balanced and stable fabric, the components sizing must be carried out through specific designing methods, and the technology must be matched to the structure characteristics specific for these fabrics. The method and the algorithm used to modify the mass are completely original and have been established as the result of studies and investigations through which the structural components were analyzed in their interdependence and interaction, with influence on the fabric mass.*

*Key-words: fabric, weave, lengthwise stripes, cross stripes, fineness, mass*

In the practice of designing and manufacturing the check pattern fabrics obtained through the association of the lengthwise and cross stripes with different weaves, set and/or yarn fineness, there are numerous cases when it is necessary to modify the mass of the existing fabric, for various reasons, among which the most frequent is the beneficiary request, as well as the manufacturer concern for diversification of the fabric assortment with the view to improve the market offer.

Taking into account that the check pattern fabrics are obtained by the combination of the lengthwise and cross stripes, technical and technological components necessary for simultaneous execution of these weaves must be used.

In this paper we shall present both the method to modify the mass of the check pattern fabrics from weave, and the specific calculus algorithm for designing the basic and auxiliary fabric parameters.

The method and computation algorithm for designing the check pattern fabrics with modified mass are materialized in a flow chart which presents the sequence of the design computations based on the logics of producing successive data necessary for next stage calculus.

The flow chart is also used as logical scheme to develop the design software for the computer assisted mass modification.

## METHODS FOR COMPUTATION AND MODIFICATION OF FABRIC MASS

The fabric mass is almost completely determined by the mass of the component fibers. The differences (±) are introduced by the weave (through the degree of crimp-shrink) and by the mass gain or loss obtained during the technological finish process.

For the computation and modification of fabric mass, the following methods are used:

- *set method* – which consists in that the yarn set is modified, while the yarn fineness is kept at its initial value, such that the fabric with modified mass has in its structure the same yarns as the reference fabric;
- *method of yarn fineness* – by which, in order to obtain the proposed mass, the yarn fineness is

modified, while their set from the reference fabric remains unchanged;

- *combined method of set and yarn fineness* – which consists in the fact that, in order to obtain a fabric with another mass, the both characteristics of the fabric component yarns, i.e. set and yarn fineness will be modified.

The check pattern fabric obtained through the association within longitudinal (in the warp direction) and cross (in the weft direction) stripes, of groups of yarns with different set, fineness and weaves, must have equal stripe size and weave repeat in both directions.

The new fabric with modified mass should be similar in aspect with the reference fabric, such that the initial size of the component checks and stripes remains unchanged.

It is well known that, by their own structure, the fabrics have two zones within their width: ground zone, $l'_f$, and selvage zone, $l_m$.

That is the reason why, in the algorithm proposed in this paper, we have only taken into account the fabric ground which contains the weaves.

Approaching the project and/or redesigning the check pattern fabrics in this way is also motivated by the fact that, currently, for weaving technologies that use non-conventional weaving machines, the selvages are conceived and executed in a different way. The only non-conventional weaving machines which execute fabrics with salvages are those produced by Sulzer-Rütti and STB companies. All the other technologies that make use of non-conventional weaving machines produced by other companies execute fabrics without salvages or with false selvages.

## Principles of the method used to modify the mass of the check pattern fabrics from weave

The method used to modify the check pattern fabrics from weave is based on the following principles:

- the effect of equal checks is obtained by simultaneously combining longitudinal and cross stripes with different weaves, sets and width;
- the number and width of the combined stripes with different weave or/and set is equal in both directions;
- the weaves from the stripes combined on the two perpendicular directions: longitudinal and cross, have equal characteristics (repeat, mean float);
- the weaves from the cross stripes must comply with certain restraints imposed by the possibilities of practical realization, taking into account that the warp yarns are unique for all the cross stripes weaves;
- the stripe weaves are adopted depending on the weave chosen for the fabric ground, such that the weave repeat in the cross stripe warp and the longitudinal stripe weft must be equal or a multiple of the ground weave repeat;
- the warp yarn fineness within the stripes with different weaves and, therefore, with different sets, can be obtained within the restraints imposed by the possibility of their denting;
- the weft count within the stripes with different weaves and, therefore, with different fineness in the case when they are executed on non-conventional weaving machines, can take any value without restraints, due to the technical operating possibilities of the system for fabric take-up and covering;
- the warp yarns with different weaves are (mandatory) wound on different warp beams, since the weaving yarn consumption is different, depending on the specific weave mean floating;
- modification of the warp yarn mass by the yarn fineness method under the condition of keeping constant the cross stripe size, part of the check effect, imposes the recalculation of the yarn number and therefore a new warping;
- modification of the warp yarn mass by the yarn fineness method implicitly supposes a new warping, since the warp yarns need to be replaced with other yarns with different fineness;
- modification of the warp yarn mass by the yarn fineness method can be accomplished without any technical and technological restraint. In the case of non-conventional weaving machines, both the yarn fineness and the number of yarns from the cross stripes with different weaves are modified through the simultaneous control of the dobby with the weft, and of the fabric taking-up and covering system;
- modification of the weft yarn mass on cross stripes with different weaves through the method of yarn fineness is carried out without modifying the repeat of weft thread, only by replacing the bobbin which delivers the weft yarns, with modified fineness.

