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Design of a new rotary dobby mechanism

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ÖZGÜN CAN GABİL ABDULLA

REZUMAT – ABSTRACT

Proiectarea unui nou mecanism de țesere cu ratieră rotativă

Mecanisme speciale cu camă care necesită o tehnologie avansată au fost utilizate în dispozitivul de acționare a noilor ratiere rotative. Electromagneții sunt în general preferați în mecanismele de selecție, dar aceștia măresc costurile de producție și fac mai dificilă întreținerea. Această lucrare își propune să conceapă un nou tip de ratieră rotativă, diferită de celelalte ratiere. În primul rând, au fost elaborate proiectarea și sinteza unui nou mecanism de acționare cu opt poziții, la același nivel și la nivel dublu pentru mișcarea oscilantă de 180°. Rezultatele cercetării au arătat că atât valorile teoretice, cât și cele experimentale ale unghiurilor de staționare ale mecanismului de acționare sunt compatibile una cu cealaltă. Astfel, s-a propus ca mecanismele proiectate să poată fi utilizate în locul mecanismelor speciale cu came la ratierele rotative. Pistoanele pneumatice și elementele de blocare au fost utilizate în mecanismul de selecție a ratierei rotative dezvoltate în acest studiu. În timpul testelor de performanță, s-a observat că pistonul pneumatic și elementele de blocare pot fi utilizate în locul electromagneților, acționând în armonie unul cu celălalt. Ca o concluzie, atunci când a fost testată performanța de lucru a ratierei, s-a confirmat că aceasta a funcționat cu o performanță ridicată și în mod durabil, cu toate mecanismele componente. În plus, procesul de formare a rostului a fost efectuat cu precizie. În cele din urmă, a fost proiectată și produsă o nouă ratieră rotativă, care a fost ușor de construit cu costuri reduse.

Cuvinte-cheie: țesere, formare a rostului, ratieră, proiectarea mecanismului, ratieră rotativă

Design of a new rotary dobby mechanism

Special cam mechanisms which require advanced technology are used in the drive mechanism of nowadays rotary dobbies. Electromagnets are generally preferred in the selection mechanisms which increase the cost of production and make the maintenance more difficult. This work aims to design a new rotary dobby different from the other dobbies. First of all, the design and synthesis of a new drive mechanism with eight members, equal and double standby at 180° oscillating motion was developed. The results of the research revealed that both the theoretical and the experimental values of the waiting angles of drive mechanism are compatible with each other. Thus, it has been proposed that designed mechanism can be used instead of the special cams mechanisms in the rotary dobbies. Pneumatic pistons and locks have been used in the selection mechanism of rotating dobby developed in the study. During the performence tests, it has been observed that the pneumatic piston and locks can be used instead of the electromagnets by providing that they work in harmony with each other. As a conclusion, when the working performance of dobby was observed, it was confirmed that dobby worked with a high performance and durably with all of its mechanisms. Additionally the shedding process was precisely carried out. Finally a new rotary dobby which was easy to construct with low cost has been designed and produced.

Keywords: weaving, shedding, dobby, design of mechanism, rotary dobby

INTRODUCTION

Woven fabrics are formed by crossing of weft and warp yarn groups under and over each other. In order for the weft yarns to be connected to the warp threads, it is necessary to separate the warp yarn groups into two different layers. This layer with a triangular section is called the shed [1–3].

The shed types are classified in three groups:

1. According to the geometric form of the shed; symmetrical opening sheds at the top, bottom and both sides [4–5].
2. According to the layout of the weft yarns in the shed; regular (clean), irregular (dirty) and semi-regular (semi-clean) sheds [6–8].
3. According to shape of shed closing; open, semi-open, bottom and middle position closed sheds [7–8].

Shedding process directly affects the weaving performance and speed. Many different shedding mechanisms have been developed for the shed opening systems. These are cam, dobby and jacquard shed opening mechanisms. Nowadays, rotary dobbies have been developed for the shedding operations in high-speed modern weaving machines. The rotary dobbies are the dobby mechanisms that convert the rotational motion of the main shaft of the weaving machine into a up-down motion of the frames by means of various gears-arms and eccentrics (cam).

Working principle of the classic rotary dobby

A classic rotary dobby consists of three main parts:

1. Drive mechanism with eccentrics (cams);
2. Selection mechanism for determining the position of the frames by cutting the connection between the eccentric shaft and the eccentric according to the weave pattern;
3. The part that generates the variable dobby shaft motion (modulator) [9].

In recent years it has been observed that the speed of rotary armatures has reached 1000 rpm and above. Thus, it is possible to operate the rotary dobbies at high speeds in air-jet and water-jet weaving machines [10]. Nowadays electronically controlled rotary dobbies are used.
In rotary doobies, the one-way rotary motion obtained from the drive mechanism must be transmitted to the main shaft of the machine. In order to achieve this kind of movement, the cam mechanism with the special structure rotating in the constant velocity is used in the drive mechanism of the rotary dobbies. In addition to the cam mechanisms in the dobby drive mechanism, servo-motor, arm and gear-arm mechanisms have also been used [11].
New dobby designs have been reached in research on rotary dobbies. Some of these are listed below:

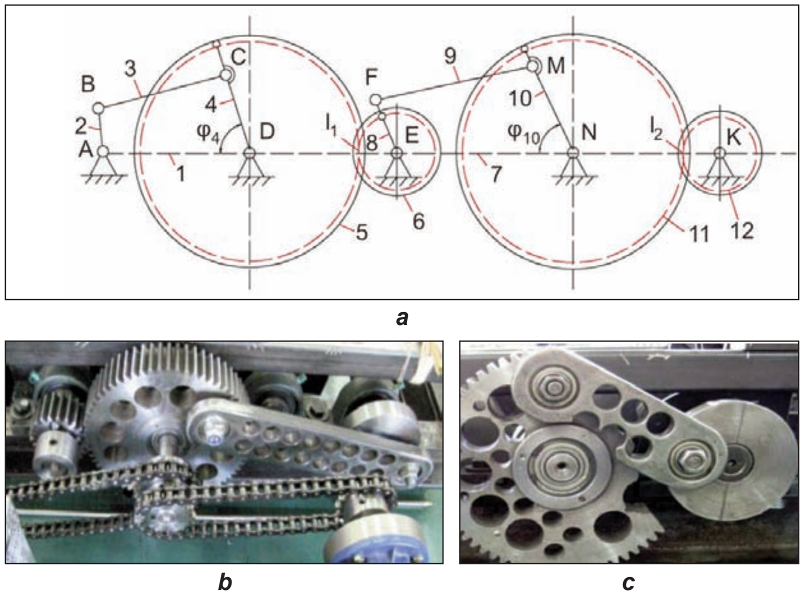


Fig. 1. Drive mechanism: *a* – kinematic scheme of newly developed drive mechanism; *b* – drive mechanism (right side); *c* – drive mechanism (left side) [11]

- Shape enclosed cam pair has been used and proposed in the developed new rotary dobby's drive mechanism [5].
- New methods have been proposed using the ADAMS® program in the design of the rotary dobby drive mechanism cams [12].
- New cam profile design and synthesis are proposed for the regulation of the motion profiles of the cam mechanisms used in the dobbies and reducing the residual vibrations of the frames [13].
- Special eight-arms mechanism has been synthesized and proposed instead of the cams used in the drive mechanism of the dobbies [14].
- New electronic selection mechanism is proposed instead of the electronic selection mechanism used in rotary dobbies. In this mechanism, the number of moving members is reduced and the test set is run smoothly [15].

Furthermore, studies have been carried out related to the subject and it has been concluded that negative control dobbies managed by micro processors will be replaced by nowaday's positive dobbies and information has been obtained that the shedding mechanisms driven by the servo motors may be widespread in the near future [9, 16]. The prominent feature about the new rotary dobby mechanism developed for the study and is the drive mechanism and the selection mechanism which makes it different from the before developed rotary dobby mechanisms.

NEW DESIGNED ROTARY DOBBY

Designing drive mechanism of new rotary dobby

This study includes the design and synthesis of the mechanism proposed as an alternative to the special cam mechanisms has been developed in the drive mechanism of the rotary dobbies used today. The mechanism is designed and produced to have 8 members, to make equal and double standby swing motion at 180°. The kinematic scheme of the mechanism and mounted status of the drive mechanism right and left sides are shown in figure 1.
The design of the dobby drive mechanism has been theoretically determined by the SAM 6.1® program. The position, velocity and acceleration of the mechanism are analyzed. Then the mechanism has been produced, the assembly and working experiments have been completed and the analysis results have been obtained. The results of the analysis were given in the results and discussionchapter.

Designing selection mechanism of new rotary dobby

Selection mechanism of the new rotary dobby consists of main shaft of double standby with 180° rotational motion which was indicated with number "1", fixed on this shaft discs of numbered 2, locks mounted on discs numbered 4, eccenstric of numbered 3, arm numbered 5, output lever of numbered 6, pneumatic piston of numbered 7, pressuring arms of numbered 8, cam of numbered 9 and dobby blade of numbered 10. Working principle of rotary dobby selection mechanism and mounted status of the mechanism are shown at figure 2. The selection process occurs while waiting on the left and right edges every 180° of rotation of the dobby main shaft.
Mechanism's working principle: While the main shaft (1) stands on the left edge pneumatic pistons (7) are drawn back with electronic signals coming from the pattern wheel (the pattern wheel isn't shown in the figure 2). The cam (9) which is started to rotate clockwise and its effect on the pressuring arms (8) reduces and the pressuring arm (8) can't push the locks (4). In this case, the locks (4) moves out of the center of the disc (2) with the impact of springs and the locks are attached to the dobby blade (10) on the left side. The connection between the disc (2) and the eccentric (3) are established. The main shaft (1), the disc

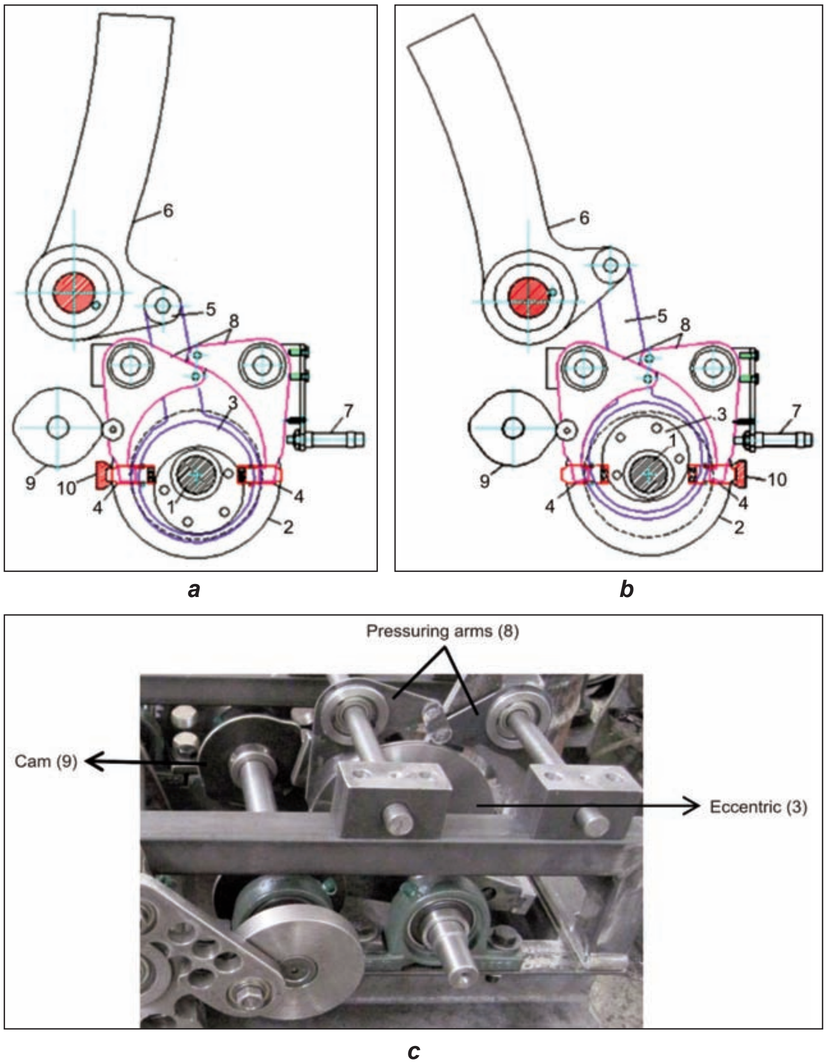


Fig. 2. Selection mechanism: *a* – output lever (6) on the right; *b* – output lever (6) on the left; *c* – mounted status of selection mechanism [11]

(2), the eccentric (3) and the dobby blade (10) rotate 180° at the counterclockwise together. Arm (5) connected to eccentric (3) makes the output lever (6) rotate from the right edge to the left edge position. Thus, the frame connected to the output lever (6) is also moved.

Re-selection process is performed when main shaft (1) of the dobby has been rotated 180° and waiting on the right side. If the pneumatic piston (7) is pushed forward, the piston (7) and cam (9) compresses the pressuring arms (8) and pushes locks (4). In this case, locks (4) can't be attached to the dobby blade (10) on the right side and connection can't be made between disc (2) and cam (3) too. Thus, the eccentric (3) connected to the arm (5) and the arm (5) connected to the output lever (6) can't move. As a result, the frame connected to the output lever (6) doesn't move. Proposed rotary dobby selection process takes place twice every 180° of rotation of the main shaft. In this case selection process has been two times faster than the one-way stand-up rotary dobbies. The technical drawing of the designed new rotary dobby and its mounted status are shown in figure 3.

RESULTS AND DISCUSSION

After the settings of the drive mechanism have been completed, the movements of the mechanism have been calculated by the SAM 6.1® program. Coordinate, velocity and acceleration analyses have been conducted. The analysis graphs obtained in the SAM 6.1® program of the proposed mechanism are shown in figure 4.

When the figure 4 has been examined it is seen that from the diagram (1), the waiting angles of the output shaft in edge condition are 63° in the right edge and 60° in the left edge. These values, which are equal to 126 and 120° of rotation of the main shaft of the weaving machine, are approximately equal to the values required for the reading and application of the dobby program. The angular displacement of the output shaft and the working speed were investigated in order to be able to perform the workability tests of the drive mechanism. Angle measuring devices with a measurement accuracy equal to 1° has been installed to the input

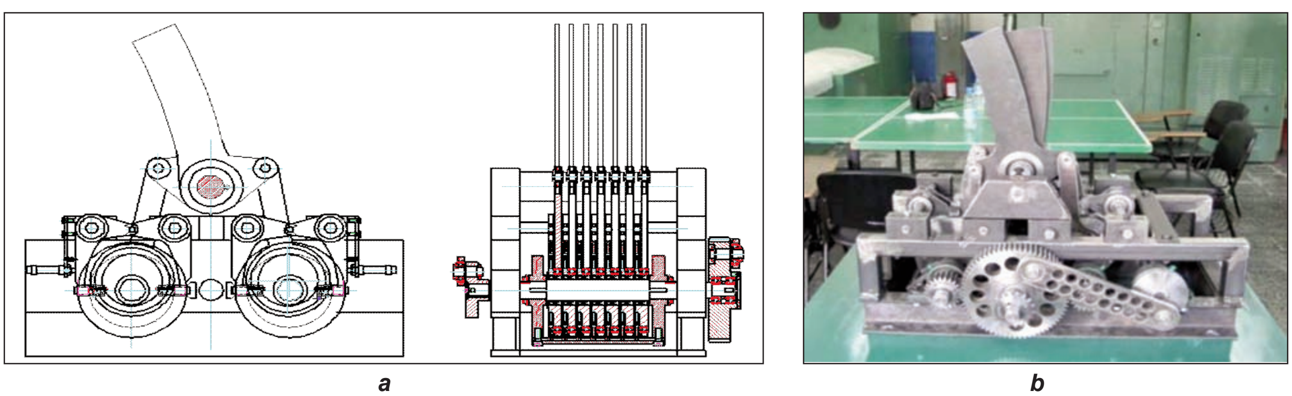


Fig. 3. Rotary dobby: *a* – technical drawing of new dobby; *b* – mounted status of new rotary dobby [11]

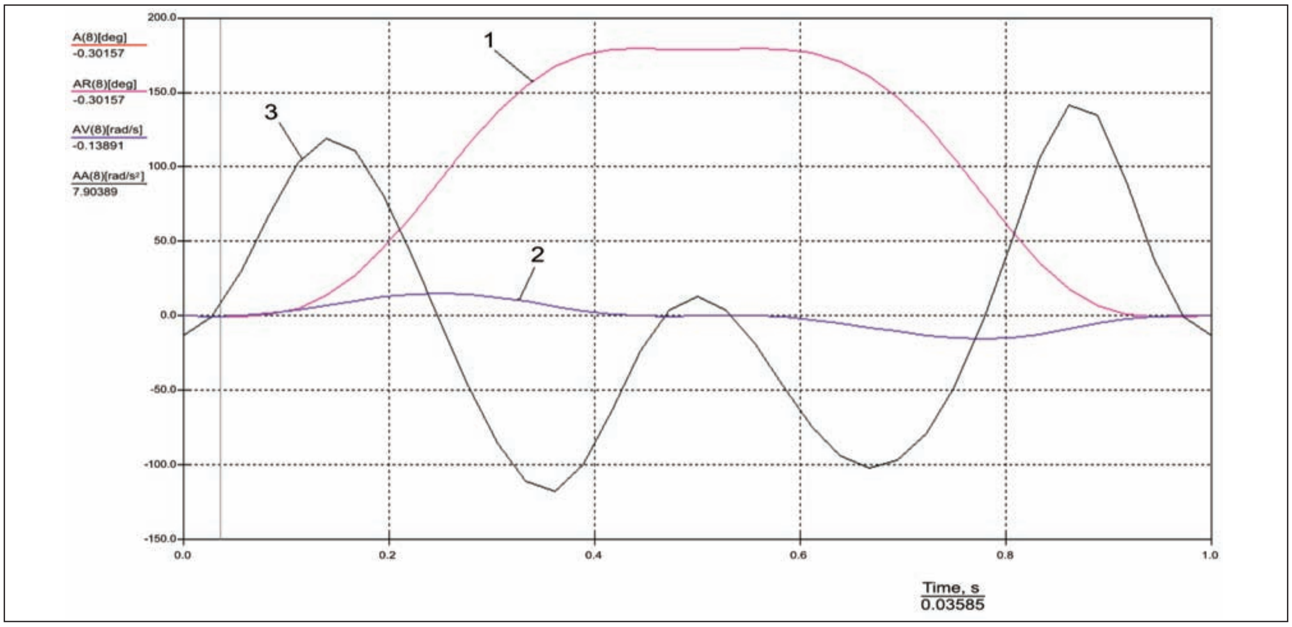
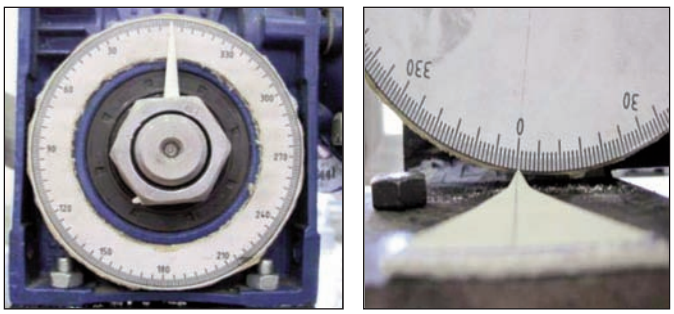


Fig. 4. The angular position (1), velocity (2) and acceleration (3) plots of the output shaft drawn in SAM 6.1® [11]



a *b*

Fig. 5. Gunner's quadrants: *a* – input shaft gunner's quadrant; *b* – output shaft gunner's quadrant [11]

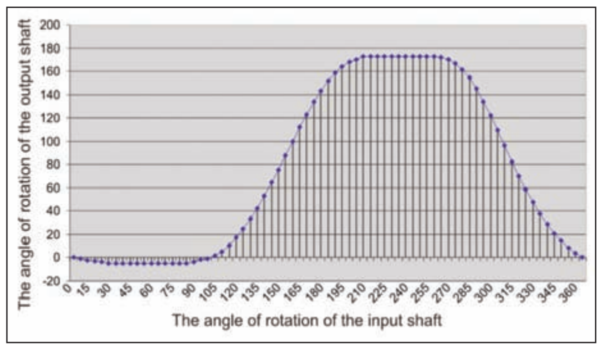


Fig. 6. Angular displacement diagram of the mechanism output shaft [11]

and output shafts of the mechanism for determining the angular displacement of the output shaft. The angle measuring devices are shown in figure 5.

The angle of rotation of the output shaft was measured at every 5° rotation angle of the input shaft for the workability experiments of the mechanism in practice. According to the obtained data, an angular displacement graph of the output shaft is plotted in the Excel® program. This graph is given in figure 6.

According to figure 6, it is observed that, the output shaft draws a waiting motion curve at 360° rotation of the input shaft. When this movement curve is examined, it is observed that the output shaft's waits while the input shaft of the mechanism is moving between the range of 25°–80°and 205°–260°. This means that the output shaft is waiting approximately 55° in both right and left edge positions. When the both graphs are analysed, the motion curve of the dobby drive mechanism and the motion curve obtained from the SAM 6.1® program are similar. It is also seen that the difference between the theoretical values of the waiting angle of the mechanism and the experimental values is slightly less than 5°. It is thought that this deviation between theoretical and practical values may be due to the spaces between the machine elements. In this way, it has been proposed that the newly designed mechanism can be used instead of the cam mechanisms used in the dobby machines.