## Stages of the method of yarn fineness for modifying the mass of the check pattern fabric from weave

Taking into account the specified principles, the conditions imposed by the topic and the practical possibilities to modify the mass of an existing fabric, at which the check patters is obtained by the association on longitudinal and cross stripes of different weaves, yarn count and/or fineness, we propose an original method which includes the following stages:

- establish the size of the fabric that serves as support for design (redesign) computations, while having $l'_f$ resulting from $l_f - l_m$, and the length $l$ = 1 m, where $l_f$ is fabric finite width, $l_m$ – selvage width; $l'_f$ – width of ground fabric (which contains the weave repeats), $l$ – the length of the considered fabric (1 m).
- make partial fabrics, consisting of longitudinal and cross stripes with identical weaves. The number of partial fabrics equals the number of weaves associated to form the longitudinal and cross stripes. Every partial fabric contains the same weave type as the weave from the similar stripes along the two directions: longitudinal and transversal.

## Algorithm for mass modification of the check pattern fabric from weave by the set method

Table 1 synthetically presents the algorithm for mass modification of the check pattern fabric from weave, as well as the stages in their logical succession.

Calculus of reference fabric mass, in g/m, is presented in equation (1):

$$Mt = \left[\sum \frac{Lu_i \cdot Pu_i \cdot Tt_{ui}}{100 \cdot (100 - a_{ui})} + \frac{Lb_i \cdot Pb_i \cdot Tt_{bi} \cdot l'_f}{100 \cdot (100 - a_{bi})}\right] \cdot \frac{100 \pm p_f}{100} \quad (1)$$

Calculus of modified mass of the reference fabric, in g/m, is shown in equation (2):

$$M't = Mt \cdot \frac{100 \pm e}{100} \quad (2)$$

Calculus of mass for the fabric with weave *i*, in g/m, is presented in equation (3):

$$Mt_i = \frac{l'_f}{100} \cdot \left[\frac{Pu_i \cdot Tt_{ui}}{(100 - a_{ui})} + \frac{Pb_i \cdot Tt_{bi}}{(100 - a_{bi})}\right] \cdot \frac{100 \pm p_f}{100} \quad (3)$$

Calculus of mass modified with weave *i*, in g/m, is shown in equation (4):

$$M't_i = Mt_i \cdot \frac{100 \pm e}{100} \quad (4)$$

Calculus of coefficient of weft set is presented in equation (5):

$$Pb_i = \frac{Pu_i}{Pb_i} \quad (5)$$

resulting

$$Pb_1 = \frac{Pu_1}{Pb_1} \quad (6)$$

Calculus of warp set in the fabric with modified mass is shown in equation (7):

$$Pu_i = \left[\frac{M't_i}{l'_f\left[\frac{Tt_{ui}}{100 - a_{ui}} + \frac{Tt_{bi}}{p_{bi} \cdot (100 - a_{bi})}\right]}\right] \cdot \frac{100}{100 + p_f} \quad (7)$$

Calculus of weft count, in yarns/ 10 cm, is illustrated in equation (8):

$$Pb_i = \frac{Pu_i}{Pb_1} \quad (8)$$

Recalculation of the modified (designed) mass with that of the fabric, in g/m, is presented in equation (9):

$$Mt_{pi} = \frac{l'_f}{100} \cdot \left[\frac{Pu_i \cdot Tt_{ui}}{(100 - a_{ui})} + \frac{Pb_i \cdot Tt_{bi}}{(100 - a_{bi})}\right] \cdot \frac{100 \pm p_f}{100} \quad (9)$$

Calculus of mass difference, calculated and designed absolute, in g/m, is shown in equation (10) and relative, in %, is presented in equation (11):

$$\Delta aMt = Mt - Mt_{p1} \quad (10)$$

$$\Delta rMt = \frac{\Delta aMt}{Mt} \cdot 100 \quad (11)$$

Table 1

| CHARACTERISTICS OF THE REFERENCE FABRICS | | |
|---|---|---|
| **Initial data** | **Symbol** | **U.M.** |
| Fabric width finite, out of which:<br>– ground with weave repeat<br>– selvages | $l_f$<br>$l'_f$ | cm<br>cm |
| Width of stripes with weave, *i*:<br>– in warp<br>– in weft | *lm* | cm |
| Yarns fineness on stripes, *i*:<br>– in warp<br>– in weft | $Lu_i$<br>$Lb_i$ | cm<br>cm |
| Yarn set on stripes, *i*:<br>– in warp<br>– in weft | $Tt_{ui}$<br>$Tt_{bi}$ | tex<br>tex |
| Total yarn shrinkage on stripes, *i*:<br>– in warp<br>– in weft | $Pu_i$<br>$Pb_i$ | yarns/10 cm<br>yarns/10 cm |
| Mass gain or loss during finishing process | $a_{ui}$<br>$a_{bi}$<br>$\pm pf$ | |

## EXPERIMENTAL PART

The application of the yarn set method for the modification of the check pattern fabric mass from weave was carried out on a fabric obtained through the association of two weaves with significantly different mean float: cloth *P*, *Ru* = *Rb* = *R* = 2, mean float *F* = 1, and satin A 5/2, *Ru* = *Rb* = *R* = 5 , mean float *F* = 2,5.

The reference fabric has the basic and auxiliary characteristics given in table 2. Redesigning theme: 12% diminution of the reference fabric mass.

### Obtained results

The table 3 contains the results obtained after performing the calculus of the components necessary to 12% diminution of the reference fabric mass.

The ratio of the warp yarns set on stripes with different weaves is presented in the equation (12):

$$p = \frac{P'u_2 a}{P'u_1 a} = \frac{350}{280} = 1{,}25 \quad (12)$$

It is identical with the ratio of warp yarns set of the reference fabric. A set differing in proportion of 1.25 is executed by denting with $c_1$ = 2, $c_2$ = 2.3 yarns/cell with the ratio (13):

$$c = \frac{c_2}{c_1} = 1{,}25 \quad (13)$$

## CONCLUSIONS

- The fabrics with check pattern from weave can be obtained through the association within lengthwise and cross stripes, of weaves with significantly different mean floats, by which one can accomplish a different degree of appearance of the yarns from the two systems, the warp and the weft, on the fabric face.

Table 2

| CHARACTERISTICS OF THE REFERENCE FABRICS | | |
|---|---|---|
| **Initial data** | **Symbol** | **Value** |
| Finite width, out of which, cm:<br>– ground<br>– selvages | $l_f$<br>$l'_f$ | 150<br>147 |
| Stripe width $L_i$, cm:<br>– in warp on the length, $l'_f$<br>– with Hessian cloth, *P*<br>– with satin weave *A 5/2*<br>– in welf per 1 cm<br>– with Hessian cloth, *P*<br>– with satin weave *A* | *lm*<br>$Lu_1$<br>$Lu_2$<br><br>$Lb_1$<br>$Lb_2$ | 3<br>76.075<br>70.925<br><br>53.24<br>46.74 |
| Yarns fineness on stripes, *i*, tex:<br>– in warp, $Tt_{ui}$<br>– with Hessian cloth, *P*<br>– with satin weave *A 5/2*<br>– in welf, $Tt_{bi}$<br>– with Hessian cloth, *P*<br>– with satin weave *A 5/2* | $Tt_{u1}$<br>$Tt_{u2}$<br><br>$Tt_{b1}$<br>$Tt_{b2}$ | 16.66<br>10 x 2<br><br>16.66<br>10 x 2 |
| Yarn set on stripes, *i*, yarns/ 10 cm:<br>– in warp, $Pu_i$<br>– with Hessian cloth, *P*<br>– with satin weave *A 5/2*<br>– in welf, $Pb_i$<br>– with Hessian cloth, *P*<br>– with satin weave *A 5/2* | $Pu_1$<br>$Pu_2$<br><br>$Pb_1$<br>$Pb_2$ | 320<br>400<br><br>240<br>300 |
| Total yarn shrinkage on stripes, %:<br>– in warp, $a_{ui}$<br>– with Hessian cloth, *P*<br>– with satin weave *A 5/2*<br>– in welf, $a_{bi}$<br>– with Hessian cloth, *P*<br>– with satin weave *A* | $a_{u1}$<br>$a_{u2}$<br><br>$a_{b1}$<br>$a_{b2}$ | 10.8<br>6.9<br><br>14.5<br>11.6 |
| Mass loss or gain during the finish process | *pf* | 3 |