CONCLUSIONS

Special cams are used to ensure the standby rotation of the dobby main shaft in the drive mechanism of classic rotary dobby. In this study, the design and synthesis of a new drive mechanism with eight members, equal and double standby 180° oscillating motion is obtained. The results of the research revealed that both theoretical and the experimental values of the waiting angles are compatible with each other. Thus, it is proposed that the eight members' synthesized mechanism can be used instead of the special cam mechanisms in the rotary dobbies.

Additionally, pneumatic pistons working with electronic signals coming from pattern wheel is used in rotary dobby's selection mechanism has been developed in the study. As a result, the rotary dobby's selection mechanism developed in the study, differs from the classic rotary dobbies that work with electromagnets. Afterwards, the dobby has been runned at different speeds in order to observe the states of the mechanisms. In the conducted experiments, it has been observed that, the standby angles of the drive mechanism have been consistent with the theoretical angles. Also the locks in the selection mechanism have been worked with the cams and the pneumatic pistons on time. It has also been found that, at all working speeds, the dobby mechanisms have been worked together durably. As a result, the basic constructional dobby drive mechanism and selection mechanism have been produced by using a standard machine element. Thus, the cost of the rotary dobby production has been reduced further and the maintenance has been made easier.

ACKNOWLEDGEMENT

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From fabric design to the dress manufacturing considering the fabric's suitability with the end use

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RODICA HARPA EMILIA VISILEANU

REZUMAT – ABSTRACT

De la designul țesăturii la fabricarea rochiei, având în vedere adecvanța țesăturii la utilizarea finală

Acest studiu investighează două țesături tip lână selectate ca fiind adecvate confecționării rochiilor pentru sezonul rece. De la început, era de așteptat ca cele două țesături să contribuie cu caracteristici diferite la fabricarea rochiilor datorită modelului și structurii diferite, fiind însă potrivite pentru utilizarea finală. Țesăturile au fost testate conform standardelor specifice pentru ansamblul proprietăților legate de purtarea reală a rochiei, unele dintre caracteristici fiind legate și de îmbunătățirea aspectului general dorit de către orice clientă, indiferent de modalitatea de cumpărare a produsului (comerț cu amănuntul sau comerț electronic). Acest fapt a fost evidențiat prin intermediul unui sondaj despre preferințele femeilor cu privire la cumpărarea articolelor de îmbrăcăminte. S-a efectuat simularea 3D a produsului, datorită facilităților de vizualizare în ansamblu a rochiei create pentru sezonul rece, prin combinarea elementelor specifice schiței, materialelor (prin materia primă, model, culori și caracteristici generale preconizate la purtare) și, nu în ultimul rând, a corpului utilizatorului. Această abordare a permis trecerea de la rezultatele experimentale obținute pentru profilul calitativ estimat după testarea țesăturilor în laborator, la simularea rochiei, facilitând percepțiile virtuale ale utilizatorilor privind adecvanța țesăturilor pentru anumite creații de îmbrăcăminte. Prin urmare, în lanțul valoric textil, țesătoriile ar trebui să-și îmbunătățească procesul de proiectare prin includerea beneficiilor simulării 3D a îmbrăcămintei. Această strategie s-ar îndrepta spre atingerea perspectivei consumatorului privind adecvanța țesăturilor pentru fabricarea articolelor de îmbrăcăminte ca produse de succes pe piață.

Cuvinte-cheie: design țesături, fabricare, confecții, destinație finală țesături, consumatori, comerț electronic

From fabric design to the dress manufacturing considering the fabric's suitability with the end use

This study covers an investigation on two wool-type fabrics selected as suitable for cold season dresses. From the beginning, it was expected that the two fabrics will bear out diverse features in dresses due to the different patterns and structures, yet suitable for the end use. The fabrics were tested following the standards for the properties linked to the actual wearing of dresses, some of the features being related also to the general appearance expected by any clothing customer, regardless of the purchasing way (retailing or e-commerce). This opinion was pointed out by a survey of women's preferences about buying clothing items. Next, it was achieved the 3D clothing simulation to visualize the cold season dress, by combining the sketch, the fabric (with raw material, pattern, colours, and overall features expected for wearing) and finally, the wearer's body. This approach allowed stepping forward from the experimental results reached for fabrics' overall quality after the laboratory testing to the dress simulation, to give customers virtual perceptions on the fabrics' suitability for particular outfits. Therefore, within the textile value chain, the weaving companies should upgrade the design process by including the benefits of the 3D clothing simulation. This strategy would move towards the reaching of the consumer's perspective on the fabrics suitability for manufacturing items of clothing as successful products on the market.

Keywords: fabric design, manufacturing, clothing, fabric end use, consumers, e-commerce

INTRODUCTION

Considered a specific niche, women's clothing is strongly influenced by trends in colors, pattern and fashion but also by the feelings about an adequate durability, a satisfactory degree of comfort in wearing and finally, yet importantly, a great aesthetic appearance, no matter what the end use is [1–4]. When the garment quality for women is defined from the weaving companies' perspective, there is a focus on the overall features that can be measured in a laboratory [5–6]. Nevertheless, a perspective acknowledged as the market feedback for textile value chain, was the awareness on the women's perspective on quality, as the consumer's viewpoint [1–6]. Therefore, predicting the overall suitability for designed end use and the products success on the market can be a hard topic for fabrics and clothing manufacturers and for retailers, thus, the improving of the fabric design strategy should be the main mandatory task in textile companies [3, 6–8].

Earlier papers investigated the relationship between the lifestyle and assessment criteria for clothing purchase [1, 4, 7]. The need for manufacturers and retailers to be aware of consumers perceptions when predicting the garment' overall quality and on the garment end-use was highlighted, and this approach should be mandatory at an early stage of the development of the textile value chain. A permanent concern of weaving companies is that even though the compliance with customers' quality specifications is beneficial, this does not guarantee achieving the consumer's idea of the overall quality. One reason is the "feeling" the consumer has when buying an item of clothing, starting with the unambiguous expectations about the product. It is worth mentioning that the consumer's impression of a woven fabric and/or clothing item is strongly influenced by the aesthetic properties perceived visually [1–2, 6–8]. The situation becomes more complex when it comes to a successful product for e-commerce and online shopping [1, 4, 9–10].

A positive effect of the globalized market is the "consumer market without frontiers", hence, in the clothing manufacturing sector, several changes came out [3, 8]. One of these is e-commerce, the most common form of distance shopping, which added another dimension to the textile value chain. At the beginning, the e-commerce strategy aim was to bypass retailers and reach the consumers directly, but this trend affected the clothing sector, where online sales increased more and more in the last decade. All over the world, online sellers seek to offer items of clothing in larger assortments and, generally, at better prices than traditional retailers (and not only during the sales season) so, the consumers are more likely to buy apparels items online from sellers/brands, regardless of the country the products are made in. The main actors engaged in the e-commerce and online clothing sales were e-retailers, textile specialists, and non-specialists with a web store. In this context, a lot of clothing companies choose to launch their websites just like the other online fashion chains, targeting as many consumer niches or even just a dedicated niche [9, 10]. In 2017, 64 % of internet users (aged 16 to 74) in the EU-28, with a share of 50.1% female users, reported the use of e-commerce and preference for online purchases of clothes and sports goods. Due to ongoing differences in comparison to the offline retail, the global e-fashion shopping is expected to get an average annual growth rate of 14.2% by 2019 [11].

In this context, the virtual prototyping appeared as an important achievement within the manufacturing chain of garments or other textile products, to create models adapted to customers' needs. In addition, the assistance of 3D CAD systems for the virtual prototyping of garments by means of simulation helps eliminate expensive physical prototypes, being provided as an effective design tool for the apparel industry [12–14]. Therefore, this raises a new challenge for the weaving companies, given that there is a big difference between providing static images of fabrics to customers and providing them with a simulation of the material embedded in the selected item of clothing [11, 15].

This paper aims to investigate the possibilities of upgrading the fabric design strategy by including the 3D clothing simulation, in pursuing the reaching of the consumer's point of view on the wool-type fabrics suitability for manufacturing cold season dresses as a successful product on the market, also including e-commerce.

MATERIALS AND METHODS

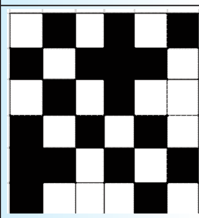
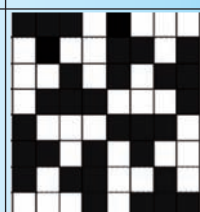
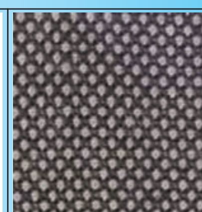
Fabrics design

Two wool-type fabrics were chosen for this study for their suitability in the end use, which is creating dresses for the cold season (autumn to winter). Table 1 summarizes the basics of the selected fabrics, with codifications F1 and F2.

Fabrics testing

The two wool-type fabrics were tested in accordance with standards [5, 6] and in a conditioned atmosphere,

Table 1

Fabrics	F1		F2	
Pattern and Sample sight				
Weave type	Crêpe weave (produced by adding and deleting binding points in a plain weave)		Crêpe weave (produced by reversing)	
Datasheet specifications				
Fibre content	Wool 45% / PES 55%		Wool 45% / PES 55%	
Width (without selvedge), (cm)	150 ± 2.5		150 ± 2.5	
Weight, g/m^2	240 ± 12		217 ± 11	
Yarn linear density, tex (warp and weft)	15 × 2 (warp); 42 × 2 (weft)		16 × 2 (warp and weft)	
	Warp	Weft	Warp	Weft
Yarn density / 10 cm	206 ± 10	180 ± 10	338 ± 10	288 ± 10
Breaking force Fr (N)	min. 40	min. 30	min. 70	min. 60
Elongation, Er (%)	min. 30	min. 25	min. 35	min. 35
Dimensional stability changes (%)	max. 1.5	max. 1.2	max. 1.5	max. 1.2
Recovery angle, α_{30min} (°)	min. 145		min. 145	

for the properties linked to the actual wearing of dresses: physiological characteristics (weight/mass per unit area, thickness, apparent density and water vapour permeability), aesthetic features (crease recovery, stiffness, flexibility, and dimensional stability after washing-ironing) and durability (abrasion resistance, slippage resistance of yarns at a seam in woven fabrics).

For the selected fabrics as coating materials in the cold season dresses, a consistent sampling was carried out and, when necessary (for durability and aesthetics features) the sampling on the warp and the weft directions were considered. Two of the performed tests for the assessment of fabrics' durability, need some punctual explanations about the set up and, due to the specific aspects, they are given below:

- Regarding the fabric's abrasion resistance: a controlled amount of abrasion with the same number of cycles for both fabrics (2000 cc) was performed with the Martindale abrasion tester. The abrasion test assessed the fabric's loss of mass and the change in appearance, with inspection interval at every 1000 cc; in table 4, the abrasion resistance was assessed by the loss of fabric's mass.
- Regarding the slippage resistance of yarns at a seam in woven fabrics performed with the Mesdan Tensolab 3: after the preparation of test specimens, the standardized testing conditions were assured for fabrics with mass ≤ 320g/m^2, designed for apparel (applied load 60 N) and measuring the seam opening after returning to 5 N.

A survey of women's preferences when buying items of clothing

Previously, an online consumer survey aimed at collecting information on women's behaviour when buying items of clothing was carried out between November 2016 and May 2017. The survey covered a total of 231 respondents spread over eleven EU Member States, namely: Belgium, Bulgaria, Czech Republic, Germany, Italy, Latvia, Lithuania, Northern Ireland, Poland, Romania, Serbia, Slovenia, and Turkey.

The survey was launched online (http://www.isondaje.ro/surveys), had eighteen questions and the results allowed finding some key trends that are also relevant for this paper.

Dress manufacturing and consumers expectations

The usual procedure for manufacturing fabrics for a ready-to-wear collection of clothing items includes in principle the following steps: market research on consumer niches and fashion trend analysis; product design including the 2D pattern sketches; acquisition of raw materials suitable for the final destination (fabric as coating/lining in the clothing item); sample production ("zero series"); evaluation and approval of the sample product; manufacturing of the assortment range of fabrics and finally, the distribution/sale within the textile supply chain (for garment companies)/ on the consumer market (for store retailing and e-commerce).

This textile value chain could be perfected if the fabric design would include the 3D garment virtual simulation. Therefore, the characteristics of the materials selected for the final product can be translated into a virtual product alternative, and a range of different items of clothing from the same fabric or a range of one item of clothing from different fabrics can be achieved. Obviously, in this manner, one can also bet on both, the fabric's success on the market and satisfying the expectations/needs of a consumer niche on a higher level.

For this paper, a 30-day free trial CLO/3D Fashion Design software [15] was downloaded and the 3D virtual simulation of a cold season dress was achieved, by including each of the two wool-type fabrics.

RESULTS AND DISCUSSION

On the fabrics features for the designed end-use

In this part, it is important to keep in mind that the two wool-type fabrics chosen for the cold season dresses have identical raw material (Wool 45%/ PES 55%) but are quite different in terms of pattern, yarn count size and yarn density, so, it was expected to bear out distinctive features for the dresses during wearing (table 1).

Tables 2, 3 and 4 show the average values of the structural and physiological features, of the aesthetic features and of the durability features, for each wool-type fabric indented for manufacturing the cold season dresses.

It should be noted that the values obtained for the mass per square meter, for the crease recovery angle, for the dimensional stability changes and for the tensile properties are proper and meet the allowable limits imposed by the specifications.

Table 2

FABRICS STRUCTURAL AND PHYSICAL PROPERTIES

Characteristics \ Fabric	F1	F2
Mass per square meter, M (g/m^2)	242	207
Thickness, g_P (mm)	0.82	0.57
Apparent density, d_a (g/cm^3)	0.295	0.363
Water vapor permeability, Pv (mg/24h)	880	860

In table 2, fabric F1 is slightly heavier and thicker, has a lower apparent density than fabric F2 and also has higher water vapor permeability than F2. Therefore, fabric F1 is expected to give a better comfort when wearing the dress.

As shown in table 3 and in figure 1 also, in terms of aesthetics features, fabric F2 performs a better crease recovery and has lower stiffness values than fabric F1, also providing a better dimensional stability after washing-ironing.

Fabric F1 has a greater stiffness value and almost similar values for flexibility compared to fabric F2. As a result, it is expected that fabric F2 will provide

Table 3

FABRICS AESTHETICS PROPERTIES					
Characteristics / **Fabric**		**F1**		**F2**	
Sampling direction		Warp	Weft	Warp	Weft
Crease recovery	Recovery angle, α_{0min} (°); α_{30min} (°)	140;148	152;163	132;169	141;168
	Average coefficient λ (%)	80	87.5	83.6	85.8
Stiffness R (mg cm)	Axial	224.1	153.2	88.9	96.8
	Total	185.3		92.8	
Flexibility H (%)	Axial	53.9	62	56.9	55
	Total	57.9		55.95	
Dimensional stability changes after washing-ironing, M_D (%)		0.6	0.8	0.4	0.4

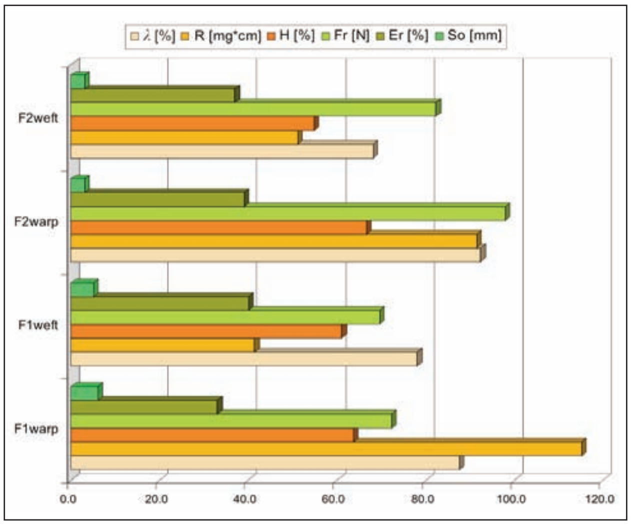


Fig. 1. Selected wool fabrics: aesthetic and durability and features depending on the threads' sampling direction (warp and weft)

better aesthetic features when wearing the dress. In addition, figure 1 shows that in terms of durability, fabric F2 performs better tensile properties than fabric F1, assuring a better resistance to abrasion (table 4).

Table 4

FABRICS DURABILITY PROPERTIES					
Characteristics / **Fabric**		**F1**		**F2**	
Sampling direction		Warp	Weft	Warp	Weft
Breaking force, Fr (N)		72.3	69.6	98	82.3
Elongation, Er (%)		33	40	39	37
Loss of fabric's mass, M_{MF}(%)	1000cc; 2000cc	0.8; 0.85		0; 0	
Sampling direction		Warp	Weft	Warp	Weft
Seam opening, S_0 (mm)		6	5	3	3

The results from the abrasion tests highlighted that a change in the mass after 1000 cc /2000 cc was only observed for fabric F1; before reaching 2000 cc, the appearance of the fabrics changed very little by the fibers out of the flat surface but without producing the pilling. In addition, the slippage resistance of yarns at the seam has smaller values for fabric F2, regardless of the testing direction (figure 1). For fabric F1, a bigger weft slippage that the warp slippage was obtained, so was the seam opening value. Therefore, fabric F2 is expected to assure a better durability when wearing the dress.

Altogether, on the wool-type fabrics features for the designed end-use, it can be expected that fabric F1 will give a better comfort, and fabric F2 will provide better durability and aesthetic features when wearing the cold season dresses.

It remains to be seen whether dresses made from these fabrics will respond to a larger extent to women's needs as consumers and whether they will be successful for the textile supply chain.

On the survey of women's preferences when purchasing clothing

Regarding the survey, only the results that allowed naming some key trends that are relevant for the purpose of this work will be discussed, to better understand the behaviour and choices of women as clothing shoppers. The sample of consumers consisted of women aged between 18 and 60 years (with an average age of 36 years), 93.1 % of them having a background in the textile field (by education in textile and professional activity).

The respondents were asked to indicate the most important factor among the nine factors considered, when deciding to purchase a clothing item and a hierarchy was obtained, as shown in figure 2. The general appearance (94.81%) and the quality of fabrics

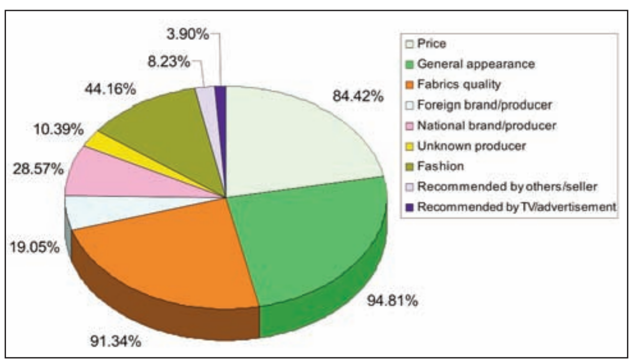


Fig. 2. Respondents sharing on the most important factor of the decision to buy clothing

Fig. 3. The 3D simulation of dresses for cold season, made of selected wool-type fabrics:
a – the 3D dresses simulation with the fabric F1; *b* – the 3D dresses simulation with the fabric F2

(91.34%) were clearly ranked first among the most important factor for which respondents would be willing to buy a clothing item, followed by price (84% of respondents) and by fashion (44.16% of respondents) which had an intermediate position. A lower share of respondents is willing to purchase a clothing item considering the other factors like national brand/producer (28.57%), foreign brand/producer (19.05%), unknown producer (10.39%) and recommended by others/seller (8.23%). The lowest share of respondents (3.90%) is willing to buy a clothing item considering the advertising strategies.

Given the basic training of respondents and the answers' relevance (with a 6.4% survey error), the ranking made by the 231 participating in the survey as potential buyers of clothes can be considered almost conclusive: the clothing appearance and the fabrics' quality could be the key factors for women willing to purchase a clothing item.

As mentioned before, the use of e-commerce and the online clothes purchases have become increasingly popular for a large segment of shoppers and, in this context, a lot of apparels companies choose to launch their websites just like the other online fashion chains. The question is whether or not the involvement in e-commerce should be a strategy also addressed by the fabrics manufacturers, which are facing a market globalization, not only within the textile value chain but as separate players too.

On the dress design and consumers' niche

As shown above, an upgraded strategy including the survey's results, should meet the needs and preferences expressed by customers. This means finding the most effective solutions that can give clients the information about the fabrics overall appearance and quality for a clothing item, and the matter here is different from providing values of the characteristics considered relevant and tested in the laboratory.

In this paper, using of the CLO3D software allowed stepping forward from the static image of fabric's sample (table 1) to the virtual simulation of fabric use (figure 3) enabling the upgrade of the fabric's design stage, before manufacturing the clothing item; it also should to be equally useful for e-commerce.

Figure 3 presents the images of cold season dresses (autumn to winter) made of the two wool-type fabrics. These helped to visualize the dress, by combining the sketch, the fabric (with the raw material, pattern, colors and the overall features expected for wearing) and, finally, the body.

This approach allowed stepping forward from the experimental results achieved following laboratory testing of the fabrics features, to the dress simulation to offer customers virtual perceptions on the fabrics' suitability for certain outfits.

CONCLUSIONS

In this study, an experimental investigation on two wool-type fabrics selected as suitable for cold season dresses (autumn to winter) was carried out, considering the possibility of upgrading the fabric design strategy by including the 3D clothing simulation, to address the wearers' preferences and needs, which are difficult to reach.