Table 3

| Characteristics | Value | U.M. |
|---|---|---|
| Mass of reference fabric, *Mt* | 183.68 | g/m |
| Modified mass (reduced by 12%), *M't* | 161.6 | g/m |
| Mass of fabric with Hessianic cloth (1), $Mt_1$ | 151.9 | g/m |
| Modified mass of fabric with Hessianic cloth (1), $M_{1C}$ | 133.67 | g/m |
| Fabric setting coefficient, $pD_1$ | 1.33 | |
| Warp set (2):<br>– calculated, $P'u_1$<br>– matched, $P'u_{1a}$ | <br>281.28<br>280 | <br>yarns/10 cm<br>yarns/10 cm |
| Weft set:<br>– calculated, $P'b_1$<br>– matched, $P'b_{1a}$ | <br>211.5<br>210 | <br>yarns/10 cm<br>yarns/10 cm |
| Mass recalculated with adapted sets deviation, $M't_1p$:<br>– absolute, $\Delta aM't_1$<br>– relative, $\Delta rM't_1$ | 132.9<br>0.77<br>0.52 | g/m<br>g/m<br>- |
| Mass of the fabric with weave 2 (*A 5/2*), $Mt_2$ | 219.3 | g/m |
| Modified mass of the fabric 2 (*A 5/2*), *M'2C* | 193.0 | g/m |
| Weft yarns set coefficient, $Pb_2$ | 1.33 | - |
| Warp yarns set (2):<br>– calculated, $P'u_2$<br>– matched, $P'u_{2a}$ | <br>351.6<br>350 | <br>yarns/10 cm<br>yarns/10 cm |
| Weft yarns set (2):<br>– calculated, $P'u_2$<br>– matched, $P'u_{2a}$ | <br>264.4<br>264 | <br>yarns/10 cm<br>yarns/10 cm |
| Mass recalculated with matched sets deviation, $M't_2p$:<br>– absolute, $\Delta aM't_2$<br>– relative, $\Delta rM't_2$ | 192.38<br>0.62<br>0.32 | g/m<br>g/m<br>- |

*Note:* The values of the yarn set were matched such that the last digit is 0 or 5.

- In order to produce an obvious contrast between the stripes with different weaves, it is recommended to have one of the weaves of plain type, having the lowest mean float, $F = 1$.
- The fabrics with check pattern from weave have a structure consisting of two distinctive parts: the fabric ground of plain weave, and the lengthwise and cross stripes, which produce the check effect with weaves with mean float $F > 1$.
- The check effect is better highlighted if the weave effect is combined with color effect.
- The method and the calculus algorithm proposed in this work are completely original, and their efficiency has been proved through practical or experimental results.

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# CRONICĂ

## ITMA 2011 – CEA MAI PRESTIGIOASĂ EXPOZIŢIE INTERNAŢIONALĂ DE MAŞINI TEXTILE ŞI ÎMBRĂCĂMINTE. Partea I

Timp de 8 zile, Barcelona a fost centrul mondial al universului tehnologic textil. La salonul internaţional de maşini textile şi îmbrăcăminte *ITMA 2011*, desfăşurat în perioada 22–29 septembrie, la Fira de Barcelona Gran Via, cel de-al doilea mare oraş al Spaniei, după Madrid, au participat 1 350 de expozanţi din 45 de ţări, de pe 5 continente. Ca şi la ediţiile anterioare, cele mai multe standuri au aparţinut unor firme care fac parte din asociaţiile companiilor de utilaje textile din ţările vest-europene: VDMA – Germania, ACIMIT – Italia, UCTMF – Franţa, BTMA – Anglia, AMTEX – Spania, GTM – Olanda, SWISSMEM – Elveţia, SYMATEX – Belgia, TMAS – Suedia. Corporaţiile participante au beneficiat de un spaţiu expoziţional de circa 100 000 m², mai redus decât la precedentul salon din capitala Bavariei. Sectoarele de activitate dominante au fost cele cu profil de finisare textilă, vopsire şi imprimare (30%), filatură (15%), ţesătorie (14%) şi tricotaje (12%).
Creşterea fără precedent a consumului de fibre la nivel mondial i-a determinat pe organizatori să ofere, pentru prima dată, la o expoziţie de maşini textile, un spaţiu expoziţional destinat în exclusivitate sectorului *Fibre & Fire*. Cumpărătorilor li s-a oferit posibilitatea de a se aproviziona cu fibre naturale, artificiale şi tehnice direct de la firmele expozante. Spaţii mai restrânse au fost alocate firmelor expozante din industria confecţiilor textile, aparatelor de laborator, condiţionării aerului, logisticii, nanotehnologiei, reciclării produselor textile.
Pentru sectorul *Research & Education*, organizatorii au rezervat un pavilion special, subvenţionat de European Textile Machinery Manufacturers Association (CEMATEX). La ediţia care a avut loc în Peninsula Iberică au fost în jur de 100 000 de vizitatori, din 138 de ţări, de pe 5 continente, 153 de mari asociaţii comerciale din întreaga lume şi grupuri profesionale de sprijin din 63 de ţări, 53 de jurnalişti şi observatori internaţionali acreditaţi, de la agenţii de presă din 19 ţări.
La recentul eveniment au participat peste 50 de agenţii guvernamentale cu profil de textile-confecţii, din 27 de ţări. Aşa cum a subliniat doamna Rita Menon, ministru secretar de stat pentru textile şi şefă a delegaţiei Agenţiei guvernamentale indiene, *„Managementul de vârf al agenţiilor participante la târg s-a implicat direct în adoptarea unor strategii de dezvoltare şi transfer tehnologic pe termen mediu şi lung, specifice fiecărei ţări emergente şi, implicit, în politica de achiziţii de tehnologii şi maşini textile de înaltă productivitate“*. Strategii similare au adoptat majoritatea ţărilor emergente din Africa, Asia, America de Sud şi Orientul Mijlociu, afiliate la *African Cotton & Textile Industries Federation (ACTIF), The United Nations Developement Organization (UNIDO), The International Textile Manufacturers (ITM), All Pakistan Textile Mills Association (APTMA), The Portuguese Association of Textile Engineers and Textile Technicians (APETT), ASEAN Federation of Textile Industries (AFTEX), Federacion Argentina de Industrias Textiles FADIT (F.I.T.A.), Chamber of Commerces of Lima, Peru (CCL)*.
Cea de-a 16-a Expoziţie Internaţională de Maşini Textile şi Îmbrăcăminte de la Barcelona şi-a deschis porţile în condiţiile vitrege ale crizelor economice şi financiare la nivel global. Nu s-ar putea spune altfel, din moment ce bursele de mărfuri şi valori „trepidează“ ameninţător, iar datoriile publice ale unor mari puteri din G8 ating sau chiar depăşesc cu mult PIB-ul. Această situaţie este o consecinţă directă a scăderii dramatice a consumului, care determină firmele să caute soluţii pentru a produce cât mai

eficient, atât sub raportul cheltuielilor de producție și circulație, cât și sub raportul prețului – făcându-l mai competitiv și mai atractiv. Un factor important al competiției economice este deficitul bugetar. La acest capitol, numai Germania și China produc și vând mai mult decât consumă. Dacă o țară are deficit bugetar înseamnă că, practic, cheltuiește mai mult decât câștigă. Nu întâmplător, domnul Stephen Combes, președintele CEMATEX, a declarat cu satisfacție: *„ITMA 2011 a depășit așteptările noastre. Având în vedere faptul că lumea contemporană se confruntă cu o criză economică și financiară de proporții planetare, am fost încântați de foarte buna calitate și înalta competență a vizitatorilor. Asociațiile companiilor noastre de utilaje textile din țările vest-europene dezvoltate au raportat just in time zeci de întâlniri de afaceri și contracte încheiate, mult mai multe decât s-au așteptat organizatorii evenimentului. Industria de mașini textile și de îmbrăcăminte trebuie să fie lăudată pentru capacitatea sa de adaptare și dorința de a investi și inova“.* Domnul Attilio Camozzi, președintele liderului strategic Marzoli, a comentat: *În timpul derulării evenimentului am demarat un număr important de întâlniri de afaceri și am finalizat contracte de peste 30 de milioane de euro, cu clienți din Argentina, India, Turcia, Turkmenistan și Uzbekistan.*

Cum era și firesc, 70% dintre vizitatori au fost din zona euro și, în special, din țările Europei occidentale. Restul de 30% au venit din țări noneuropene, în special din India, Japonia și China. Recordul de participare l-a atins Italia, cu peste 9%. Pe locul 2 s-au situat profesioniștii din țara-gazdă, pe locul 3 – omologii lor din India, iar pe pozițiile 4 și 5 – experții domeniului textil din Germania și Turcia. Pe locurile următoare s-au situat vizitatorii de pe celelalte continente: din Brazilia, Iran și – ca de fiecare dată la ultimele 6 ediții – tigrii asiatici chinezi, taiwanezi, sudcoreeni și japonezi. Marea majoritate a vizitatorilor au provenit din rândul specialiștilor în produse textile și vestimentare – realizate prin tehnologii de ultimă oră, de mare productivitate și de o excepțională calitate. Un număr important de participanți au constituit cumpărătorii, adică oamenii de afaceri din managementul de vârf cu drept de decizie și care reprezentau interesele liderilor din Asia, Europa occidentală și America de Sud. *„La târg au fost prezenți experți internaționali din rândul factorilor de decizie ai giganților strategici planetari, care dezvoltă, de ani buni, cele mai avansate tehnologii în domeniu“* – a declarat doamna Sylvia Phua – CEO la MP International Pte Ltd și organizatorul saloanelor ITMA 2011 și ITMA 2015, care va avea loc în principalul oraș al Italiei de Nord, în care se găsește celebra frescă Cina cea de Taină a lui Leonardo Da Vinci.