The main outcomes should support the usefulness of the subject, mainly for the fabrics producers. Regarding the online consumer survey on women's behavior when buying clothing items, out of the nine considered factors (price, general appearance, fabrics quality, foreign brand, national brand, unknown producer, fashion, recommended by others/seller and advertising), the clothing general appearance (for 94.81% of respondents) and the fabrics' quality (for 91.34% of respondents) turned out to be the key incentives for women willing to buy a clothing item. Since the fabrics' quality was considered of great importance for the consumers, the weavers should take it more into account. Considering the laboratory testing results for two wool-type fabrics made of 45% Wool / 55% PES suitable for the end-use, a differentiation was made, given the overall qualitative profile: one of the fabrics has a better potential in terms of comfort, and the other fabric provides better aesthetic and durability features for the cold season dress. However, the most important feature for the women surveyed turned out to be the clothing general appearance. This is why, for the success of the textile value chain, the weaving companies should eventually upgrade the design strategy before manufacturing fabrics, by including the benefits of the 3D garment simulation, if they want to keep in mind the consumers' preferences on the fabrics' suitability for the end use. Actually, this method allowed the visualization of the dress, advancing from the static picture of a fabric's sample by combining the sketch, the fabric, and the body, in order to assess the general appearance. This approach can be useful and have great benefits in terms of efficiency all the more so today, when commerce is heavily made online. Hence, along with garment producers, the fabrics manufacturers should also consider the 3D clothing simulation when focusing on the consumer nice and want to increase the wearer's satisfaction and by default, the sales.

This work is an attempt to advance from laboratory testing of the fabrics' quality profile to reaching the clients' virtual perceptions on the fabrics' suitability for the end use, enabling them to obtain an overall appearance of two cold season dresses made from the above designed fabrics. The feedback on the fabrics suitability will consist of the preferential buying of one of the two dresses.

It is important, however, to find out if this upgraded strategy is worth the efforts, considering the overall additional costs for the fabrics producers. As a future work, the authors are considering making studies on the subjective evaluation by visualization and handling of both, fabrics and dresses made of the selected fabrics, by a panel of assessors.

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Optimization and valorization of recycled fiber in non-woven fabric

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REZUMAT – ABSTRACT

Optimizarea și valorificarea fibrelor reciclate din nețesute

Gama și volumul produselor textile utilizate zilnic cresc exponențial în întreaga lume, atât în țările dezvoltate, cât și în cele în curs de dezvoltare. Prin urmare, problemele legate de gestionarea și valorificarea deșeurilor devin o provocare care necesită studii economice și tehnice aprofundate. În acest context, ne-am propus în această lucrare să prezentăm valoarea adăugată a două tipuri de deșeuri textile ale firelor și confecțiilor textile colectate de la producătorii de denim albastru. O evaluare a calității fibrelor regenerate prezintă proprietăți fizice și mecanice satisfăcătoare care le permit să fie utilizate pentru producerea materialelor textile nețesute. S-a investigat un set de proprietăți, iar rezultatele au arătat că structurile nețesute pot fi considerate o alternativă bună pentru exploatarea firelor și fibrelor de țesături reciclate.

Cuvinte-cheie: reciclare, fibră de bumbac, nețesut, industria textilă

Optimization and valorization of recycled fiber in non-woven fabric

The range and volume of textile products used every day is growing exponentiallythroughout the world, in both developed and developing countries. Therefore, the issues of waste Management and valorization become a challenge that requires depth economic and technical studies. In this setting, we aimed in this paper to give an added value of two kinds of textile wastes: yarns and textiles garments wastes collected from Blue denim manufacturer. A quality assessment of the reclaimed fibers shows satisfying physical and mechanical properties that allow them to be used to produce nonwoven textiles materials. A set of properties are investigated and results revealed that nonwoven structures can be considered as a good alternative for yarn and woven recycled fibers exploitation.

Keywords: recycling, cotton fiber, nonwoven, textile industry

INTRODUCTION

Several challenges related to environmental protection and economic benefitsmake recycling a preferred option for solid waste management.Therefore, recycling and reuse of industrial wastes became of great interest either by developed and developing countries [1–3].

The textile industry is characterized by many disposable products that create multiple environmental issues over its entire life cycle. Textile recycling is the method of reusing or reprocessing used clothing, fibrous material and clothing scraps from the manufacturing process. Clothing textile waste can be recycled and re-fiberized [4–5]. Youjiang Young presented an overview on textile waste recycling, focusing on the case of carpet [6]. This study contained a general assessment of fibrous waste, sources and material properties. A. Bartl et al. presented the state-of-the art in recycling fibers and the available technologies for textiles, carpets, composites and end-of life vehicles [7]. They demonstrate that fibers recycled from waste can be converted to a valuable raw material if processed properly. The quantitative and qualitative assessment of textile fiber waste is often linked with waste management and valorization. HALIMI et al. evaluated the waste percentage and the good fiber fraction for two cleaning machines and a card before the weaving step [8–10]. After this, the quality of recovered fibers was reviewed and confronted to other virgin material. These fibers can be blended in a good proportion without noticeable changes in final product quality. In addition, many studies have demonstrated that the reclaimed fibers can be reused and inserted with different proportion in different products with higher added value. Recently, nonwoven and fiber reinforced composites got considerable attention in numerous applications that can support the use of these recycled fiber.

Bechir Wannassi et al. worked to give an added value to cotton wastes by producing a new low cost yarn based on recycled yarn fibers [11]. Hence he investigated the effect of the raw material and the recycling process on the final quality of reclaimed fibers.

Finally, DoE method was used to find the optimum conditions for recycling process [12–13]. Related studies are achieved in order to develop new or alternative materials that aim to attain fuel efficiency, cost effectiveness, increased safety, and always with a target on capability to recycle or biodegrade [14].

In addition to a set of other investigated uses of reclaimed fibers on composites materials [15–17], Natascha M. van et al., after a life cycle assessment and eco-design of smart textiles, have demonstrated the importance of material selection through e-textile product redesign [18]. Results suggest several priority areas for environmental improvement of fibers [19].

In this study, we are interested inexploiting at the same time two kinds of wastes: yarns and fabric wastes collected from Blue denim manufacturers. The quality of recycled fibers is assessed then used to make a dry nonwoven. As a second part, the mechanical characteristics of these nonwovens were optimized to orientate their exploitation.

MATERIALS AND METHODS

Fibre recycling and characteristics

Waste characteristics

Yarn wastes used in this work are collected at the end of an Open-end process.Fabricwastes were collected from the end of the weaving process of Society of Textile Industries (SITEX). All tests in this study are conducted in the laboratory of SITEX Company while respecting ISO 139 standard. This standard describes the conditions of ambient that are 20 ± 2°C and 65% ± 4% air relative humidity. 24 h of conditioning of the materialis carried out before each test.

Wastes recycling process

The two kinds of wastes cannot be exploited in their current state and form. Then, restoringtheir initial state and transforming them to frayed fibers opens the door to several exploitation possibilities. For that, a mechanical process was adopted. Firstly, the yarn and woven waste was cut into small pieces with a length between 5 cm and 10 cm. The second step was to use a fraying machine to transform this waste into fibers. At that level, we aimed to use frayed fiber in producing non-woven with satisfactory characteristic to be used in automotive, home building, furniture, mattress, home furnishings, apparel and other industries. For different reasons related to fibers properties and finished products, needle-punching technology is used to make non-woven. The overall process followed for fraying and non-woven manufacturing is presented in the flowchart of figure 1.

Recycled fibers characteristics

In addition to the manufacturing process and a set of other technical constraints, the use of the recycled fiber is mainly related to their quality and characteristics. For this reason, Advanced Fiber Information System (AFIS) and High volume instrument (HVI) are used to characterize the two kinds of recycled fibers.

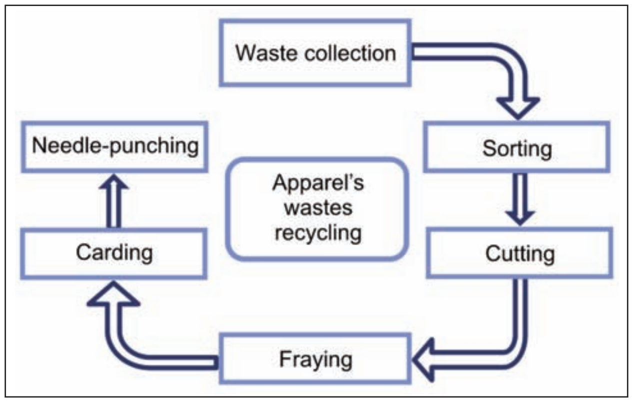


Fig. 1. Wastes recycling process

The main measurements include: the mean length, the length upper percentiles, the length CV%, and the Short Fiber Content, micronaire, length uniformity, strength, color, trash, maturity… etc.

Preparation of needle-punched nonwoven fabric and characteristics

Preparation of needle-punched nonwoven fabric

The preparation of needle-punching nonwoven fabric has gone through four stages. It started by the raw material opening by the machine openers. In this first stage, the cleaning and blending seem to be crucial in order to supply regularly the carding machine. Secondly, blended fibers were carded with cotton carding machine in order to remove dirt particles, fiber alignment and web formation. During the next stage, the non-woven consolidation is performed by Needle-punching machine. This method consists of mechanically interlocking fibers by repeatedly punching through the fiber web with an array of barbed needles (figure 2, *a*). Typically, needling is used to consolidate a fibrous structure, to densify it and control the porosity (figure 2, *b*).

Non-woven testing and evaluation

All tests and nonwoven characterization were conducted in a conditioned laboratory (65% RH and 20°C) while respecting ISO standards and recommended methods. Nonwoven samples were randomly cut (100 cm^2) and before the determination of weight and thickness. The measurement was repeated 10 times for each test. The mechanical properties

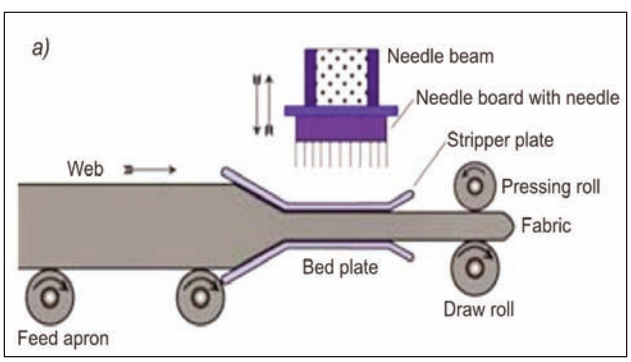


Fig. 2. (a) Needle punching principles and (b) Non-woven sample

including breaking strength and elongation were determined using ISO 13934-1(1999) standard.

DESIGN OF EXPERIMENTS

The overall properties of non-woven produced from frayed fibers are mainly related toraw material properties and the needle punching process. A preliminary and literature study consultation show that the factors: fiber type (FT, YRF: fibers from frayed yarn; WRF: fibers from frayed fabric) needle punching passage (NPN) and layer number (LN), were influential on the quality of nonwoven. Table 1 show the levels of each factor considered in DoE. Therefore, L09 orthogonal array (table 2) was selected for the experimentation and each experiment was performed three times and the average in each experiment was considered as the response variable.

Table 1

Level	Fiber type (FT%)		Needle punching passage number	Layer number
	YRF	WRF	NPN	LN
1	75	25	1	2
2	50	50	2	4
3	25	75	3	8

Table 2

Sample	FT		NPN	LN
	YRF	WRF		n
1	25	75	2	1
2	25	75	3	2
3	25	75	4	3
4	50	50	2	2
5	50	50	3	3
6	50	50	4	1
7	75	25	2	3
8	75	25	3	1
9	75	25	4	2

YRF – recycled yarn fibers.
WRF – recycled woven fibers.

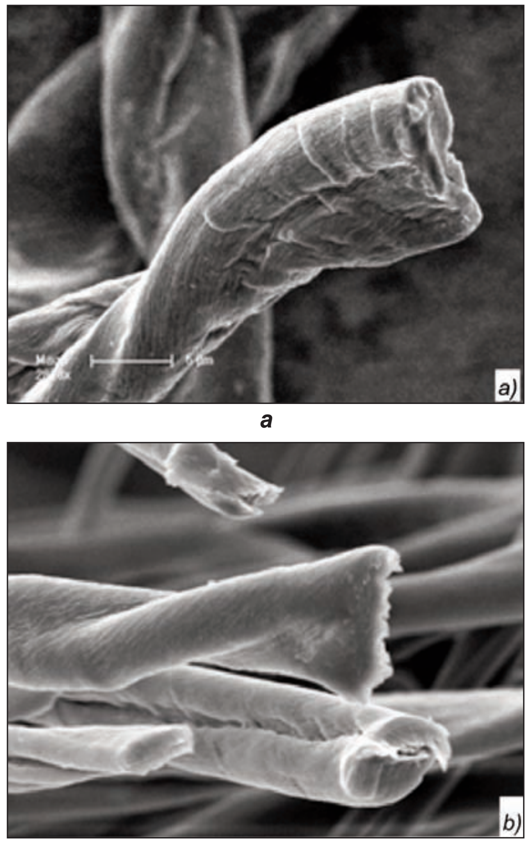
RESULTS AND DISCUSSION

Comparison of virgin and recycled fibers

Recycled fiber characterization seems to be crucial to steer this material valorization. The testing of fibers was always of importance to the manufacturer who desires its exploitation. For this reason, the quality of recycled fiber will be compared to that of virgin cotton fiber.

Morphological comparison

The SEM micrographs of virgin and recycled fiber are illustrated in figure 3. It can be seen that the virgin fiber present regular cut section (figure 3, *a*). On the other hand, and do to repeated constraints during treatments from spinning to finishing, recycled fiber present irregular cut section (figure 3, *b*).



a

b

Fig. 3. SEM microographs of fracture surface of: *a* – virgin cotton fiber, *b* – recycled fiber

Mechanical and physical comparison

Figure 4, *a* presents three attributes which describe the length distribution in the cotton samples: SFC (short fiber content), L(W) (Mean length) and UQL (Upper Quarter Mean Length). It seems clear that the virgin cotton has the lowest short fiber content and longer fiber distribution. On the other side, woven recycled fibers contain the highest short fiber content and lower mean length and UQL. These results can be explained by the yarn interweaving in woven wastes which need higher mechanical constraints to be frayed. Despite these mechanical constraints in waste fraying, the mechanical properties of woven recycled fiber, elongation and strength, are slightly better than recycled yarn fiber figure 4, *b*. In addition, the warp threads which run vertically through the length of the fabric, present high mechanical properties than weft threads run horizontally across the width of the cloth. It is very important to mention in this stage that this comparison does not take into account the effect of cotton origin since yarns and woven are made from the same virgin cotton blend.

Contrary to the length attributes and mechanical properties; which are relatively affected by recycling process, a set of advantages come out with physical characteristics such as: neps count, micronaire and maturity figure 4, *c* and *d*. In addition, woven and yarn recycled fibers present less neps, higher maturity and equal micronaire compared to virgin cotton (VC). These results can be explained by the fact that for yarn and woven wastes, neps and immature fibers

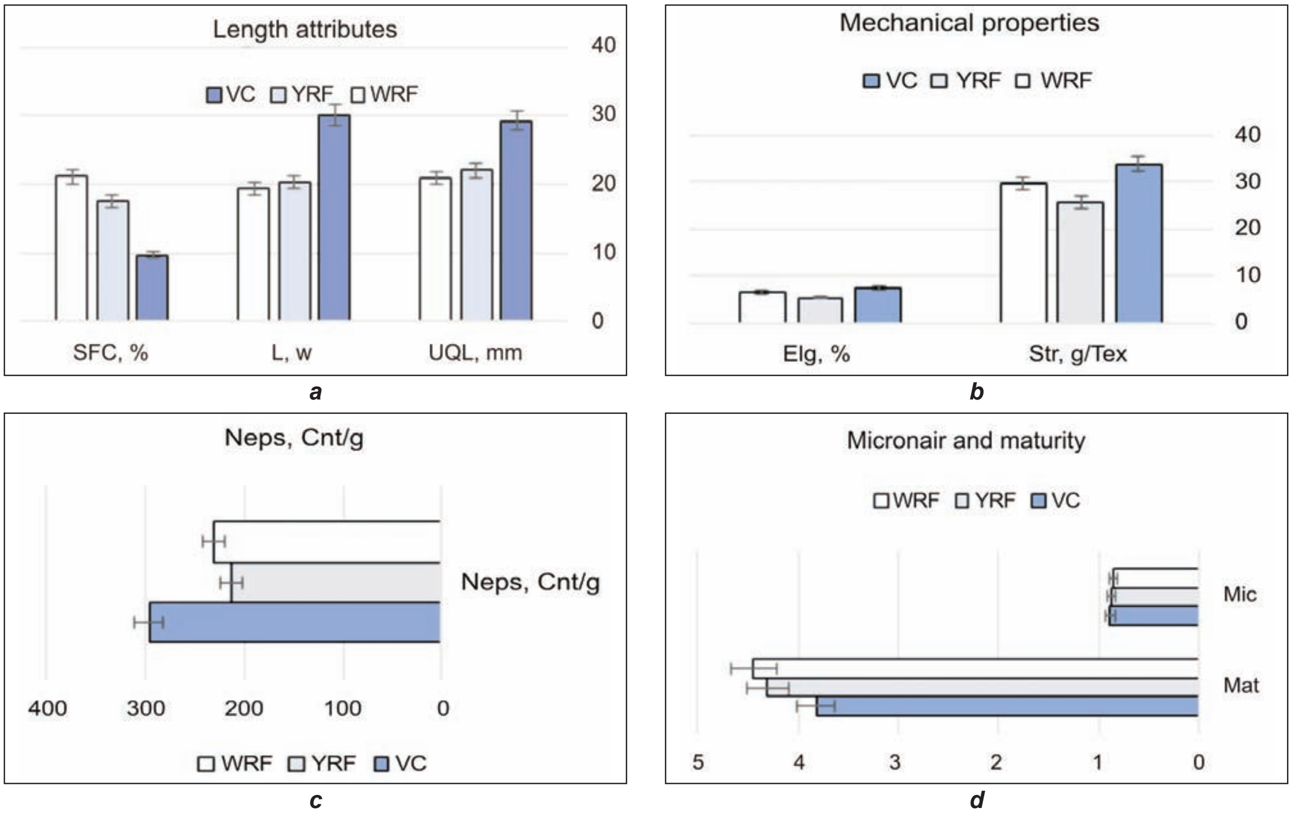


Fig. 4. *a* – Length attributes comparaison; *b* – Mechanical properties comparaison; *c* – Neps count comparaison; *d* – Micronair and maturity comparaison

are already eliminated during opening and cleaning process. Whereas, micronaire is nearly the same since we compare wastes from the same cotton origin. Current results and those from literature and technical reports [19–21], shows that these two categories of recycled fibers acquire a set of properties that enable them to be exploited in dry nonwoven manufacturing.

Nonwoven quality optimization

Nonwoven mechanical properties are very important to orientate its applications and uses. The basic aim of this part was to determine the influence of: fiber type, needle punching passage number and layer number on the area density, thickness, strength, elongation and stress.

Surface weight and thickness

The main effect plot shows that the two factors FT (fiber type) and NPN (needle punching passage number) do not have a significant effect on the surface weight and the nonwoven thickness. On the other hand, the layer number (LN) has an increasing effect on the surface weight and thickness. Indeed, it is obvious that the adding of more material generates a weight and thickness rising (figure 5). It can be concluded that the initial form of recycled materials (yarn or woven) doesn't have an effect on the physical properties of obtained nonwoven.

Strength and elongation

Figure 6, *a* illustrates clearly that the layer number is the most influential factor on the nonwoven strength,

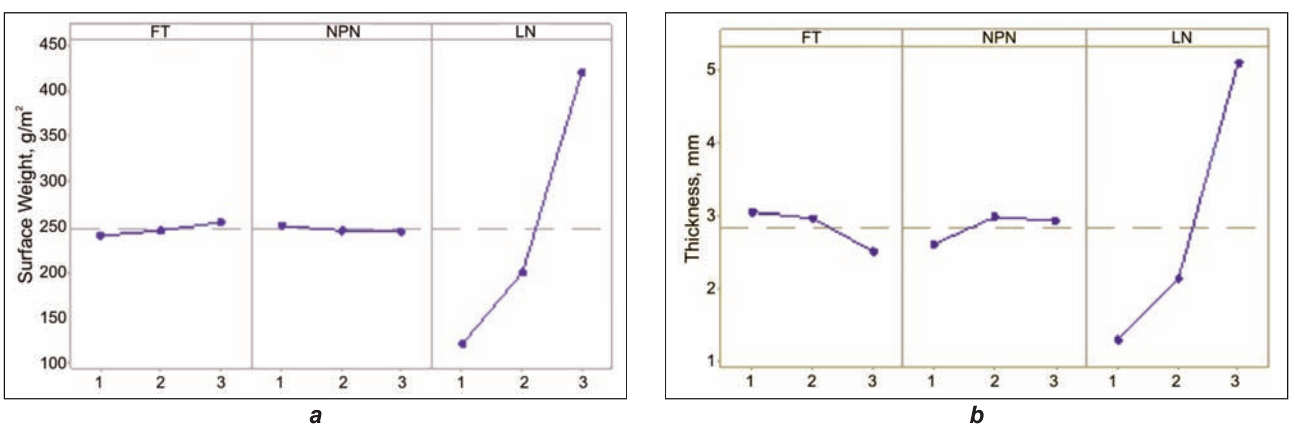


Fig. 5. *a* – Main effect plot for nonwovensurface weight; *b* – Main effect plot for nonwoven thickness

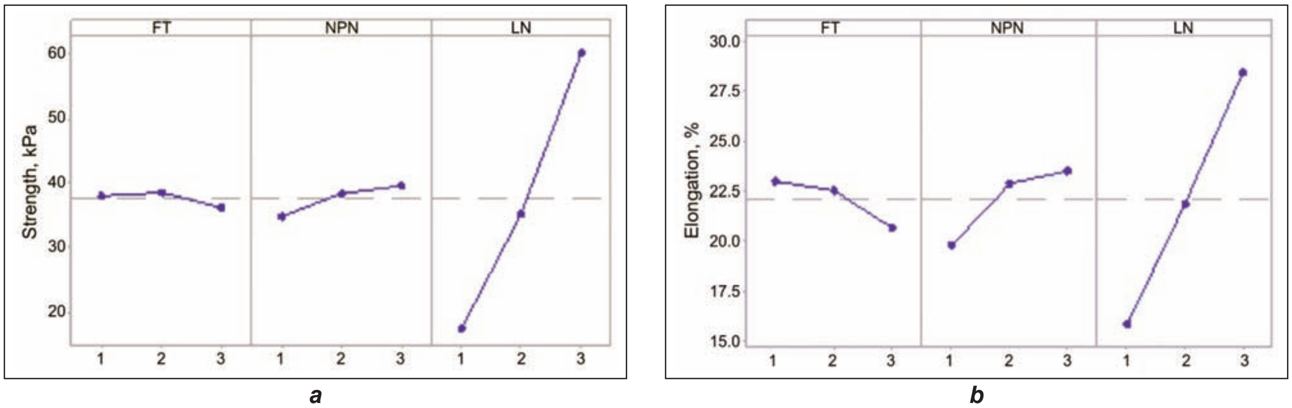


Fig. 6. *a* – Main effect plot for nonwoven strength; *b* – Main effect plot for nonwoven elongation

then we note the needle punching passage number whereas the effect of fiber type is, relatively limited. These results can be explained by the fact that with the increasing of layers gives more material to the structure and at the same time; the number of passage improve fibers overlapping with a deep penetration of barbed needles.