În timpul celor 8 zile, cât a durat salonul de la Barcelona, s-au desfășurat, în sesiuni paralele, *simpozioanele ITMA 2011* pe teme legate de ***Viitorul Textilelor și Îmbrăcămintei**,* în care experții în domeniu au prezentat și analizat un număr impresionant de clustere tehnologice și programe naționale cu mesaje ecologiste: *World Textil Summit (WTS), Sustainable Textile Leaders Roundtable, Forumul liderilor strategici din industria coloranților, IFAI Advanced Textiles Europe 2011, Reuniunea internațională a tinerilor antreprenori din sectorul textil*. La evenimentele organizate de CEMATEX și MP International Pte Ltd au participat peste 7 000 de reprezentanți ai industriei și mediului academic de pe mapamond, reprezentanți ai comisiilor din Europa, Asia, Africa și America de Sud, precum și ai presei internaționale de specialitate.

Între 23 și 25 septembrie, peste 700 de profesioniști de marcă, din 46 de organizații de profil, au urmărit, în pavilionul Research & Education, prezentarea a 24 de teme de cercetare, sub deviza *„Reinventing the futures“*. Legat de aceasta, domnul Stephen Combes, presedintele CEMATEX a declarat: *„Suntem încântați că, față de ediția precedentă, numărul de unități participante la R & E s-a dublat datorită unor subvenții substanțiale acordate de organizatorii salonului“.* Temele incluse în programul pavilionului au fost susținute de cadre didactice din mediul academic și de cercetători de calibru din universități, colegii și institute de cercetare-dezvoltare-inovare: *Ghent University, Department of Textiles, Institut für Textil- und Verfahrenstechnik Denkendorf (ITV-Denkendorf), Ecole Nationale Superieure dingenieurs Sud Alsace, Citta Studi SpA, The Institut für Textiltechnikof RWTH Aachen University (ITA), Fraunhofer Institute for Industrial Mathematics ITWM, Cetex Institut fur Textil und Verarbeitungsmaschinen gemeinnutzige GmbH, London College of Fashion, Instituto Tecnologico Textil (AITEX), Institut Dinvestigacio Textil i Cooperacio Industrial de Terrassa-UPC, Shinshu University – Faculty of Textile Science and Technology from Japan, Taiwan Textile Research Institute (TTRI), D.K.T.E. Societys Textiles & Engineering Institute from India*. Comunicările prezentate s-au referit la cercetări aprofundate legate de dezvoltarea unor produse cu o înaltă valoare adăugată, solicitate pe piața globală: textile tehnice pentru industria automobilelor și industria aerospațială, textile industriale, textile de protecție, textile de interior și textile medicale.

Cele mai apreciate de experții domeniului au fost temele cu mesaje puternic ecologiste legate de reducerea drastică a consumului de materii prime și de utilități (apă, energie electrică, combustibili) pe unitatea de produs textil. Până în prezent, puține organizații tehnologice și de cercetare au realizări practice remarcabile în ecologia textilă. Printre acestea se află *Bruckner Group, A. Monforts Textilmaschinen GmbH* etc.

Pentru a demonstra cât de complexă este rezolvarea practică a conservării resurselor, vom prezenta un produs ecologic de vârf, optimizat de-a lungul anilor de renumitul finisor din Monchengladbach, care de peste un secol oferă pe piața globală mașini și echipamente de finisaj textil de calitate, performante și fiabile. În ultimul deceniu, gigantul din landul Renania de Nord-Westfalia a reușit sa pună la punct un număr important de soluții practice inovative, care facilitează reducerea cu 60% a consumului de utilități – apă, energie electrică, combustibili – în procesul de vopsire, finisare şi sanforizare a produselor țesute şi tricotate din bumbac.