It can be seen in the main effect plot (figure 6, *b*) that fiber type has a negative effect on nonwoven elongation. Indeed, adding woven recycled fibers reduces-the elongation property. In addition, results can be explained by the higher short fiber content in recycled woven that can be slipped inside the structure during breaking. Before being needle-punched, the web was formed with parallel fibers. But during this process, the vertical action of needles causes an entanglement between fibers which forms the web and its orientation becomes more random. Therefore, if the passage numbers of fiber web on the needle-punching machine increase, the orientation of fibers become more and more random. For this reason, during dynamometric test the rupture of the specimen was carried out only when the fibers become parallel (under the action of stretching).

Consequently, the nonwoven elongation increases when the passage number increase (fiber orientation more randomly). On the other hand, layer number and the needle punching passage numbers have an increasing effect on nonwoven elongation.

CONCLUSION

A quality assessment of recycled fibers obtained from two different kind of post-industrial wastes indicate that in spite of the repeated mechanical constraints; their physical and mechanical properties enable them to be exploited in dry nonwoven manufacturing.

According to the level average analyses, nonwoven strength, elongation is significantly affected by number of layer and needle punching passage number. Results indicate that needle punching passage number and the layer number are more influent on recycled fiber nonwoven properties then recycled fiber type.

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Design of high mechanical and thermal resistant composites using marine plant waste

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REZUMAT – ABSTRACT

Proiectarea compozitelor cu rezistență mecanică și termică ridicată

Au fost investigate proprietățile mecanice și termice ale unei structuri compozite fabricate din matrice de polipropilenă ranforsată cu fibre de deșeuri marine, Posidonia oceanica. Am demonstrat că această fibră disponibilă în mare parte pe coasta mediteraneană prezintă multe avantaje în comparație cu alte fibre naturale utilizate în mod convențional ca armătură. De fapt, fibra Posidonia este extrasă cu ușurință numai prin acțiune mecanică. În plus, aceasta îmbunătățește proprietățile mecanice ale întregului compozit, fără a fi nevoie de compatibilizatori datorită hidrofobiei sale. În cele din urmă, în afară de performanțele mecanice, s-a demonstrat că încorporarea fibrei cu un raport ridicat nu-și degradează proprietățile termice care sunt o specificitate a fibrelor rezistente termic, care ar putea avea ca rezultat producerea unei game variate de aplicații.

Cuvinte-cheie: compozite, fibra Posidonia, performanțe termice și mecanice, tratament pe bază de silan

Design of high mechanical and thermal resistant composites using marine plant waste

We investigate the mechanical and thermal properties of a composite structure manufactured from polypropylene matrix reinforced with marine waste fibers, Posidonia oceanica. We show that this fiber largely available on Mediterranean coasts presents many advantages compared to other natural fibers conventionally used as reinforcement. In fact, Posidonia fiber is extracted easily with only mechanical action. Moreover, it enhances the mechanical properties of the whole composite without any need of compatibilizers due to its hydrophobicity. Finally, apart from the mechanical performances, we demonstrate that the incorporation of the fiber with high ratio does not degrade its thermal properties which are a specificity of thermally resistant fibers that could open a wide range of applications.

Keywords: composites, Posidonia fiber, thermal and mechanical performances, silane treatment

INTRODUCTION

The use of natural cellulosic fibers as reinforcements in composite materials has increased thanks to the benefits of these fibers such as ecological aspects, low cost, light weight and high specific modulus [1]. Moreover, compared to high performance fibers such as glass and carbon ones, natural cellulosic fibers present no health risks for manufacture employees or end users. Markets associated to these composites are touching a wide range of applications in many industrial fields like transport and buildings. The thermoplastic polymeric matrices are preferred to thermosets due to their low production cycle and lower costs of processing. Several natural fibers such as hemp, jute and flax have been studied as a reinforcement and filler in thermoplastic polypropylene (PP) matrix to prepare composites [2]. Those studies were performed to investigate and improve the mechanical and thermal performances such as tensile strength, impact strength, young's modulus, thermal stability, etc. Researchers have shown that the compatibility between matrix and fillers is crucial parameter to obtain a low cost with high performances composites as it avoids chemical compatibilization. In this work, we use Mediterranean Posidonia (*Posidonia oceanica*) fibers as filler. That is a marine plant which loses leaves in autumn, and its waste deposits can be found mainly along sandy coasts, forming wedge structures, from a few centimeters to several meters thick, denominated "aegagropiles" [3]. These sea wastes are not appreciated by the swimmers because of their bad smell emitted gazes and the pollution caused to beaches. Furthermore, the government incurs significant financial losses to remove that dirt and these wastes are burned or re-immersed in the sea [4]. The valorisation of this available, low price and renewable biomass for the production of environmentally friendly industrial products is an important economic and ecological challenge [5]. Some researches were conducted to explore the use of Posidonia fiber, as a low cost and renewable adsorbent for removing dyes, or as fiber production of cellulosic derivatives [6–7]. Other research works studied the performances of Posidonia fibers as reinforcement for composite materials [8]. They focused on the effects of adding Posidonia fiber on the mechanical and thermal properties of the obtained material using twin screw extruders which damage the fiber structure. In the present work, we propose to study the influence of chemical treatment of fibre on thermal and mechanical properties of a composite manufactured from polypropylene (PP) matrix and Posidonia oceanica waste fibers reinforcement. The ecological aspect associated to this fiber does not come only from the valorisation of this natural resource, but also from the ecological extraction method of the fiber itself based on one step mechanical process. Single screw extruder is used to avoid excessive damage of fibers structure.

MATERIALS AND METHODS

Fibers extraction and composite preparation

The balls of Posidonia were harvested from the coasts of Tunisia. They were manually frayed and placed on a horizontal opener. The balls opened manually are driven by a rolling lurking and then they are engaged in a threshing cylinder. Subsequently, they are driven by means of a toothed roller in order to separate fibers. By centrifugal force and aspiration, fibers are driven upwardly and the waste falls down. The fiber obtained after this mechanical treatment will be considered as raw fibers. To apply chemical treatment, Posidonia fibers were soaked in aqueous solution containing 1% by weight of silane coupling agent (aminosilane) and initiator 0.05%, which converts the alkoxysilane groups to silanol. The pH was adjusted to 3.5 with acetic acid in order to prevent polymerization of silane into polysiloxane. After continuous stirring of the whole mixture for 10 minutes, the fibers were immersed in the solution and the mixture was stirred for one hour. The fibers were subsequently dried in an oven at 60 °C for 24 hours [9].

To prepare the composite structures, the thermoplastic polymer used as matrix is homopolymer polypropylene (PP). It was in the form of pellets of 3 to 4 mm in diameter. The treated and non treated fibers were crushed using a crusher RETSCH SK100. After grinding, we carried out a sifting with a sieve of 200 microns and therefore the length of the fibers used for extrusion is between 200 μm and 2 mm. The maximum proportion used in fiber was 30%. Beyond this ratio, extrusion was impossible. Then, mixtures of two mass proportions (20 % and 30 %) were prepared by weighing. The fibers are conditioned at a temperature of 105 °C before preparing such mixtures. The above mixtures will feed a single screw extruder. The screw is divided to three temperature regions of 190 °C, 200 °C and 210 °C. To mold our samples, we used thermo-compression. It consists of two parallel plates with controlled temperatures which could be separated in controlled distance allowing inserting a mold. The mold used in this study is a brass one leading to composite plate of 120 × 120 mm^2 with a thickness of 4 mm. Then, the molding of the composites is carried out as follow: Once the mold has been filled with composite extracted from the extruder, it is placed on the lower plate of the heating press and receives its cover. The upper plate is then slowly lowered until closed and maintained under pressure for 30 seconds. Then, the mold is removed from the press and then cooled by means of a cooling system maintained at the temperature of fresh water. Once the mold is cooled, disassembly and extraction of the composite specimen is carried out.

Mechanical analysis of composites

The tensile test of the specimen were determined using universal testing machine (Instron), according to ISO 527, with a traveling speed of 0,8 mm/min and a cell of 30 kN. The distance between clamps for traction is fixed to 60 mm.

Thermal analysis of fiber and composites

A thermobalance SETARAM SETSYS TG12 was used to study the thermal stability (TGA) of the composite and its components. Samples (m ≈ 70 mg) are placed in a nacelle, and were subjected to a temperature scan from 20 to 700 °C with a rate of 10 °C/min under nitrogen flow (55 ml / min). A combustion step is necessary between two analyzes to remove residual particles in the device. The derivative of TGA curves (DTG) was obtained using TA analysis software.

Fourier transform infrared spectroscopy of Posidonia fibers

The FTIR spectra of raw and surface treated natural fibers were recorded in a Perkin-Elmer FT-IR spectrometer Frontier which is connected to an ATR accessory. In the ATR technique, the fiber sample is pressed against a crystal (Diamond) and the infrared beam interacts with the sample at the interface. Absorbance was measured over a range from 4000 to 400 cm^{-1}.

RESULTS AND DISCUSSIONS

Effect of fiber treatment on mechanical properties of composites

Table 1 summarizes the mechanical properties associated to the matrix and the composites reinforced with 30% of raw and treated fibers. These samples are denominated PP, Comp RPF-PP and Comp TPF-PP, respectively. It demonstrates that addition of fiber increases the Young modulus of the reinforced material and reduces its elongation at break: the plasticity zone of the material is restricted. Therefore, the rigidity of the material increases due to the interaction

Table 1

Specimen	Fiber weight ratio (%)	E (Gpa)	σ (Mpa)	ε (%)
PP	0	0.88 ± 0.03	20.34 ± 0.93	10.53 ± 0.27
Comp RPF-PP	30	1.34 ± 0.07	17.70 ± 0.66	2.84 ± 0.34
Comp TPF-PP	30	1.39 ± 0.07	19.22 ± 0.56	2.25 ± 0.14

between fibers and matrix. Many researchers have observed the same behavior for natural fibers reinforced thermoplastic matrix and have attributed the improved mechanical properties to increased dispersive interactions [10].

It can be noted also that the reinforcement of polypropylene matrix with Posidonia fibers changes the tensile properties of composite material. Indeed, whatever the nature of the fiber reinforcement (raw or treated) added to the matrix, the Young's modulus increases. Thus, the rate of increase of this mechanical parameter is about 52 % for the raw Posidonia fibers and 58 % for the fibers treated with silane (Comp TPF-PP) compared to pure polypropylene. This affirms well the trend widely illustrated in the literature: the incorporation of compatibilized reinforcements within the matrix contributes to an improvement of the mechanical response of the system [1, 5]. This enhancement could be attributed to a better dispersion of the fibers within the matrix and that was confirmed with scanning electron microscope images associated to breakage faces of composites shown on figure 1. In fact, we observe more fibers for treated sample attributed to better dispersion within the matrix. Moreover, for both composites, it is clear that slippage between matrix and reinforcements occur during tensile measurements leading to holes or to fibers coming out of the polymer. This result could be explained by the fact that the matrix and fibers adhesion is not based on chemical interaction but on physical affinity. To investigate the treated and untreated fibers surface state, they were submitted to FTIR experiments, which spectra are presented in figure 2, *a*. Both bands at 1166 cm^{-1} and 940 cm^{-1} represent respectively the Si-O-C and Si-OH connections. This proves that the hydroxyl groups of the cellulose were blocked with the silane. Then the fiber's surface becomes more hydrophobic.

This result explains the enhancement of the mechanical properties of composites reinforced with treated fibers. Thus, when the Posidonia fibers were treated with silane, physical affinity occurs leading to better interaction and sticking between matrix and fibers. Nevertheless, even the raw Posidonia fibers contribute to a large increase of the mechanical performances under tensile stress of the composite which constitutes a big advantage of the Posidonia fiber as it does not need any chemical operation neither to be extracted, nor to be dispersed within the hydrophobic matrix. This is due to the hydrophobic character associated to this natural reinforcement experimentally approved [11]. Moreover, comparison between the mechanical properties under tensile stress of polypropylene reinforced with a widely used natural fiber which is raw hemp under the same forming conditions show that Posidonia fibers lead largely to a better Young modulus. In fact, this modulus increases from 1.013 GPa for hemp [10] to 1.34 GPa for Posidonia. This could be attributed to the more hydrophobic character of Posidonia compared to hemp fibers confirmed by the lower content of humidity of 2.1 % for Posidonia fiber versus 10 % for hemp fiber [11–12].

Effect of fiber weight ratio and treatment on thermal properties of composites

Figure 2, *b* shows the thermogravimetric behavior DTG of neat polypropylene (Neat PP), raw Posidonia fiber (RPF) and polypropylene matrix reinforced with 30 % of raw Posidonia fiber (Comp RPF-PP (30%)). We observe that matrix decomposition begins at about 390 °C and continued until the maximum decomposition temperature at 453.66 °C. At this temperature, the polymer chains are degraded completely. The decomposition is totally completed over 500 °C and the residual mass is only 3.5 % of the original mass. For Posidonia fibers, there are three mass loss regions: 51–105 °C, 225–400 °C and temperature higher than 400 °C. The first region corresponds to the observed dehydration of the fiber at 105 °C. Beyond this area, and up to 225 °C, the mass varies little which shows good thermal stability. Beyond this temperature, there is a loss of mass resulting in a shoulder on the DTG curve and which is related to the decomposition of the fibers by depolymerizing hemicellulose and pectins at about 277 °C. Maximum degradation occurs at about 322.81 °C (about 130 °C lower than the matrix), which reflects the degradation of cellulose. In the case of composite with 30 % of reinforcements, the DTG curves do not correspond to what would be obtained by summing the contributions of each partial component (Posidonia and PP).

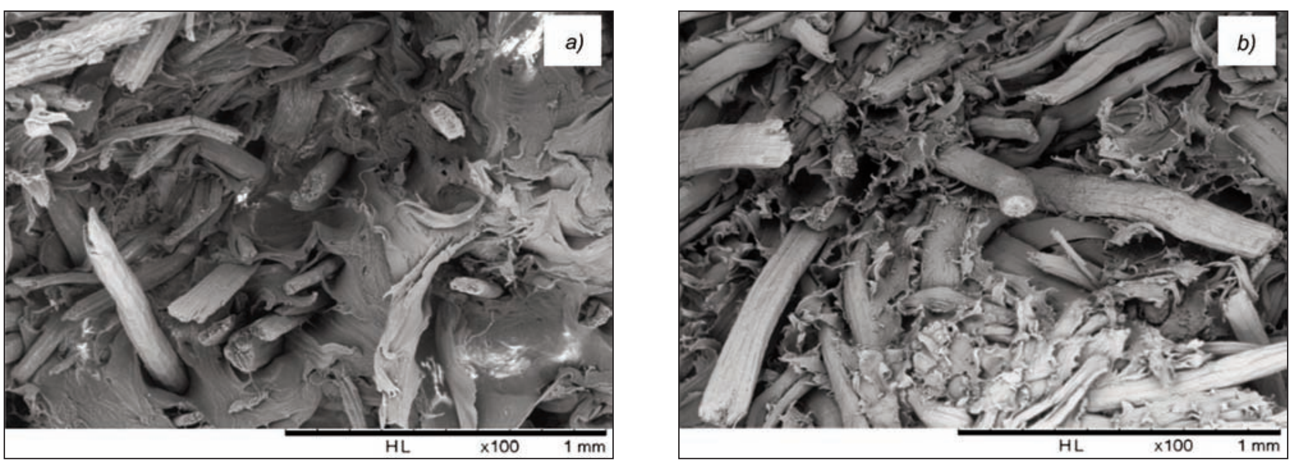
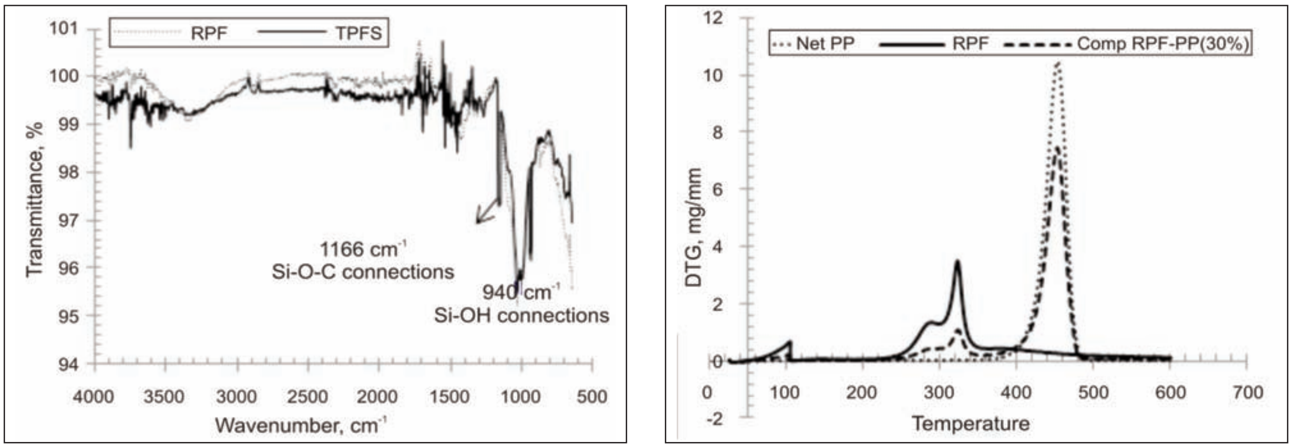


Fig. 1. SEM micrographs of fracture surfaces associated to composites with (a) raw and (b) treated Posidonia fibers



a *b*

Fig. 2. *a* – FT-IR spectra of untreated (RPF) and treated (TPF) Posidonia fibers; *b* –DTG curves for neat PP matrix, Raw Posidonia Fiber and composite reinforced with 30 % of raw Posidonia fiber (Comp RPF-PP (30 %))

In contrary, we observe a low intensity peak at T = 323.7 °C, which reflects the degradation of the fiber. This slight shift associated to the decomposition temperature of fibers suggests that the thermal stability of Posidonia oceanica inside the PP matrix is slightly increased. In fact, the matrix that has more resistance to high temperature enrobes the fibers thus having some protecting effect leading to a slight increase of the fiber degradation temperature. Also another peak of high intensity at 452.28 °C could be observed, which corresponds to the degradation of the polypropylene chains. This peak corresponds to what we observe for neat polymer. From these observations, it is clear that the incorporation of fibers do not affect the overall thermal stability of polypropylene. This characteristic of conserving the thermal stability of composites reinforced with Posidonia fibers is an asset for these natural resources in particular for thermal insulation applications. In fact, most researchers concluded that thermal stability of polypropylene reinforced with other natural fibers decreases once adding fibrous reinforcement.

Jakab et al. noted that the maximum rate of PP decomposition decreases by about 10 % when mixed with wood fibers [13]. Ragoubi et al. reported that adding 20 % of raw miscanthus fibers reduces the maximum temperature of composite degradation by 6 °C [10]. It was detected at 470 °C for reinforced composite versus 476 °C for neat PP matrix. Tajvidi and Takemura found that the overall thermal degradation of the composites obtained by adding of wood flour, kenaf fiber and rice hulls to polypropylene seemed to be an average of the thermal behavior of the component [14]. This asset associated to Posidonia comes from intrinsic properties of this fiber: the surface hydrophobicity and the chemical constitution. In fact, hydrophobicity enhances adhesion between polypropylene matrix and fibers. This physico-chemical affinity is proved to improve the thermal stability of the material [15]. In that latter work, Joseph et al. reported that the thermal stability of the sisal/PP composite was higher than that of the fibre and the neat matrix, due to better fibre–matrix adhesion after alkaline treatment. In addition, Rahmoune et al. found that soda and silane treatment improve the thermal stability thanks to the fiber structure modification after these chemical and physical treatments [16]. Moreover, the presence of phenolic groups constituting the fiber cells induces a flame retardant character to the fibers, therefore explaining improved thermal stability [17]. This is also confirmed by the important calorific power of Posidonia fiber. In fact, Ntalos G. and Sideras A. reported that Posidonia oceanica has more calorific values than the conventional biomass like bagasse, rice husks and corn cobs [18]. This important calorific value means that this biomass traps more heat which explains their important thermal properties.