Noul stenter european Montex, cu lățimea de lucru de 8 000 mm, a făcut senzație în rândul profesioniştilor de marcă prezenți la eveniment. Stenterul *Bruckner 1800* (cu 6 camere) – expus prima dată la ITMA 1991, de firma germană din Siegsdorf, şi îmbunătățit de-a lungul anilor – este total depăşit de stenterul ecologic *Montex 8 000,* oferit în premieră mondială la salonul de la Barcelona de liderul mondial în inovații din Monchengladbach. Noul produs cu înaltă valoare adăugată, prezentat la salon într-un stand de 500 m², a fost unul din punctele de atracție ale evenimentului de la Barcelona. Noul echipament se compune din 5 camere integrate de recuperare a căldurii *Eco booster HRC*, plasate sub umbrela Montforts. Fiecare cameră reduce anual consumul de apă cu 100 litri/ unitate de produs, cel de energie cu 10–35% şi cel de gaz cu 20%. Echipamentul este dotat cu un sistem performant de curățare complet automatizată, cu disc rotativ fluff-sieves şi două conducte de evacuare pentru fiecare cameră. Cuplat cu sistemul *Hercules-V* (cu lanț heavy-duty de tip vertical) de curățare a textilelor tricotate, a nețesutelor şi textilelor tehnice, sau cu sistemul *Maraton* (cu lanț de tip vertical), noul echipament ecologic *Montex 8000 stenter* este ideal pentru curățarea perfectă a țesăturilor tehnice, cum sunt covoarele pentru autovehicule, la care sunt necesare temperaturi de curățare diferite pe cele două părți ale produsului. Folosit în combinație cu sistemul *TwinAir Stenters*, echipamentul ecologic *Montex 8 000 stenter* permite ca temperatura aerului de uscare a duzelor din partea superioară să fie cu 30ºC mai mare decât temperatura aerului la duzele din partea inferioară. Vizualizarea operațiilor de curățare este monitorizată pe ecranul din fața operatorului, printr-un sistem inteligent de teleservice, dotat cu un ecran tactil accesibil operatorilor cu pregătire medie.

În acelaşi context de interes global, experții în domeniu au discutat, în cadrul pavilionului R & E, direcțiile de cercetare ale economiei ecologice la nivel global. Nu întâmplător, Asociația producătorilor germani afiliați la *VDMA Textile Machinery* a acordat un interes major inițiativei *BluECOmpetence,* lansată la nivel național în iulie 2011, de *Grupul LMT* din Schwarzenbek. Este vorba de o generalizare – la nivelul întreprinderilor industriale din țara brandurilor *BMW, Mercedes Benz, Porsche, Audi, Volkswagen* şi *Grob Aerospace AG* – a măsurilor practice de eficientizare a conservării resurselor prin soluții durabile. Numele şi ego-ul inițiativei pleacă de la ideea că, în următorul deceniu, autovehiculele şi aeronavele vor fi tot mai uşoare şi, în consecință, vor consuma din ce în ce mai puțin combustibil. Strategia globală pe termen mediu şi lung derivă din sintagma: Investeşti în conservarea resurselor, investeşti în viitor! Tehnologiile textile ale viitorului trebuie să fie în concordanță cu conceptul de dezvoltare durabilă/ sustainable development, să satisfacă nevoile prezentului, fără a compromite capacitatea generațiilor viitoare de a-şi satisface nevoile prezentului. Ele reprezintă nucleul viitorului eveniment textil, care va avea loc peste 4 ani şi la care firmele expozante din zona euro vor fi obligate să vină cu produse şi cu cât mai multe soluții practice viabile. Pe acest segment se va derula competiția acerbă dintre fabricanții de textile vest-europeni şi cei din țările tigrilor asiatici.

## Următorul salon ITMA 2015 – în Italia, la Milano

Din punct de vedere social şi economic, industria textilă şi de îmbrăcăminte reprezintă un utilizator major de tehnologii. În consecință, este normal ca acesta să încerce să răspundă pozitiv tuturor provocărilor. În economia contemporană globalizată – bazată pe cunoaştere – cele 16 ediții ITMA organizate de CEMATEX, la fiecare 4 ani (tabelul 1), au oferit – încă de la primul salon, care a avut loc acum 60 de ani, în 1951, în oraşul Lille, din nordul

Table 1

| Anul | Oraşul | Țara | Spațiul expozițional, m² | Firme expozante |
|---|---|---|---|---|
| 1951 | Lille | Franța | 12 465 | 270 |
| 1955 | Bruxelles | Belgia | 20 585 | 453 |
| 1959 | Milano | Italia | 36 659 | 616 |
| 1963 | Hanovra | Germania | 61 622 | 828 |
| 1967 | Basel | Elveția | 72 543 | 881 |
| 1971 | Paris | Franța | 114 373 | 1 072 |
| 1975 | Milano | Italia | 12 000 | 1 160 |
| 1979 | Hanovra | Germania | 120 000 | 1 068 |
| 1983 | Milano | Italia | 125 000 | 1 100 |
| 1987 | Paris | Franța | 145 000 | 1 286 |
| 1991 | Hanovra | Germania | 186 000 | 1 480 |
| 1995 | Milano | Italia | 166 000 | 1 436 |
| 1999 | Paris | Franța | 156 000 | 1 391 |
| 2003 | Birmingham | Anglia | 100 000 | 1 279 |
| 2007 | München | Germania | 102 000 | 1 451 |
| 2011 | Barcelona | Spania | 100 000 | 1 350 |
| 2015 | Milano | Italia | - | - |

Franței – soluții inovative originale de construcție a maşinilor textile şi confecțiilor.