CONCLUSIONS

The use of Posidonia oceanica as reinforcement of thermoplastic polymers is an interesting solution for upgrading this natural waste in beaches and entailing an elevated economical cost for local governments. Polypropylene reinforced with Posidonia oceanica could be used in multiple applications replacing wood and wood like products. Then, in this study we investigated the influence of silane treatment applied to Posidonia fibers on the tensile and thermal properties of reinforced polypropylene composites. Results prove that the young modulus of Posidonia reinforced PP was enhanced and better elastic modulus was obtained when composites were reinforced with fibers treated with silane, compared to raw fibers. Reinforcement with Posidonia oceanica fibers does not induce any degradation to the thermal stability of the matrix which constitutes a great asset relatively to conventional natural cellulosic fibers. This asset comes from intrinsic properties associated to the fiber: surface hydrophobicity and chemical constitution of the fiber containing phenolic groups. In fact, hydrophobicity enhances adhesion between polypropylene matrix and fibers that has a synergistic effect on thermal stability of the material. The presence of phenolic groups induces a flame retardant character to the fibers which improves thermal stability. This work offers environmental friendly materials for a wide range of industrial applications due to its coupling to high mechanical and thermal performances.

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Multi-functional effects of textiles dyed with madder roots powder (Rubiatinctoria)

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REZUMAT – ABSTRACT

Efectele multifuncționale ale textilelor vopsite cu extract din rădăcină de roibă (Rubiatinctoria)

În acest studiu, tricotul de 100% bumbac a fost supus tratamentului preliminar de mordansare cu tanin de mimoză și tanin de mimoză/alaun și vopsit cu un colorant extras din rădăcină de roibă. Gradul de epuizare a fost realizat prin spectroscopie UV-Vis. Rezistența culorii la lumină, spălare, frecare (umedă și uscată) și transpirația țesăturilor mordansate și vopsite au fost evaluate conform standardului ISO specific.

Probele au fost testate la protecția împotriva radiațiilor ultraviolet și activitatea antibacteriană împotriva tulpinilor de Staphylococcus aureus. Rezistența culorii la spălare și lumină sunt slabe, iar rezistența la transpirație și frecare este moderată. Țesăturile vopsite demonstrează un efect excelent de protecție UV și o bună activitate antibacteriană. Chiar și subțiri, materialele utilizate pentru hainele de vară vopsite cu roibă ar putea oferi un mijloc eficient și comun de a proteja corpul uman împotriva efectelor nocive ale radiațiilor ultraviolete.

Cuvinte-cheie: colorant natural, tanin de mimoză, alaun, protecție UV, activitateantimicrobiană

Multi-functional effects of textiles dyed with madder roots powder (Rubiatinctoria)

In this study, 100% cotton knit was premordanted with mimosa tannin and mimosa tannin/alum and dyed with a dyestuff extracted from Madder root. The degree of exhaustion was carry out by UV-Vis spectroscopy. The color fastness to light, wash, rubbing (wet and dry) and perspiration of the mordanted and dyed fabrics were evaluated according to specific ISO standard.

The samples were tested for ultraviolet protection and antibacterial activity against Staphylococcus aureus strains. The color fastness to washing and light are poor and the fastness to perspiration and rubbing is moderate. The dyed fabrics demonstrate an excellent UV protective effect and a good antibacterial activity. Even thin, the materials used for summer clothes dyed with madder could provide an effective and common mean to protect the human body against the harmful effects of UV rays.

Keywords: natural dye; mimosa tannin; alum, UV protection; antimicrobial activity

INTRODUCTION

Rubiatinctorum also called madderis one of the oldest dye used in paintings, for textiles and leather dyeing [1–2]. The extract of madder roots contains up 36 anthraquinone compounds [3]. The main 15 color components extracted from the root of Rubia Tinctoria are grouped together in the Colour Index as C. I. Natural Red 8, among which the most important ones are alizarin, purpurin, xanthopurpurin, rubiadin, pseudopurpurin, munjistin, lucidin and, the glycosidic compounds ruberythric acid and lucidinprimeveroside [4–5].

The main issues raised by the use of natural dyed textiles are the effects on human health and the environment and coloristic resistance to wearing and maintenance.

In Ayurvedic medicine, Indian madder is used as an immune regulator, blood purifying herb, antioxidant, to regulates blood pressure and blood vessel constriction, treatment of kidney and bladder stones, laxative, mild sedative [6]. Rubiatinctorum is used as antifungal [7] and antimicrobial [8] medicine and has antioxidant capacity superior to 1 m MTrolox equivalent (hydrosoluble form of vitamin E) [9].

Even former studies reported a mutagenic potential of RubiaTinctorium [10–11] due to 1,3-dihydroxyanthraquinones which bear a methyl orhydroxymethyl group on carbon-2 such as lucidin [12], new scientific researches demonstrate the lack of dye'cytotoxic activity [9].

More than that the, absorbing in UV region, the materials dyed with madder could provide an effective and common mean to protect the human body against the harmful effects of UV rays, such as premature aging and skin cancers [13–14].

Along the time different recipes were used to dye cotton with madder roots, the most renown being the Turkey red process involving 7 up to 20 stages [15]. Being a so complex process, different others synthetic and natural mordants are used to increase the fixation of the dye and to improve the light/wash fastness of the dyestuff compounds.

The aim of this research was to investigate the effect of mordants on dyeing fastness, the UV protection and antibacterial activity of cotton knit dyed with MadColor, extracted from Madder root.

MATERIALS

Textile material: chemically bleached 100% cotton knit with weight of 165 g/m^2, yarn fineness: 59.2 ± 5.2 Nm, thickness: 0.79 mm.

Dye: Mad-Color: dyestuff extract of Madder root (Rubiatinctoria); dyestuff content: 110 g/Kg; supplied by NIG Nahrungs-Ingenieurtechnik GmbH, Austria.

Mordents: alum ($KAl(SO_4)_2 \cdot 12H_2O$) from Sigma-Aldrich; mimosa tannin powder supplied by Silva Chimica (St Michele Mondovi, Italy); it contains 80–82% flavonoid monomers and oligomers (robinetinidin, fisetinidin, catechin, delphinidin), 1% of amino and imino acids, carbohydrates.

Mordanting and dyeing process: The cotton knit was pre-mordanted with mimosa tannin and alum for one hour 30–40 °C and 3 hours at ambient temperatura. The mordanted fabrics were dyed with 4% Mad Color on weight of fibre (owf) foronehour at 80 °C, maintaining the liquor ratio 1:25 and then allowed to cool down, rinsed with clean water and air-dried.

CHARACTERIZATION

UV-Vis spectroscopy (UV-VIS-NIR Perkin Elmer Lambda 950 spectrophotometer) was used to determine the maximum absorption specific of dyes and mimosa tannin and to evaluate the degree of exhaustion representing the amount of dyestuff or mordant diffused in the fibers.

The color fastness of mordanted and dyed fabrics were evaluated according to ISO standards: colour fastness to washing (ISO 105-C06:2010), alkaline and acid perspiration (ISO 105-E04:2013), rubbing (ISO 105-F09:2009) and color fastness to light (ISO 105-B02:1999).

Ultraviolet protection factor (UPF) was measured on UV-VIS spectrophotometer (Cary 50, Varian, Australia) fitted with an Diffuse Reflectance Accessoryacross the wavelength range 280 to 390 nm. Thereported values are the average of eight measurements made on sub-samples taken from the fabrics. The samples were tested for microbial activity in Staphylococcus aureus according to SR EN ISO 20645/2005. Textile fabrics – Determination of antibacterial activity – Agar diffusion plate test.

RESULTS AND DISCUSSIONS

The appearance of mordanted and dyed materials

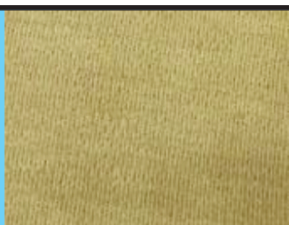
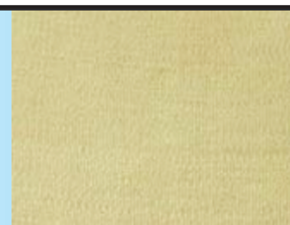
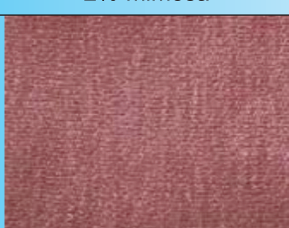
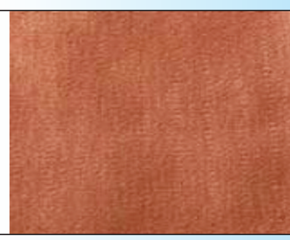
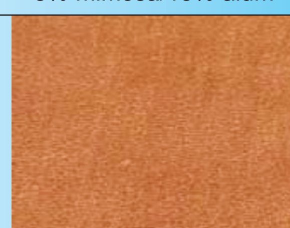
The appearance of mordanted and dyed materials are shown in the table 1.

The mimosa tannin colors the fabrics in brown-yellow, the shade becoming darker as the tannin concentration increases. The alum gives lighter shades to fabrics. The red color of the fabrics mordanted with mimosa tannin and dyed with extract from Rubia Tinctoria could be attributed to tannins, polyphenolics compounds and polysaccharide and free sugars [16]. The red-orange and orange colors of the fabrics mordanted with 2% mimosa/4% alum and respectively 8% mimosa/15% alum and dyed with Rubia are due to the arrangement of anthraquinone structures around the aluminum cation used in the pre-mordanting process. Other studies show that the yellow-orange color could be determined by the high content of heterosidic dyes such as are lucidinprimeveroside, ruberythric acid (alizarin primeveroside), galiosin (pseudopurpurinprimeveroside) and rubiadinprimeveroside [17]. The aglycones compounds (alizarin, purpurin, pseudopurpurin, lucidin, xanthopurpurin and rubiadin) induce a more orange-red color.

UV-VIS spectra of Mad-Color

The UV-VIS spectra of the 0.143 g/L Mad-Color dye is shown in the figure 1.

Table 1

			
2% mimosa	8% mimosa	2% mimosa/4% alum	8% mimosa/15% alum
			
4% Rubia/2% mimosa	4% Rubia/8% mimosa	4% Rubia/2% mimosa and 4% alum	4% Rubia/8% mimosa and 15% alum

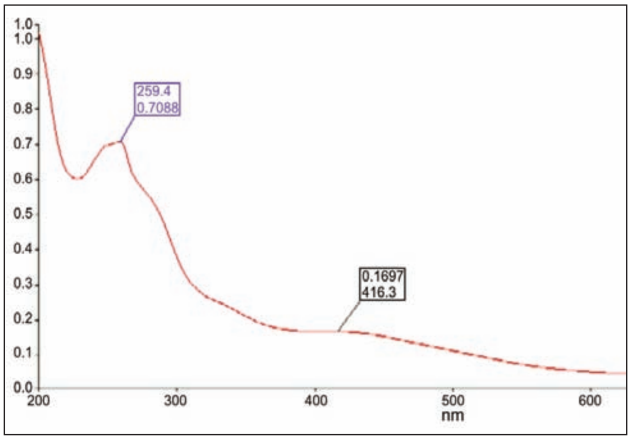


Fig. 1. UV-VIS absorption spectrum of Mad-Color

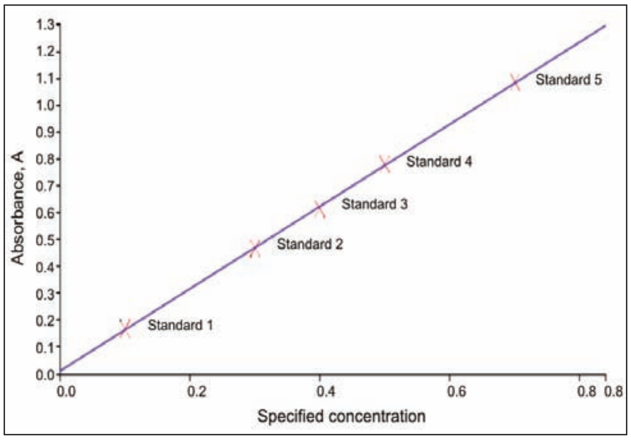


Fig. 2. Calibration curve of Mad-Color at λmax = 416 nm

Table 2

Sample	The dyebath resulting from dyeing the cotton knit mordanted with:	Initial concentration, g/L*	Final Concentration, g/L**	The dyebath exhaustion
1	8% Mimosa	0.3887	0.4359	–12.14
2	2% Mimosa	0.3988	0.4074	–2.15
3	8% Mimosa, 15% Alum	0.4243	0.5053	–19.09
4	2% Mimosa, 4% Alum	0.3607	0.5011	–38.92

* Initial concentration represents the concentration of 4% Mad-Color solution used to dye the cotton
** Final concentration represents the concentration of Mad-Color dyebath solutions after dyeing of cotton mordanted with different mordants.

The aqueous solution of Mad-Color (RubiaTinctoria extract) has two maxima absorption peaks at 259 nm and 416 nm, representing the absorption of acetophenone- and benzoquinone chromophores. The absorption at 259 nm is caused by the electron transfer bond in the benzenoid ring and one keto group and the absorption at 416 nm is due to the local excitation bond of the C=O of the quinone chromophore [18].

The anthraquinone compounds with λmax near to that found by us include ruberythric acid (406 nm), lucidinprimeveroside (415 nm) and alizarin (424 nm) [19–20].

For the Rubia dye components, other literature data [21] indicate the absorption maxima at λmax = 198, 249, 279 nm, 423 nm for alizarin, at λmax = 255, 292, 479, 485 and 512 nm for purpurine [22] 493 and 460 nm for pseudopurpurine, λmax = 224, 256, 415 nm for ruberythric acid and λmax = 200, 246, 285, 406 nm for lucidinprimeveroside. Considering this data, it is assumed that the main components of the coloring powder used could bea mixture of ruberythricacid, lucidinprimeveroside and alizarine.

During the dyeing process, the ruberythric acid and the lucidinprimeveroside are usually hydrolyzed to alizarin and lucidin. Lucidin is hardly detected in dyed textiles [23], due to its oxidation to nordamnacanthol in the presence of oxygen by endogenous enzymes [24] or its enzymatically transformation to a quinone groups [25].

Dye-bath exhaustion

Absorbance of the dyebath solutions before and after dyeing was measured at λmax = 416 nm.

For the determination of the concentration, a calibration curve was made in 5 points (0.1 g/L, 0.3 g/L, 0.4 g/L, 0.5 g/L, 0.7 g/L dye) at 416 nm (figure 2).

The percentage dye-bath exhaustion (E%) was calculated using equation 1:

$$E\% = 100 \times (1 - C_1/C_0) \qquad (1)$$

where: C_0 and C_1 represent the concentration of dye solution before and after dyeing, respectively.

The concentrations of the initial and final solutions of Mad-Color recorded at λmax = 416 nm are displayed in the table 2.

The slight variation in the initial concentration of the dye solution from 0.3607 g/L to 0.4243 g/L is determined by the large number of compounds present in the Mad-Color powder, responsible for the different shades obtained almost in the same conditions [26].

Higher final concentration values than the initial ones demonstrate that the after dyebath contains both the color components of Mad-Color and probably, mimosa tannin compounds with structures similar to the dye components that migrate from the material to the solution during dyeing.

This hypothesis is confirmed by higher concentrations of the final solutions resulting from the dyeing of the fabrics mordanted with 8% mimosa tannin than those mordanted with 2% mimosa tannin. On the other hand, a higher concentration of tannin implies a larger number of occupied active sites which are no longer available for the absorption of the dye which remains in solution.

The addition of alum does not have a positive effect on the degree of exhaustion. Certain studies [27] have shown that although aluminum has the role of fixing low molecular weight compounds (e.g., alizarine molecules) to the substrate in the case of higher molecular weight molecules such as glycosylated compounds, aluminum hindered the dyeing process. As has been shown, the basic component of Mad-Color dye is lucidinprimeveroside, a glycoside having two sugar moieties attached to the anthraquinone structure. Due to its increased steric bulk, it could limit the number of molecules that are able to arrange around the aluminum ion and, therefore lowers the exhaustion degree.

Colour fastness of knits dyed with Mad-Color

Evaluation of colour fastness of knits dyed with Mad-Color is presented in table 3.

The Indian standard requirements for minimum change in colour of natural Rubiadye on cotton fabric to washing, light and rubbing is 4–5, and to perspiration is 3 [28]. Our results demonstrate a very low fastness rating to washing, and light, regardless of the type and concentration of mordants used. The perspiration fastness is slightly better for knit mordanted with 8% mimosa and 15% alum, not because of the dye itself but because the knit is dyed with a smaller amount of dye and consequently, a less amount of dye migrates from the material in solution. Rubbing fastness, especially dry rubbing, is high.

Ultra violet radiation (UPF) protection factor assessment of materials dyed with Mad-Color

The values of the sun protection factor and of the transmissions in the UVA and UVB regions are presented in table 4.

According to Australia/New Zealand Standard AS/NZS 4399:1996, the textilescould provide a good protection if UPF is 15, 20, very good protection if UPF is 25, 30, 35, or excellent protection if UPF is 40, 45, 50, 50+.

Having a UPF equal to 10, the white knit doesn't provide any protection against UV rays. Instead, the same material mordanted with mimosa tannin and dyed with Mad-Color ensures an excellent UV protection no matter the type or concentration of mordants.

It has been shown that alizarin in the madder dye improves the UV protective effect of textiles due to its absorption in the UV region (λmax = 250 nm) [29].

Table 3

Fastness to: /Sample		R + 8% mimosa	R + 2% mimosa	R + 8% mimosa + 15% alum	R + 2% mimosa + 4% alum
Washing	color change	1	1	1	1
	color staining*	4/4-5/4/4-5/4-5/4	3-4/4-5/3-4/4-5/4-5/3-4	3-4/4-5/3-4/4/4-5/4	4/4-5/4/4-5/4-5/4
Acidic-perspiration	color change	1-2	2	2-3	2
	color staining*	2-3/2/1-2/3/2-3/2-3	2-3/2-3/1-2/3/2-3/2-3	2-3/2/2-3/3/2-3/3	2-3/2/2-3/3/2-3/3
Alkaline-perspiration	color change	2-3	3	4	3-4
	color staining*	2-3/2/1-2/3/2-3/2-3	2-3/2-3/1-2/3/2-3/2-3	2-3/2/2-3/3/2-3/3	2-3/2/2-3/3/2-3/3
Rubbing	dry	4-5	4-5	4-5	4-5
	wet	3	3-4	3	3
Light	Gray scale	3**	3***	3***	3***
	Blue scale	3	3	3	3

*Diacetate/Cotton/Polyamide/Polyester/Acryl/Wool; Exposure time: ** – 14 hours; *** – 7 hours.

Table 4

Samples	Mean UPF	Mean UVA Transmission	Mean UVB Transmission	Calculated UPF	UPF rating
undyed (white) Cotton	13.051	10.152	7.145	11.829	**10**
knitmordanted with 2% mimosa	316.134	0.234	0.278	277.242	**50+**
knitmordanted with 2% mimosa and dyed with Mad Color	216.930	0.507	0.434	153.174	**50+**
knitmordanted with 8% mimosa	179.150	0.775	0.493	150.111	**50+**
knitmordanted with 8% mimosa and dyed with Mad Color	140.793	0.947	0.636	125.532	**50+**
knitmordanted with 2% mimosa 4% alum	418.690	0.175	0.186	350.775	**50+**
knitmordanted with 2% mimosa 4% alumand dyed with Mad Color	229.963	0.402	0.406	194.800	**50+**
knitmordanted with 8% mimosa 15% alum	412.343	0.077	0.211	296.006	**50+**
knitmordanted with 8% mimosa 15% alum and dyed with Mad Color	1376.710 (1047.600)	0.244 (0.111)	0.077 (0.084)	586.236 (497.602)	**P+**

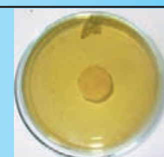
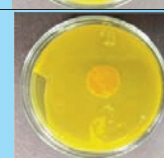
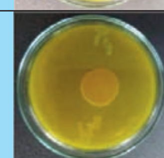
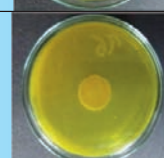
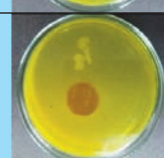
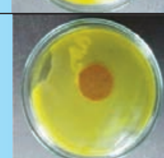
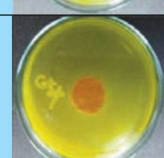
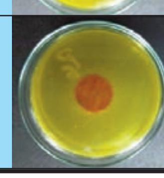
The dyeing of knit mordanted with 2% mimosa, basically leads to UVA radiation blocking (only 0.234 being transmitted) and to the penetration of a reduced amount of UVB rays (0.434) providing excellent protection for the human body.

If dyeing is done on a knit mordanted with 8% mimosa, the amount (0.947) of UVA rays penetration increases slightly compared to knitted mordanted with 2% mimosa and dyed, providing an excellent protection (UPF > 50+). The effective UV transmission trough the fabrics required by the AS/NZS 4399: 1996 standard is from 6.7 to 4.2 for a good protection, from 4.1 to 2.6 for a very good protection and less than 2.5 for an excellent protection.