Ca urmare a evoluțiilor spectaculoase ale industriilor de vârf din domeniul mecanicii, chimiei, nanotehnologiei, electronicii şi tehnologiei informației (IT), nivelul tehnologic al industriei textile şi de îmbrăcăminte a cunoscut de-a lungul celor 16 ediții un progres uriaş şi continuu. Folosirea microprocesorului, introducerea automatizării complete a unor operații de filare, țesere, tricotare, finisare şi confecții, monitorizarea activității utilajului/echipamentului, a secției şi chiar a întregii fabrici constituie componente de bază ale industriei textile moderne. Abia după o jumătate de secol, tot în Franța, dar în oraşul muzeelor Luvru, Orsay, Beaubourg, Rodin, Cluny, Picasso şi Montparnasse, expoziția maşinilor textile a început să fie unanim recunoscută ca fiind cel mai important eveniment în domeniul textil de pe mapamond. La salonul parizian din 1999, organizat în Parcul Expozițional Porte de Versailles, 1 391 de companii emergente prezentau, pe o suprafață de 12 ori mai mare decât cea de la Lille, maşini şi echipamente de ultimă generație pentru sectorul textil, cu consumuri relativ reduse de materii prime şi energie, randamente şi productivități ridicate, în condițiile obținerii unor produse textile de înaltă calitate şi de îmbrăcăminte inteligentă la un înalt nivel de funcționalitate şi de design. De la ediția de la Birmingham, spațiul activ expozițional s-a stabilizat la 100 000 $m^2$, iar numărul aşa-numitor participanți-turişti a fost în continuă scădere. În schimb, a crescut, de la o ediție la alta, numărul de vizitatori cu experiență profesională de excepție. Nu întâmplător, la conferințele salonului de la Barcelona au participat peste 7 000 de specialişti de marcă ai domeniului, din care mulți lucrează în cele mai prestigioase universități de profil şi în institute de cercetare-dezvoltare-inovare din lume**.** Viitorul salon ITMA va avea loc în perioada 12–19 noiembrie 2015, la Fiera (Rho), în oraşul în unde se află strada shopping-ului de lux – Fashion Quadrilatero Via Montenapoleone. La viitorul salon, producătorii din zona euro vor expune mult mai multe modele de maşini textile şi de îmbrăcăminte, în care vor fi încorporate noi soluții ecologice viabile, care să satisfacă cerințele conceptului global de dezvoltare durabilă. Cu siguranță, cele mai multe exponate de vârf vor fi aduse de întreprinderile industriale cu profil textil afiliate la Asociația companiilor de utilaje *VDMA Textile Machinery,* din țara lui Goethe şi a celui de-al doilea exportator mondial.

Perspectivele economiei globale s-au schimbat foarte mult de la târgul de maşini textile care a avut loc în capitala Bavariei, focalizat pe tema *„Spațiu al inovației".* În cei patru ani, s-au înregistrat creşteri fără precedent ale consumului de materii prime (bumbac, lână, fibre chimice) şi de utilități (apă, energie electrică, combustibili), la nivel mondial. Inundațiile catastrofale din Pakistan şi Thailanda, alunecările de teren din Turkmenistan, interzicerea exportului bumbacului indian, slabele recolte din America, comenzile incredibil de mari solicitate de China şi India au determinat o explozie a prețurilor la materiile prime textile. După cum se ştie, bumbacul este cea mai folosită materie primă naturală pentru îmbrăcăminte. Euforia speculativă pentru bumbac a intrat într-o fază acută, prețurile depăşind bariera psihologică de 2 dolari/livră. De la începutul anului 2010, prețul a crescut cu 155,8%. Aceasta înseamnă că, în următorii ani, prețurile produselor de îmbrăcăminte din bumbac vor creşte.

Pe fundalul îngrijorător al crizei economice şi financiare la nivel planetar, studii şi statistici recente arată că industria globală de maşini textile şi îmbrăcăminte este sensibil departe de a intra într-o veritabilă recesiune. Optimiştii nu vor sa piardă acest interval favorabil repornirii motoarelor creşterii. Pe primul loc se situează industria tricotajelor, care a înregistrat, în 2010, la nivel mondial, cel mai ridicat nivel de investiții. Vânzările de maşini rectilinii de tricotat automate au crescut cu 187% (51 100 de maşini vândute), iar cele circulare de tricotat cu 36% (34 500 de maşini vândute). Din nou Asia, cu prioritate China, a fost destinația preferată: 92% din totalul investițiilor!

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