If only the UV rays on UVA domain penetrating the fabrics are considered, is observed that the smallest amounts of radiation are transmitted through the fabrics mordanted with 8% mimosa and 15% alum (Mean UVA Transmission = 0.077) and through the fabric mordanted with 8% mimosa 15% alum and dyed with Mad Color 2% mimosa (Mean UVA Transmission = 0.111). If only the amount of transmitted UVB radiation

Table 5

THE MICROGRAPHS OF ANTIBACTERIAL ACTIVITY OF UNDYED AND DYED FABRICS AGAINST STAPHYLOCOCCUS AUREUS

Sample	Inhibition zone (mm)	Growth	Description	Evaluation	Picture
Control	0	Moderate	Without the inhibition zone	Insufficient effect	
Mordanted with 2% mimosa	0	Small	Without inhibition zone, some restricted colonies	Limited efficacy	
Mordanted with 8% mimosa	0	Small	Without inhibition zone, some restricted colonies	Limited efficacy	
Mordanted with 2% mimosa / 4% alum	0	Small	Without inhibition zone, some restricted colonies	Limited efficacy	
Mordanted with 8% mimosa / 15% alum	0	Small	Without inhibition zone, some restricted colonies	Limited efficacy	
Dyed with Mad Color and mordanted with 2% mimosa	0	None	Without inhibition zone, without multiplication	Satisfactory effect	
Dyed with Mad Color and mordanted with 8% mimosa	0	None	Without inhibition zone, without multiplication	Satisfactory effect	
Dyed with Mad Color and mordanted with 2% mimosa / 4% alum	0	None	Without inhibition zone, without multiplication	Satisfactory effect	
Dyed with Mad Color and mordanted with 8% mimosa / 15% alum	0	None	Without inhibition zone, without multiplication	Satisfactory effect	

is taken into account, the smallest values of the mean UVB transmission and consequently, the best protection against UVB radiationare obtained for knitted fabrics with Mad Color, previously mordanted with 8% mimosa, 15% alum and for the knitmordanted with 2% mimosa and 4% alum.

Antibacterial activity evaluation

SR EN ISO 20645/2005 standard (Determination of antibacterial activity-agar diffusion plate test): the manitolsalt Aagar gel is prepared for the lower layer without bacteria. (10 ± 0,1) mL gel is placed into each sterilized Petri dish and allow gel to solidify. Another amount of gel is prepared for the upper layer and cooled to 45 °C in a water bath. 150 ml of gel is inoculated with 1 mL of *Staphylococcus aureus* bacterial working solution (1–5 × 10^8 µg/mL). The container is vigorously stirred for the uniform distribution of bacteria. (5 ± 0,1) mL are introduced in each Petri plates and allow the gel to solidify. The textile specimens (2 cm diameter) are placed on the surface of the nutrient medium and then incubated at 37°C for 18 h – 24 h. The antibacterial evaluation is based on the absence or presence of bacterial multiplication in the contact area between the agar and the test specimen and on the occurrence of a possible inhibition area around the specimens. Inhibition zones were calculated using the following formula: $H = (D - d)/2$, where: H is the inhibition zone in mm; D – the total diameter of specimen and inhibition zone in mm; d – the diameter of specimen in mm.
Table 5 shows the micrographs of antibacterial activity of undyed and dyed fabrics against *Staphylococcus aureus*.
Hier the data about methodic that you have used for antibacterial activity determining must be described.
According to EN ISO 20645:2004 standard, the treatment is considered effective if the inhibition zone is ≥ 1–0 mm and no growth under specimen is detected, whereas 0 mm inhibition zone and slight growth is evaluated as limited effect and without colonies multiplication is evaluated as satisfactory effect.
The inhibition zone is zero mm for all the tested samples. The untreated cotton knit doesn't have any antibacterial activity. The efficacy of the fabrics mordanted with mimosa tannin and mimosa tannin/alum is limited, a small growth of bacteria colonies is observed on the materials. The dyed fabrics have a "satisfactory effect" as long as any bacterial growth is detected on their surface. Different studies [8] reported the antibacterial activity of the madder dye, the responsible compounds for this effect being considered alizarin, purpurin and quinizarin [30–32] wich affect the bacterial cell wall. Due to their redox potential, these molecules form complexes with amino acids, inhibiting the synthesis of proteins and the bacterial growth [33].

CONCLUSIONS

Knit cotton fabric was premordanted with mimosa tannin and mimosa/alum and then dyed with Mad Color powder extracted from Rubia Tinctoria. Being a complex mixture, it is very difficult to identify the exact components responsible for dyeing of textiles, the UV-Vis spectra suggesting as main components ruberythricacid, lucidinprimeveroside and alizarine.
The exhaustion degree, spectrophotometrically evaluated, has demonstrated the presence of dye and mimosa tannin in the after dye bath. Colour fastness to washing and light is poor while the fastness to perspiration and rubbing is moderate. The mordanted and dyed knitted fabrics highly improve the UV protection ability by lowering the penetration of UV rays through the materials. Moreover, the dyed fabrics inhibit the bacterial growth, probably due to presence of madder specific molecules on the material surface of the fiber.

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Analysis of thermal properties, water vapor resistance and radiant heat transmission through different combinations of firefighter protective clothing

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REZUMAT – ABSTRACT

Analiza proprietăților termice, rezistența la vapori de apă și transmisia căldurii radiante prin diferite combinații de îmbrăcăminte de protecție pentru pompieri

Această lucrare experimentală este un efort de a identifica posibilitatea îmbunătățirii performanței de protecție termică a îmbrăcămintei de protecție pentru pompieri la diferite niveluri de densitate a fluxului de căldură. Îmbunătățirea performanțelor de protecție termică înseamnă îmbunătățirea timpului de expunere la fluxul de căldură, ceea ce va oferi un timp suplimentar pompierilor pentru a-și îndeplini sarcinile, fără să sufere leziuni grave. Au fost investigate patru combinații multistrat diferite de îmbrăcăminte de protecție pentru pompieri. Fiecare combinație constă dintr-o carcasă exterioară, barieră împotriva umidității și căptușeală termică. De asemenea, a fost utilizată foaie de aerogel ca înlocuitor al barierei termice. Inițial, s-au investigat proprietăți cum ar fi rezistența termică, conductivitatea termică și rezistența la vapori de apă ale ansamblurilor de țesături multistrat. Ulterior, aceste combinații au fost expuse unor niveluri diferite de densitate a fluxului de căldură radiantă, de exemplu la 10, 20 și 30 kW/m^2 conform standardului ISO 6942. S-a observat că acele combinații în care pătura de aerogel a fost utilizată ca barieră termică dobândesc o rezistență termică mai mare, rezistență la vapori de apă și valori mai reduse ale densității fluxului de căldură transmisă.

Cuvinte-cheie: îmbrăcăminte de protecție pentru pompieri, rezistență termică, performanța de protecție termică, densitatea fluxului de căldură

Analysis of thermal properties, water vapor resistance and radiant heat transmission through different combinations of firefighter protective clothing

This experimental work is an effort to seek the possibility of improvement in thermal protective performance of firefighter protective clothing at different levels of heat flux density. Improvement in thermal protective performance means enhancement in the time of exposure against the heat flux, which will provide extra time to firefighters to perform their duties without suffering from severe injuries. Four different multilayer combinations of firefighter protective clothing were investigated. Each combination consists of outer shell, moisture barrier and thermal liner. Aerogel sheet was also employed as a substitute to thermal barrier. Initially, properties like thermal resistance, thermal conductivity, and water vapor resistance of multilayer fabric assemblies were investigated. Later on these combinations were exposed to different levels of radiant heat flux density i.e. at 10, 20 and 30 kW/m^2 as per ISO 6942 standard. It was noted that those combinations in which aerogel blanket was used as thermal barrier acquire greater thermal resistance, water vapor resistance and have less transmitted heat flux density values.

Keywords: firefighter protective clothing, thermal resistance, thermal protective performance, heat flux density

INTRODUCTION

Firefighter protective clothing is multi-layer garment which secures the firefighter from threats like external radiant heat flux, chemical spillage, flame and delivers thermal equilibrium to human body [1]. Firefighter protective clothing comprises of exterior shell, moisture barrier and thermal barrier [1–3]. The exterior shell comprises of those substrates which are developed to have contact with flame and heat without degenerating or burning i.e. they prevent ignition when have direct contact with flame and must have property of water repellence and good thermal insulation. Mostly fibers like meta-aramids (Nomex), combination of meta-aramid and paramid (Nomex III A), polybenzimidazole (PBI), Zylon and some fibers with flame resistant finishes like Proban and Pyrovatex are utilized in outer layers. The moisture barrier is located between exterior layer and thermal barrier. This layer is impermeable to water but permeable to water vapors. Its primary objective is to shield the body of firefighters from blood pathogens and liquefied chemicals. Moisture barrier is micrporous membrane available in the market as Goretex, Proline, Cross tech, Action, Neo Guard. The thermal barrier protects human body by blocking the environmental heat and utilizes flame retardant fibers and their blends. It can be nonwoven, quilted batting, laminated woven, lining fabric and knitted fabric and spun laced [3–6]. In terms of protective performance of firefighters, time is the main factor. Enhancement in thermal protection increases the time period for firefighter to carry out their activities without any significant injuries. As a result, firefighters can spend more time in hazardous environment saving precious lives and damages caused by fire without injuring themselves [7–9]. Thermal protective performance is influenced by several factors like thermal conductivity, water vapor resistance and impact of air gaps [7]. Thermal protective performance is evaluated by several tests like bench scale test (Heat guard plate, TPP tester) [10–14] or full scale test methodology like thermal manikin [15–16]. Several scientific investigations inculcating numerical models and experimental studies were performed under different levels of radiant heat exposure to study thermal protective performance of firefighter protective clothing. These studies employ test methodologies from bench scale testing to full scale manikin to evaluate the thermal protective behavior of clothing under various levels of radiant heat exposure [17].

For enhancing the thermal protection of firefighters, the utility of silica based aerogel or aerogel blankets in firefighter protective clothing is the focus of attraction for many researchers. It is a light weight porous substrate synthesized from gel by substituting liquid phase with gaseous phase [18–19]. There are several different types of aerogels. Among all of them, silica based aerogels have very interesting properties because of their inflammable nature and lower thermal conductivity than air in same conditions [20]. Silica based aerogel is hydrophobic substrate having porosity greater than 90% and specific surface area of nearly 1000 m^2/g. The thermal conductivity of silica based aerogel is approximately 0.015 W/mK [21–22]. All of these characteristics make silica based aerogels a favorable candidate for utility in firefighter protective clothing as thermal barrier. Silica based aerogels are available on commercial basis as Nanongel particles by Cabot corporation and as pyrogel blankets by Aspen aerogel [23]. Pyrogel 2250 is flexible blanket consisting of trimethylsilylated silica gel and oxidized polyacrylonitrile fiber (OPAN) [24]. Oxidized polyacrylonitrile fiber has outstanding insulation properties and very high Limiting Oxygen Index (LOI) [25].

The main aim of this research is to enhance thermal protective performance of firefighter protective clothing. For this purpose four combinations of high performance fabrics were made. Each corresponding combinations were characterized by Alambeta and Permetest. Afterwards, these combinations were evaluated by X637 B machine (ISO 6942 standard) for determining transmission of heat through multilayer protective clothing assemblies at 10 kW/m^2, 20 kW/m^2 and 30 kW/m^2 to evaluate the thermal protective performance in terms of transmitted flux density Q_c and % age transmission factor.

EXPERIMENTATION

Materials and methodology

All fabric layers utilized in firefighter protective clothing for this experimentation were supplied by Kivanc group Turkey and Vochoc Company Czech republic. Aerogel blanket (Pyrogel 2250) was supplied by Ayvaz Yalitim Company from Turkey. This layer was used as substitute layer to thermal barrier. Two different outer shells, one moisture barrier and one thermal liner were employed. Four different combinations of clothing assemblies were prepared (table 1 and table 2).

Thermal conductivity and thermal resistance

Evaluation of thermal resistance, thermal conductivity and thickness of monolayer and multilayer protective clothing arrangement was done with the help of Alambeta (non-destructive method), a patent of Prof. Lubos Hes [27] manufactured by Sensora company is a computer controlled device measuring thermal

Table 1

Layer	Fabric code	Component	Weave type	Fabric weight (g/m^2)	Thickness (mm)
Outer layer 1	O(1)	% 75 Metaaramid-23% Paraaramid-%2 Antistatic	Twill	202	0.488
Outer layer 2	O(2)	Proban (100 % cotton)	Twill	300	0.864
Moisture barrier	M	PU membrane laminated to nonwoven	Nonwoven	128	0.94
Thermal liner	T	50/25/25 Aramid/Viscose/FR icastar	Needlepunching nonwoven	400	3.424
Aerogel blanket (Pyrogel 2250)	P	Silica aerogel with reinforced polymers	Nonwoven	400	2.78

Table 2

Sr #	Fabric arrangement in multilayer clothing assembly	Fabric code	Thickness (mm)	GSM (g/m^2)
1	Outer shell (1) + Moisture barrier + Thermal liner	A	5.202	730
2	Outer shell (2) + Moisture barrier + Thermal liner	B	5.362	828
3	Outer shell (1) + Moisture Barrier + Aerogel sheet	C	4.638	730
4	Outer shell (2) + Moisture Barrier + Aerogel sheet	D	4.776	828

characteristics of monolayer and multilayer protective layers as per EN 31092 standard [26–27]. Five measurements were taken for each sample.

Relative water vapor permeability (RWVP %age) and water vapor resistance (R_{et})

Water vapor resistance R_{et} (m^2Pa/W) and relative water vapor permeability (RWVP% age) under steady state conditions was evaluated by PERMETEST (non-destructive method) which is also patent of Prof. Lubos Hes and was developed by Sensora company as per ISO 11092 standard [28]. The higher the value of relative water vapor permeability, the lesser will be the water vapor resistance and there will be better thermal comfort [29]. Five measurements were taken for each specimen.

The radiant heat testing equipment

The radiant heat testing equipment X637 B Protective clothing was used to measure radiant heat transmission through material or material assembly according to ISO 6942 standard. This equipment consists of small curved copper plate calorimeter with area of (50 mm × 50.3 mm) with mass of 35.9 to 36 grams. A radiation heat source consisting of six carbide heating rods along with moveable test frame having cooling device and specimen holders is shown in figure 1. The size of the sample was 230 mm × 80 mm which is placed on the face side of calorimeter and subjected to a specific level of radiant heat and time for temperature escalation of 12°C and 24°C (RHTI12 and RHTI24) in the calorimeter was noted and outcomes are articulated as radiant heat transmission index and the % age heat transmission factor [30]. Five specimens are required for testing at each level of heat flux density.

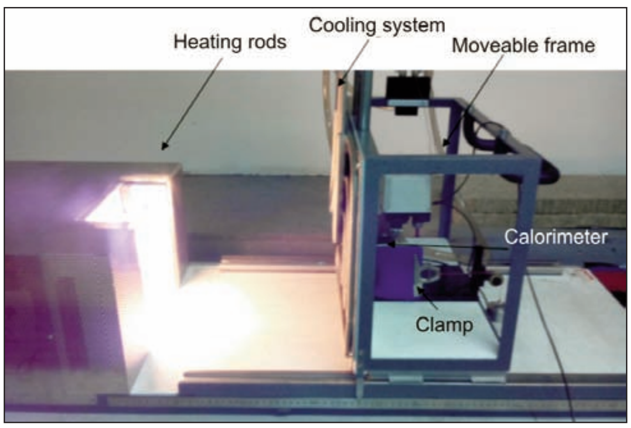

Fig. 1. Radiation heat testing equipment

RESULTS AND DISCUSSION

Evaluation of thermal conductivity and thermal resistance

Thermal conductivity, thermal resistance and thickness were evaluated by Alambeta for monolayer and multilayer protective fabric assemblies and their corresponding values were mentioned in figure 2 respectively. Thermal resistance, R_{th}, of textile substrate is a function of the actual thickness of the textile fabric and its thermal conductivity. This relationship is given by following equation:

$$R_{th} = \frac{h}{\lambda} \quad (1)$$

R_{th} is thermal resistance (m^2K/W), h – thickness of textile substrate. This thermal resistance is inversely proportional to thermal conductivity. Thermal conductivity and thermal resistance are not only contingent on thickness of the fabric assemblies and but also on physical and chemical properties of textile substrate. Greater the thickness, greater will be the thermal resistance of the material. However, this is not only the whole scenario, the porosity and density of the textile substrate also plays a vital role in thermal behavior of the medium. Textile substrate with closed and small pores is able to trap air inside the substrate. The illustration of this phenomenon is the due to fact that air has a lower thermal conductivity than materials constituting the sample [31]. On the other hand, thermal conductivity enhances with the relative humidity absorbed by the material [32]. Consequently, the thermal conductivity of highly hygroscopic material is more as compared to less hygroscopic substrate. From figure 2, it can be noted that a high value of thermal resistance was witnessed in arrangement of multilayer protective clothing having aerogel layer as an alternate to thermal liner (sample C and D). There might be several reasons. One reason might be that this substitute layer encloses silica based aerogel which has very less thermal conductivity even lower than still air. Because of porosity and nanometer pore size, silica based aerogels are highly insulating materials [30].

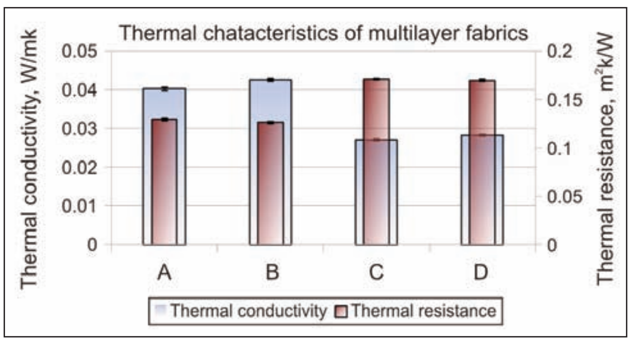

Fig. 2. Thermal conductivity and thermal resistance values of multilayer protective clothing

By means of mass, Aerogel is 96% of air making it least dense man-made substrate [30]. Because of gaseous structure of aerogel and low thermal conductivity of gas, there might be blockage of conductive heat transfer [34]. The porous architecture of aerogel is responsible for gaseous structure of aerogel [35–36]. In addition to that, convective heat transfer is deterred because construction of aerogel does not allow circulation of air [34]. The other reason is that this aerogel blanket also contains oxidized polyacrylonitrile (OPAN) fiber which has very low thermal conductivity (0.030 W/mK) and very high limiting oxygen Index (LOI) i.e. almost 45% which is greater than LOI of meta aramid, para aramids and PBI. Moreover it has outstanding flame resistant properties as compared to the high performance fibers [24] which ultimately results in high thermal resistance in monolayer and multilayer fabric assemblies. Consequently, specimen C and D which employ aerogel layer as an alternate to thermal barrier offers more thermal resistance as compared to specimen A and B. On the other hand, thermal resistance of specimen A was slightly greater than specimen B. This might be due to the fact that specimen A has outer shell O(1) containing 75 % and 23 % of meta aramid and para aramid fibers respectively which have inherent flame retardant and better insulation characteristics as compared to specimen B in which the main ingredient of outer layer is cellulosic material (cotton) which offers more thermal conductivity and less thermal resistance as compared to outer layer of specimen A [36].

Evaluation of water vapor resistance

Water vapor resistance was determined by PERMETEST apparatus which gives two values i.e. relative water vapor permeability (RWVP%) and water vapor resistance (R_{et}). Barker et al mentioned that the influence of moisture on thermal protective performance is a function of exposure conditions, amount of moisture in the turnout system and its permeability and insulation properties [37]. A careful analysis of figure 3 revealed that more water vapor resistance was witnessed in specimen C and D utilizing aerogel blanket. This might be due to hydrophobic nature of aerogel and presence of closed pores inside the structure of aerogel blanket. However, still there was some water vapor permeability in specimen C and D which might be due to the high absorbing capabilities of aerogel, enabling the aerogel blanket (pyrogel 2250 sheet) to absorb moisture due to wetting and transport it to environment, especially when it was placed next to skin despite of the fact that aerogel has very low air permeability [38–43]. It was also witnessed by Xiamong et al. that there was no significant relationship between air permeability and water vapor permeability in case of multilayer assemblies having aerogel particles sprayed between the layers [43]. As the percentage of aerogel increases more amount of water vapor permeability was witnessed and less permeability of air was observed.

It might be noticed that low water vapor resistance can sometimes create problem if exterior pressure is high as compared to interior pressure inside clothing allowing the moisture to breach inside the garments instead of evacuating it out of the garment.

The type of fibers plays a key role in moisture vapor permeability. An examination of figure 3 reveals that specimen having meta-aramid as outer shell offer slightly more water vapor resistance R_{et} as compared to combinations having probanas outer shells. This might be due to fact that Meta aramid has less moisture regain but greater wicking ability as compared to proban which have cellulosic content. Consequently,

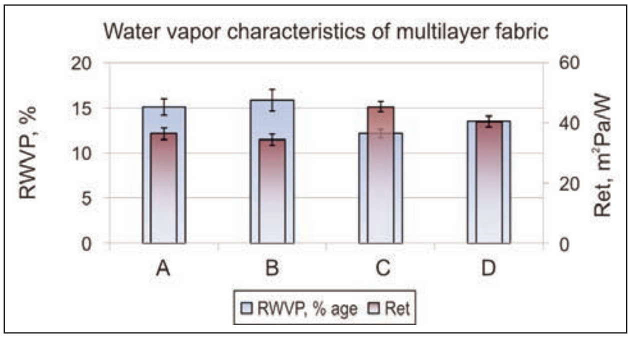

Fig. 3. Water vapor resistance and relative water vapor permeability %age of multilayer protective clothing

specimen having meta-aramid as outer shell has higher R_{et} values [38].

Transmission of radiant heat flux through multilayer protective clothing

This apparatus comprises of a radiation heat source which can generate heat flux density up to 80 kW/m^2 along with calorimeter which evaluates heat flux. The outcomes of this test are the two threshold times i.e. Radiant heat transfer index (*RHTI* 24 and *RHTI* 12) respectively, incident heat flux density (Q_o) and transmitted heat flux density (Q_c) and percentage heat transmission factor (%age *TF*) (table 3).

RHTI 12 = Threshold time in (sec) when temperature of calorimeter increase in 12°C.

RHTI 24 = Threshold time in (sec) when temperature of calorimeter increase in 24°C

$$Q_o = \frac{C_p RM}{a.A} \quad (2)$$

R is rate of rise of the calorimeter temperature in the linear region in °C/s; M – mass of copper plate in kg; C_p – specific heat of copper 0.385 (kJ/Kg°C); a – the absorption coefficient of the painted surface of calorimeter; A – area of the copper plate in m^2.

The transmitted flux density, Q_c in kW/m^2, is evaluated by the following equation:

$$Q_c = \frac{MC_p 12}{A.(RHTI\ 24 - RHTI\ 12)} \quad (3)$$

$\frac{12}{RHTI 24 - RHTI 12}$ is mean rate of rise of the calorimeter temperature in °C/s in the region between a 12°C and 24°C rise where *RHTI* 12 indicates time to acquire increase of (12 ± 0.1)°C rise in temperature. *RHTI* 24 means time to attain increment of (24 ± 0.2)°C.

Equation 4 delivers the percentage heat transmission factor, % age *TF* (Q_o) for incident heat flux density level.

$$\%\ age\ TF = 100 \cdot \frac{Q_c}{Q_o} \quad (4)$$

A perusal of table 3 reveals that values of transmitted heat flux density Q_c and percentage Transmission factor (%age *TF*) increases sequentially with increase in level of incident heat flux density. It was also noted

Table 3

Sr #	Name of material	*Q_o (kW/m²)	RHTI12	RHTI24	RHTI24 – RHTI12	Q_c (kW/m²)	%age TF
1	P	10	54.55 ± 2.828	102.6 ± 2.969	48.05	1.36 ± 0.006	0.136
2	A	10	58.2 ± 0.424	101.0 ±, 0.015	42.8	1.55 ± 0.014	0.155
3	B	10	74.1 ±.707	128.65 ± 2.757	54.55	1.212 ± 0.045	0.121
4	C	10	84.55 ± 0.777	163.35 ± 3.181	78.8	0.839 ± 0.026	0.083
5	D	10	97.4 ± 6.929	195 ± 2.5738	97.6	0.677 ± 0.132	0.067
1	P	20	33.25 ± 5.727	54.15 ± 8.273	20.9	3.164 ± 0.390	0.158
2	A	20	36.7 ± 0.989	57.05 ± 1.343	20.35	3.249 ± 0.056	0.162
3	B	20	46.7 ± 6.081	58.55 ± 6.293	11.85	5.580 ± 0.100	0.279
4	C	20	44.6 ± 0.457	70.8 ± 2.596	26.2	2.524 ± 0.050	0.126
5	D	20	58.15 ± 0.919	79.956 ± 1.484	21.806	3.033 ± 0.079	0.151
1	P	30	33.3 ± 0.141	48.75 ± 0.353	15.45	4.280 ± 0.058	0.142
2	A	30	27.85 ± 0.070	40.35 ± 0.494	12.5	5.290 ± 0.181	0.176
3	B	30	31.4 ± 2.121	38.15 ± 2.474	6.75	9.79 ± 0.516	0.326
4	C	30	41.5 ± 1.272	61 ± 2.969	19.5	3.391 ± 0.297	0.113
5	D	30	44.15 ± 1.626	59.8 ± 1.272	15.65	4.225 ± 0.096	0.140

* RHTI = Radiant heat transfer index.

that minimum values of transmitted flux density Q_c (kW/m²) were observed for the samples having aerogel blanket as thermal liner. A similar pattern was also noted in %age TF values for the specimen having aerogel sheet [41]. This might be due to fact that silica based aerogel blanket contains almost 96% of air and air is a good insulator blocking the amount of heat passed through the specimen. Moreover, these aerogel samples consist of oxidized polyacrylonitrile polymer which have very good thermal stability and can withstand higher amount of heat flux and has very high limiting oxygen index (LOI) of almost 45 % [40]. The lower the value of transmitted heat flux density, the lesser will be amount of heat passed through fabric assemblies towards calorimeter allowing more time to firefighter to perform their duties before acquiring burn injuries. Table 3 also depicts that greater difference between *RHTI* 24 and *RHTI* 12, lesser will be the value of transmitted flux density Q_c (kW/m²) and %age *TF* respectively, which indicates that specimen can withstand respected heat flux for longer time period allowing firefighters to perform their duties for longer duration before getting burn injuries. At 10 kW/m², the lowest values of Q_c and %age *TF* were witnessed for specimen C, D. These values were higher for specimen A and B having no aerogel blanket. It was also noted that there was minor difference in the values of Q_c and %age *TF* values for aerogel sheet, sample A and specimen B respectively. At 20 kW/m², the situation was slightly different i.e. the Q_c and %age *TF* values of specimen B is significantly higher than rest of the samples and negligible difference for the values of Q_c and %age *TF* was witnessed for

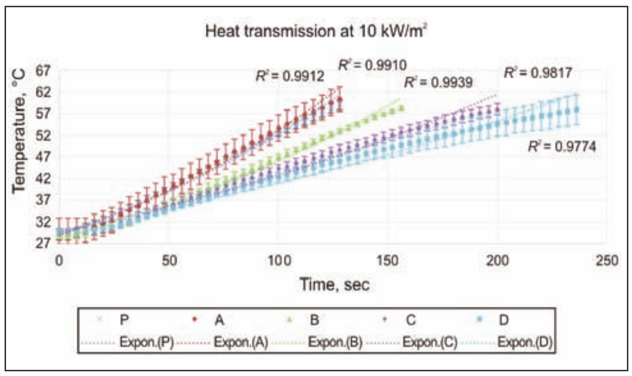

Fig. 4. Heat transmission at 10 kW/m²

aerogel sheet, specimen A and specimen D. The lowest value of %age *TF* and Q_c for 20 kW/m² was observed for specimen C. At 30 kW/m², a trend similar to that of 20 kW/m² was noted i.e. the least value of Q_c and %age *TF* was observed for sample C and highest value was observed sample B. However, this time there was significant difference in values Q_c and % age *TF* for specimen A and aerogel sheet.

A glance at figure 4 reveals that at 10 kW/m² the curve of specimen D and specimen C are much flatter as compared to the curves of specimen B, specimen A and aerogel layer (P) respectively. The flatter the curve, the slower will be rate of increase in temperature, which will give more time of exposure to specimen when subjected to radiant heat flux. The flatter curve also indicates less damage to the corresponding fabric layers of the specimen. However, there were no gaps in the curves of aerogel blanket and specimen A, which have very close values of Q_c

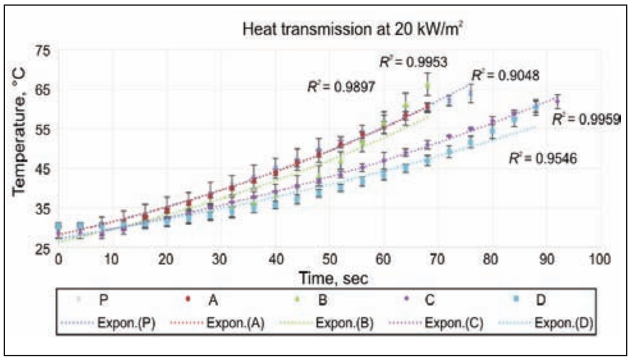

Fig. 5. Heat transmission at 20 kW/m^2

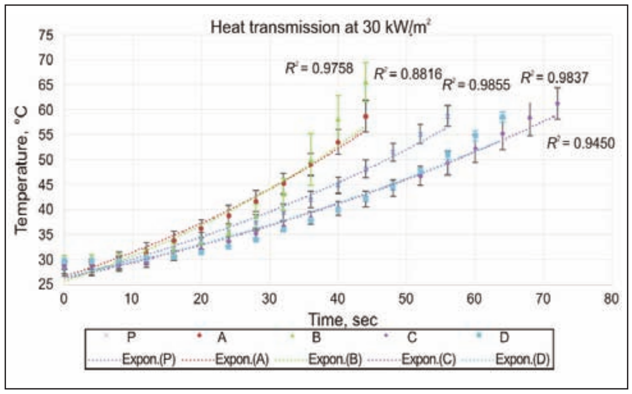

Fig. 6. Heat transmission at 30 kW/m^2

and *TF*. Figure 4 also depicts clear gap between curves of specimen B and curves of specimen A and aerogel blanket (P), which is also highlighted from the values of Q_c and % age *TF* from table 3.

From figure 5, it can be seen that at 20 kW/m^2, there was quite similarity between the curves of specimen A and aerogel sheet (P). The pattern of the curve B at 20 kW/m^2 was different than that of the curve of specimen B at 10 kW/m^2. The rate of increase of temperature was smooth till 50 sec for specimen B but after wards there was sharp increment in the rate of increase of temperature which indicates sudden damage to the corresponding layers of specimen B as the time of exposure increases. The curve of specimen C was much flat and there was no unusual variation. However, in case of specimen D, the pattern of the curve was flat till 70 sec but later on it becomes very steep indicating certain damage to layers of specimen especially the outer layer. This is also evident from values of Q_c and %age *TF* which are more than that of specimen C.

In case of 30 kW/m^2 from figure 6, there was dissimilarity in the pattern of the curves for aerogel blanket and specimen A showing that there was more damage of fibers at higher flux density as compared to aerogel blanket. But the curve of specimen B shows irregularity after 30 sec showing sudden sharp increment in the temperature, which is clear indication of decrease in thermal protective behavior of specimen due to damage of fiber which allows swift passage of heat after 30 sec causing increase in values of Q_c and %age *TF*. The curve of specimen D was short as compared to curve of specimen C. However, after 70 sec, there was irregular increase in temperature for specimen D due to which greater values of Q_c and %age *TF* are witnessed in table 3 for specimen D.

The curve of specimen C was regular, flat and long showing better thermal protective behavior of specimen C at 30 kW/m^2. Thus the fabric assembly having aerogel has better thermal protective behavior as compared to other samples. This might be due to fact that Infrared radiation that plays a significant role in transference of heat can also be absorbed by aerogel [40–42] due to which aerogel blanket offers better thermal stability and insulation as compared to other specimen.

CONCLUSION

It can be inferred that safety of firefighters is dependent on the protective performance of firefighter protective clothing. If this protective performance can increase time of exposure of firefighters against heat flux, it may result in saving precious lives and useful stuff. It was also witnessed that there was significant increase in thermal resistance and water vapor resistance when aerogel blanket was utilized as alternative layer to thermal barrier and when meta-aramid layer was utilized as outer shell. When the samples were exposed to various levels of heat flux density, it was noticed that those combinations in which meta-aramid and aerogel substrate was utilized deliver better thermal stability especially when subjected to high heat flux densities. This might be due to the nature of fibers involved in these substrates which offers better thermal stability against higher level of heat flux. However, it was also witnessed that there was overall trend of increase in transmitted heat flux density with increase of incident heat flux density. This might be due to damage incur to fibers in different layers as a result of which thermal stability is decreased at higher heat flux densities. The use of aerogel shows significant improvement for thermal protection of firefighter clothing and can be used when high range protection is required from heat.

ACKNOWLEDGMENT

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A novel approach for identification of pills based on the method of Depth from Focus

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REZUMAT – ABSTRACT

O abordare nouă pentru identificarea pilingului pe baza metodei Depth From Focus (adâncime de focalizare)

Pentru evaluarea automată a pilingului materialelor textile, informațiile despre adâncimea de focalizare reprezintă una dintre caracteristicile cele mai importante și mai eficiente în extragerea pilingului din imaginea țesăturii. Tehnicile de scanare cu laser sunt adesea folosite pentru a obține imagini 3D cu adâncime de focalizare. Cu toate acestea, din cauza costului ridicat și eficienței scăzute a sistemului de scanare cu laser, cercetatorii au descoperit că tehnica nu este adecvată pentru analiza țesăturilor. Acest studiu prezintă o nouă abordare pentru obținerea imaginii cu adâncime de focalizare folosită pentru a extrage pilingul prin introducerea metodei Depth From Focus (DF). Această abordare captează, în primul rând, o secvență de imagini cu aceeași viziune la diferite poziții de focalizare la microscopul optic automat. Poziția cu cea mai bună focalizare (z) a fiecărui pixel (x, y) a fost determinată prin alegerea stratului de imagine care arată claritatea maximă și s-a format imaginea cu adâncime de focalizare. Acest studiu propune un nou criteriu de evaluare a clarității, care se bazează pe variația gradienților. Ulterior, câteva puncte de bază care indică suprafața de fundal au fost selectate din imaginea cu adâncime de focalizare, iar coordonatele de adâncime (x, y, z) în aceste puncte de bază au fost utilizate pentru a calcula un plan de fundal preconizat. Prin intermediul planului de fundal, a fost extras pilingul deasupra fundalului. O probă de țesătură cu o singură fibră a fost prezentată pentru a ilustra procesul și rezultatul abordării.

Cuvinte-cheie: adâncime de focalizare, detectarea pilingului, evaluarea clarității imaginii

A novel approach for identification of pills based on the method of Depth From Focus

For automatic pilling evaluation of textiles, the depth information is one of the most critical and effective features in extracting pills from fabric image. Laser-scanning techniques are often used for acquiring 3D depth images. However, due to the high-cost and low-efficiency of Laser-scanning system, researchers have found it unsuitable for fabric analysis. This paper illustrates a new approach for acquiring the depth image used to extract pills by introducing the method of Depth From Focus (DFF). This approach firstly captures a sequence of images of the same view at different focal positions under the automatic optical microscope. Then the best-focused position (z) of each pixel (x, y) was determined by choosing the layer of image declaring the max sharpness and formed the depth image. This paper proposed a new sharpness-evaluation criterion which was based on the variance of gradients. Afterwards, a few basic points indicating the background area was selected from the depth image, and then the depth coordinates (x, y, z) at these basic points were used to calculate a predicted background plane. Via the background plane, pills above the background were extracted. A fabric sample with a single fiber upon it was presented to illustrate the process and result of the approach.

Keywords: Depth from Focus, pill detection, sharpness evaluation

INTRODUCTION

Pilling is defined as the entangling of fibers during washing, dry cleaning, testing, or wear to form balls or pills that stand proud of the surface of a fabric [1]. To examine pilling, the fabrics are treated to form typical pills by tumbling, brushing, or rubbing specimens with abrasive materials in a machine and then comparing the processed fabrics with visual standards to determine the degree of pilling on a scale ranging from 1 (very severe pilling) to 5 (no pilling) [2]. Such evaluations are mainly dependent on experts involved and therefore low-efficient and subject.

Testing pilling performance of the fabric has been a problem for a long time. Since image analysis was introduced into fabric-testing industry, pilling evaluation has been made a great improvement. Previous valuable works have made lots of efforts to extract pills on the fabric surface [3]. Many researchers have tried to separate the pills from the background by image threshold [4]. Some researchers performed Fast Fourier Transform (FFT) and wavelet transform [5] to the pilled fabric image with a regular pattern. However, these works encounter with the interference from fabric color and pattern. Laser 3D scanner can acquire the depth information of fabrics to avoid the interference. Due to the high cost and low efficiency of this kind of scanning system, researchers believe that a video camera, together with an effective algorithm to identify pills is still of great research and practical value.

In this paper, we attempt to introduce the concept of depth from focus (DFF) to reconstruct a depth image for pilling analysis. In 1990, E. Ens put forward the concept of depth from focus [6]. Due to the limited depth of field, light microscope can ensure the clearness of the target partly clear while other parts are fuzzy [7]. When the object is in the focus position, it exhibits clearly in the image. Therefore, for the same object, in a series of images captured at different focal positions, the object is clear in one certain image, while fuzzy in other. Therefore, the distance to an object in scene can be deduced by knowledge of current camera positions and the degree that the object is in focus.

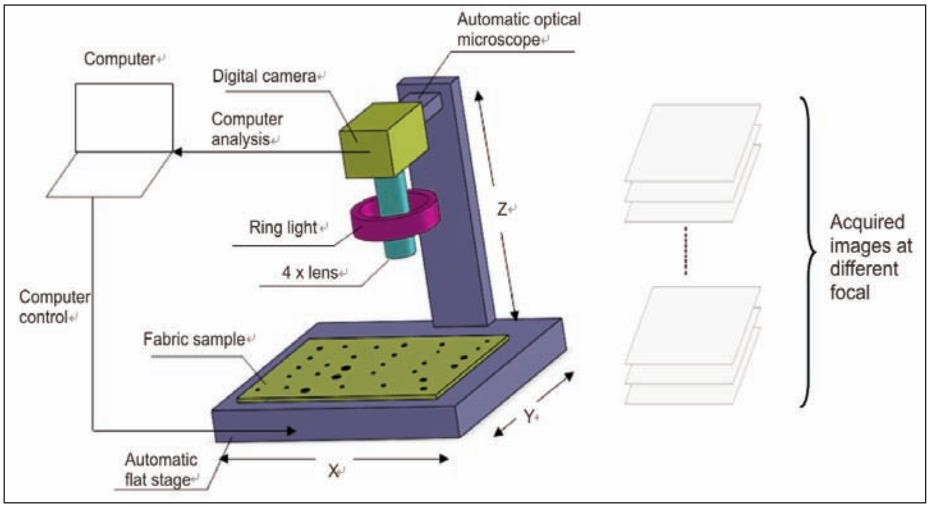

Fig. 1. The Image Acquisition System

The most difficult task of this technique is devising a robust sharpness-evaluation algorithm. The idea of using a sharpness matrix to measure the degree of the in-focus was first proposed by Muller & Buffington, who claimed that a sharpness matrix should produce a global extrema for a focused image [8]. Muller & Buffington proposed three new criteria for automatic focusing: Squared gradient, Laplacian and Signal power. Comparing with common multi-focus object, fabrics exhibit richly-textured features. The in-focus image of the fabric presents more abundant texture than images out-of-focus. According to the characteristics, a novel sharpness-assessment based on gradient variance was introduced in this paper. The gradient variance indicating the contrast of gradients can reflect the texture of the region.

This paper introduced a novel method to extract pills from fabric image based on the theory of DFF. In order to see the fibers in pill balls clearly, the fabric images were captured under the 4×lens by using a optical microscope. A series of images of the same view of fabric was captured at different focal positions. By comparing the sharpness in each layer of image, the depth value of each pixel was determined. Several local background areas were identified based on the depth image and the coordinates (x, y, z) of these area were used as the basic points to simulated the predicted background plane by using the least square method. By using the predicted background plane, the local z-position thresholds can be calculated to extract pills from background according to the depth values.

EXPERIMENTAL WORK

To reconstruct a depth image of the fabric, a sequence of images of the same view of fabric was captured at different focal positions under the optical microscope. A Sharpness-judging algorithm was proposed in this paper to indicate the clearness of each pixel and therefore was used to select the layer of image which declared the best clearness of the pixel. Once the z-positions of all pixels are acquired, the depth information of the fabric can be digitized by using one pixel as the height unit. By analyzing the structural features and spatial distribution of each target type, two threshold values-the degree of altitude differences and number of altitude-jump points-were used to identify fabric surface. The coordinates (x, y, z) of the identified pixels were then used to simulate the predicted fabric surface plane whose coordinates describe the relationship between the surface depth (z-position) and the (x, y) position of the scene. The elevation of each pixel is the distance between the pixel and the predicted fabric plane. Since the fabric surface pixels were on or near the predicted fabric background plane, the fabric surface can be filtered according to the elevation.

Image acquisition

An automatic microscopic equipped with motorized x-y stage to transport the slide was used in this paper. The automatic microscopic system is commonly equipped with a motorized x-y stage to transport the slide and a focusing device to adjust the focal plane of the objective lens. With the optical microscope, the sequential images were recorded with a CCD camera, and the object images were reconstructed in depth image by using DFF method. The fabric sample were magnified by 4×microscope objectives (0.25 NA), by which the fibers of pilling balls can be seen clearly in the captured pilled images. Figure 1 is a diagram of the image analysis system. The hardware used in this work was assembled with simple components. These included a computer, a digital camera, an optical microscopy with motor-controlled stage and a ring-shaped light installed on 4×lenses. The movement of stages was controlled by the computer through a serial port.

Pre-processing of de-noise for original images

Real images containing noise could cause great interference for acquiring depth from focus, due to the fact that noise points present sharp gradient and thus influence measuring sharpness. The median filtering was used in this paper. The 3×3 template window was applied in the median filter. The transform gray level of pixel $T(x, y)$ can be expressed as follows:

$$T(x, y) = median\begin{Bmatrix} G(x-1, y-1), G(x, y-1), G(x+1, y-1), \\ G(x-1, y), G(x, y), G(x+1, y), \\ G(x-1, y+1), G(x, y+1), G(x+1, y+1) \end{Bmatrix} \quad (1)$$

where $G(x, y)$ refers to the gray value of pixel (x, y). The contrast of depth images when median filtering algorithm was processed (figure 2, *b*) and not processed (figure 2, *a*).

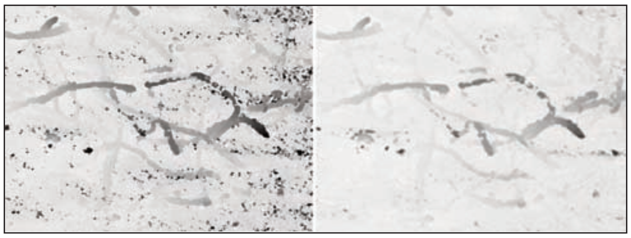

Fig. 2. *a* – The depth image without de-noise processing; *b* – the depth image with de-noise processing

Sharpness-judging algorithm

Many reaches have been studies several section-judging functions. Theses judge algorithms are based on the indicators such as Variance, max frequency and LBP-transformation. However, these algorithms did not work out well in our studies for pills fabrics which exhibit multi-textured and multi-focus phenomenon. When humans observe a texture image, the borders which exhibits high gradient evoke their interests first. The gradients are high on the border of two targets and low in the body of one target. Therefore, the gradients are fluctuant when the image is in-focus. For the de-focused image or the de-focused area of an image, the border between two targets is not conspicuous; resulting in the gradients varies little among the image or the area.

In this paper, a 7×7 sharpness matrix centered with the pixel whose sharpness was to be measured was used to assess the clearness of a certain pixel. Based on the theory above, the sharpness of the matrix was expressed by the variance of the gradient in the area.

The algorithm was realized by following steps:

The first step was to record the gradient of each pixel in the matrix. The gradient was defined as Eq.5. Assuming $P_i(x, y)$ refers to the pixel in *i*-th layer of images at the pixel coordinate (x, y), and $S_i(x, y)$ is the gradient of $P_i(x, y)$, the following three-dimensional Gradient Matrix (GM) recorded the gradient of each pixel in the $P_i(x, y)$-centered region.

$$GM_i(m,n) = \arg S_i(m,n) \quad (2)$$

The second step was to calculate the sharpness of the matrix. Assuming $C_i(x, y)$, (i =1, 2,…, 41) is the clearness of the $P(x, y)$-centered matrix, and $U_i(x, y)$ is the average gradient value in GM_i, then

$$C_i(x, y) = \sum [GM_i(m, n) - U_i(x, y)]^2 \quad (3)$$

As discussed before, the sharpness of a pixel can be expressed by the sharpness of matrix centralizing in the pixel. We can build the clearness matrix *DCM* in which the sharpness of a pixel can be calculated by Eq.4

$$DCM(i, x, y) = \arg G_i(x, y) \quad (4)$$

Calculating the depth value of each pixel

From figure 3 we can see that the sharpness of a pixel exhibit unimodal distribution. The sharpness reaches a extreme point when the pixel is in-focus at the corresponding layer of image. The depth value of the pixel can be deduced by the lens position where the focused image was captured.

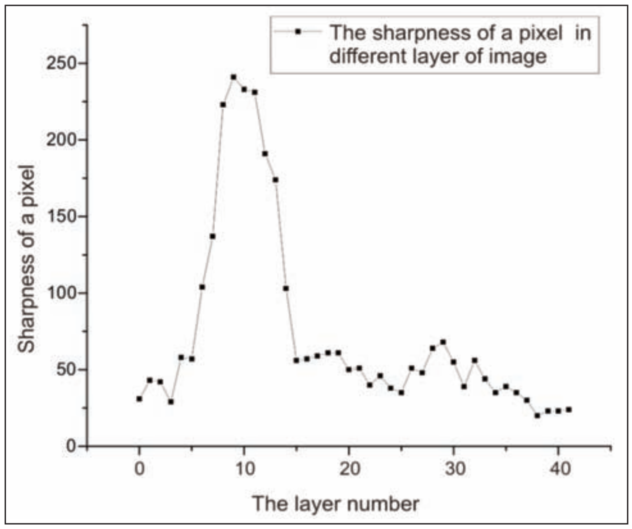

Fig. 3. Sharpness of a pixel in different image layers

Predicting the fabric background plane

After the *z*-positions of all the pixels were obtained, the depth image was constructed (figure 4). Since the range of gray value is 0 to 255, all the *z*-positions were normalized to 256 degrees. In the constructed image, pixels with higher intensity of gray value are at a lower depth value.

From the pilled fabric depth image, it was noticed that the pills have a distinct difference with background in depth. Thus, once the depth of the fabric surface background is acknowledged, pixels above the fabric surface can be extracted.

The most difficult part is that the *z*-position of fabric surface in the area covered by pills is uncertain, due to the interference of the pills. However, the *z*-positions of fabric surface in these areas could be predicted according to the "flat areas" which were not

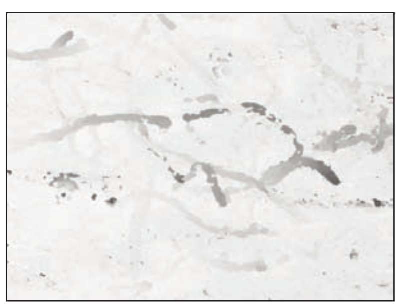

Fig. 4. The depth image

covered by pills. In this step, we utilized the depth coordinates (x, y, z) of “flat areas” to calculate a predicted background plane. The predicted background plane allows the computer to know the z position of the background at any (x, y) position and therefore pixels beyond background can be identified as pills. Figure displays the flowchart of this pill-extraction scheme. The chart of extracting pill pixels is shown in figure 5.

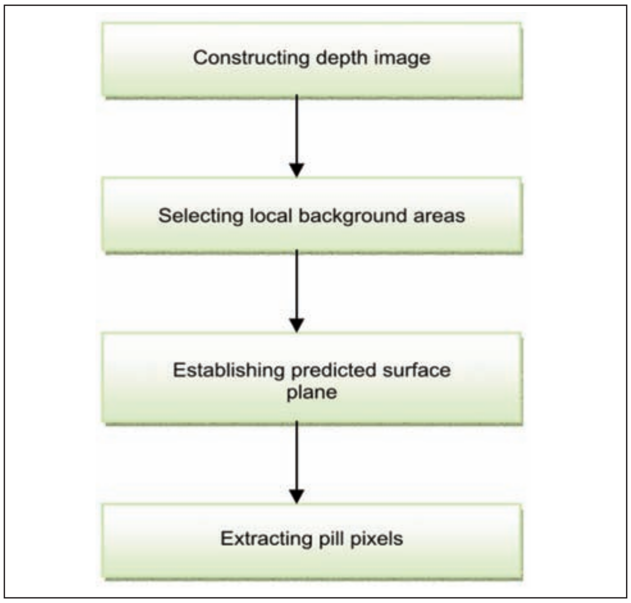

Fig. 5. The chart of extracting pills

Pixels in the depth image belong to one of the three target types: noise, pills and the fabric surface. Pixels on pills are often of high level of depth value while present height difference with proximal pixels. The depth of a noise pixel is isolated with surrounding pixels. Pixels on fabric surface are often of low level of depth value and share similar depth value with nearby pixels. Via analyzing the structural features and the general rules of spatial distribution of the three different target types (noise, pills and background). Table 1 describes and illustrates each target type based on the altitude change information of proximal points.

Table 1

Target type	Description	Diagram
noise	Having major altitude differences with almost all the proximal points	
pills	Having major altitude differences with a majority of proximal points while minor altitude differences with the rest	
back - ground	Having minor altitude differences with almost all the proximal points	

Due to the variant configuration and distribution of pills, the possibility of misjudgment could still exist. Therefore, a small local background area was used instead of a single background point to increase the stability and accuracy of our algorithm. The plane coordinates (x, y) of the local area refers to the coordinates of the central point in area, and the z-position of the background area is the average depth of all points in the area.

Here, a 40×30 window was used to scan the whole image to find a local area without pills. The window moved through the whole image in zigzag from top-left to bottom-right corner. At each stop, a background-judging function was called to determine whether the scanning 40×30 local area is the background area. Figure 6 illustrates the representative pills area and background area. The local areas are remarked by red rectangles and sideward images are enlarged of the red rectangles.

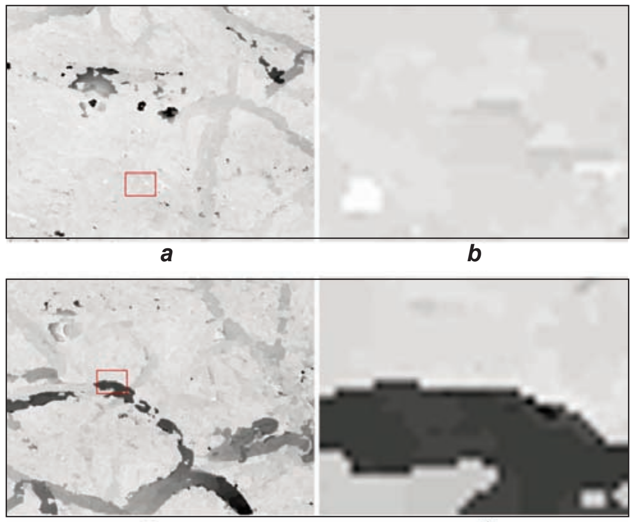

Fig. 6. *a* – An local window of pills; *b* – the enlarged image of the red window in *a*; *c* – an local window of background; *d* – the enlarged image of thered window in *c*

Figure 6, *b* shows the enlarged image of the local background area and figure 6, *d* exhibits the local pills area. We can define the local background area mathematically as follows:

Assuming the scanning 40×30 region is Ω, The flatness of the region (Fl) can be expressed in Eq.6.

$$Ave = \frac{\sum d(x,y)}{N},\ (x, y) \in \Omega \qquad (5)$$

$$Fl = \frac{\sum (d(x,y) - Ave)^2}{N},\ (x, y) \in \Omega \qquad (6)$$

where $d(x, y)$ is the depth value of the pixel (x, y), and N – the total number of pixels in region Ω.

Here, an experimental threshold values was set for the parameters Fl. If the parameter was under its threshold value, the window can be considered as the flat area”. Figure 7 shows all the identified local background areas in the depth image.

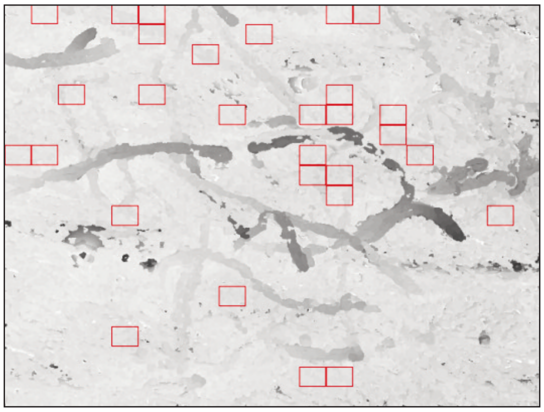

Fig. 7. The identified local background windows

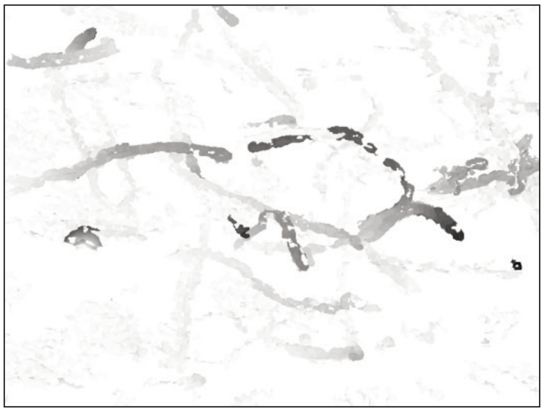

Fig. 8. The identified fuzz and pills

Three-dimensional coordinates (x, y, z) of each local background window were used to predict the background plane by using the least square method.

The background plane is a linear function expressed as

$$z = ax + by + c \quad (7)$$

where z is the depth position, (x, y) are the pixel positions and (a, b, c) are the coefficients.

By using this predicted background plane, the depth value of the background at any positions (x, y) can be determined. Since the real depth value of each pixel (z) was already known according to the depth image, if the depth value (z) is larger than the background depth value (z_b), the pixel (x, y) was identified as the fuzz or pills. The identified fuzz and pills were illustrated in figure 8.

RESULTS

A fabric sample with a single fiber upon it was used to illustrate the step and result of the algorithm. On the image acquisition step, the stage moves along the z-axis as images acquired at different focal positions. In this research, the size of a acquired image is 800 × 600 pixels with pixel dimensions of 2 × 2 μm, so the actual fabric area evaluated by this system is 1.6 × 1.2 mm^2. The total number of layers for the same view is 60, and the step in z-axis is 25 μm. Partly of the acquired images are shown in figure 9.

After the acquisition of the sequential images, the sharpness-evaluation algorithm based on the variance of the gradient was utilized to determine the focused position of each pixel.

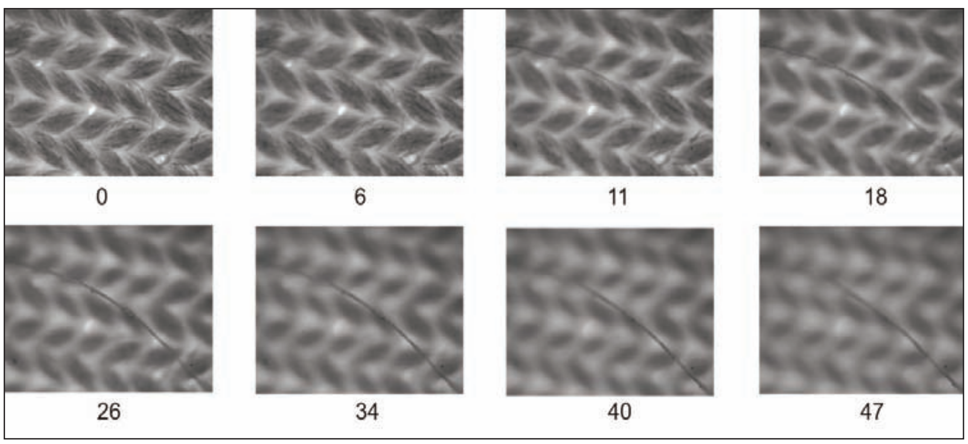

Fig. 9. Partly of the acquired images

Assuming the position where 0-th layer of image was captured as the original point, since the step in z-axis is 25 μm, the depth value (d) of each image can be expressed in Eq.8.

$$d_i = i * 25, \quad i = 0, 1, 2, \ldots, 59 \quad (8)$$

Where i refers to the layer number of the image and the unit of d is μm.

Figure 10, *a* conveys the depth image with identified local background areas. Figure 10, *b* illustrates the extracted pills based on the predicted background plane. From figure 10, *b*, it can be seen that the fiber upon the fabric can be completely extracted with the DFF method. As comparison, this paper presents other three sharpness-evaluation criterion to construct depth image. Three common sharpness-evaluation algorithms: variance, histogram entropy and sum-gradient were used to determine the best-focused positions and construct the depth image. From figure 11, *a*, we could find that the entropy algorithm could identify the texture of the fabric well in the depth image; however

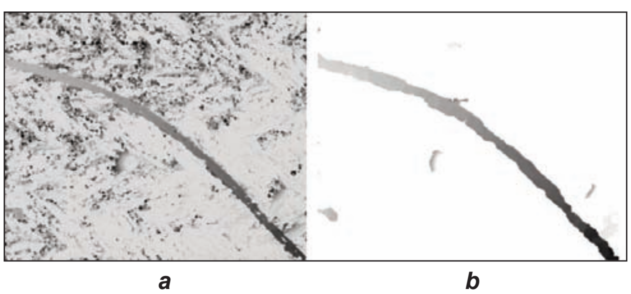

Fig. 10. The depth image and the extracted pills

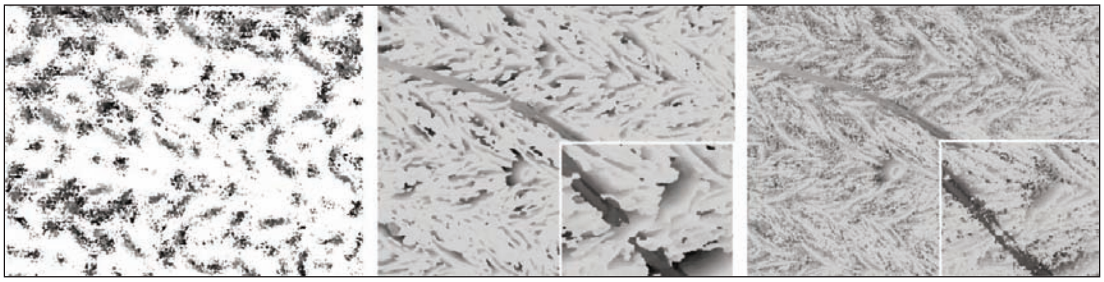

Fig. 11. The depth image with other sharpness-evaluation algorithms

the fiber upon the fabric was missing. Both the variance and the sum-gradient sharpness-evaluation criterion lost parts of the fiber information, as Shown in figure 11, *b* and figure 11, *c*.

CONCLUSION

This work has described the pill identified method based on DFF. This method requires for an automatic microscope, a digital camera and a computer with pill identification algorithm embedded, which is more convenient and much cheaper than Laser-scanning system. With the method of DFF, the best focused position of each pixel can be located and a depth map of the whole image can be estimated. Several local background areas were identified as basic points to calculate a predicted background plane. Pills whose depth values were upon the background were extracted according to the predicted background plane. The sample fabric with a fiber put upon it was used to illustrate the process of this method. By comparing the depth image constructed by other three common sharpness-evaluation criterion, the sharpness-evaluation algorithm based on the variance of the gradients was verified to maintain more complete pill information.

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Efficient removal of Indigo dye from aqueous solution by an innovative method of emulsion liquid membrane

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REZUMAT – ABSTRACT

Eliminarea eficientă a colorantului Indigo din soluția apoasă printr-o metodă inovatoare cu membrană lichidă de emulsie

Extracția colorantului Indigo din soluția apoasă este studiată în acestă lucrare utilizând membrane lichidă de emulsie (ELM). Emulsia de apă/ulei (W/O) a fost preparată prin amestecarea fazei apoase cu fază organică la o viteză de omogenizare ridicată. H_2SO_4 și hexanul au fost utilizați ca agent de stripare intern și, respectiv, diluant organic. Monooleatul Sorbitan, cunoscut ca Span-80, a fost utilizat ca surfactant în fază organică. Această emulsie de W/O a fost ulterior amestecată cu fază de alimentare externă care conține colorant Indigo pentru a produce emulsie dublă W/O/W. Stabilitatea membraei a fost optimizată prin experimentarea diferiților parametri de funcționare. ELM preparat în condiții optime a fost în cele din urmă utilizat pentru a îndepărta colorantul Indigo din soluția apoasă. Studiul parametrilor de proces care afectează eficiența de extracție a fost, de asemenea, efectuat. În condiții optime ale parametrilor, cum ar fi raportul de volum al emulsiei/aliementării, concentrația colorantului în alimentare, viteza de agitare și timpul de contact al celor două faze, s-a constatat că extracția colorantului Indigo este de 99%. Prin urmare, s-a ajuns la concluzia că ELM este o tehnică atractivă și eficientă pentru eliminarea coloranților.

Cuvinte-cheie: membrane, emulsionare, stabilitate, extracție, colorant Indigo

Efficient removal of Indigo dye from aqueous solution by an innovative method of emulsion liquid membrane

Extraction of Indigo dye from aqueous solution is studied in this research using Emulsion Liquid Membrane (ELM). Water/Oil (W/O) emulsion was prepared by mixing aqueous phase with organic phase at an elevated homogenizing speed. H_2SO_4 and Hexane were used as internal stripping agent and organic diluent respectively. Monooleate Sorbitan commonly known as Span-80 was used as surfactant in organic phase. This W/O emulsion was later mixed with external feed phase containing Indigo dye to make W/O/W double emulsion. Stability of the membrane was optimized by experimenting different operating parameters. The ELM prepared under the optimum conditions was finally used to remove Indigo dye from aqueous solution. The parametric study of the process parameters affecting the extraction efficiency was also performed. Under optimum conditions of parameters like volume ratio of emulsion/feed, dye concentration in feed, stirring speed and contact time of two phases, the extraction of Indigo dye was found to be 99%. Therefore, ELM was found to be an attractive and effective technique for the removal of dyes.

Keywords: membranes, emulsification, stability, extraction, Indigo dye

INTRODUCTION

Discharge of a huge quantity of wastewater containing toxic organic solutes is a common practice of many industries now-a-days. Amongst these, textile industry is a major contributor of promoting environmental degradation in terms of water pollution globally. Textile wastewater is known to contain strong color, high pH, temperature, COD and low biodegradability [1]. This effluent may contain different hazardous chemicals, dyes and pigments. Not only the large scale industries, but the small scale industries commonly called as cottage industries of textile also indulging a remarkable negative impact on environment. Ajrak industry is one example of a classical cottage industry of textile usually exist in India and Pakistan. This small scaled industry usually operated in villages; produces "Ajrak"; a piece of dyed cloth and printed with unique patterns. Among different colors being applied on Ajrak, blue is one of the prominent color usually achieved with Indigo dyes. Traditionally, this Indigo dye was of natural origin but its increasing demand and high cost of natural dyes has replaced it with synthetic Indigo dyes which are highly toxic, carcinogenic and mutagenic [2]. Ajrak industry also adopts the similar practice of disposing the untreated wastewater directly into surface water. This practice of discharging the effluent containing lethal contamination into water streams is not only destructive for aquatic ecosystem but also toxic for human beings. In a report, synthetic indigo is thought to be contaminated in water streams posing several threats into the marine species as it can be oxidized into "isatin" then be hydrolyzed to "Anthranilic Acid"; a hazardous compound that is toxic to Aquatic life [3].

ELM is one promising technique for the treatment of various industrial wastes since its invention. The extraction process by ELM was introduced for the first time by N. N. Li [4]. This technique has many advantages over the other treatments methods which has made this process more significant and highly prospective. Many studies have been carried out for the extraction of different species from water by using ELM technique like heavy metals [5, 6], precious metals [7], phenol [8], organic acids [9–10], aniline [11], bioactive material [12]. Removal of different classes of dyes through ELM process with extraction efficiency above 99% is reported in different studies. An efficient removal of acid dyes [13–14], Anionic dyes [15–16], cationic dyes [17–18], reactive dyes [19], crystal violet and methylene blue dyes [20] is reported in literature. To the best of our knowledge, no work has been done on the extraction of Indigo dyes by ELM process. The present study is aimed to remove Indigo dye from the aqueous solution by using ELM technology considered as one highly hazardous contaminant present in the effluent of "Ajrak" Cottage industry.

EXPERIMENTAL

Material

Sorbitanmonooleate commercially known as Span-80 and sulfuric acid (97% purity) used in this study was obtained from Merck. Hexane fraction from petroleum used in this research was also a laboratory reagent grade manufactured by Fisher Scientific (UK). Indigo dye was courteously collected from the local textile cottage industry of Ajrak. ULTRA-Turax T-25 Homogenizer was used for the emulsification of aqueous internal phase and organic phase, whereas the mixing of W/O emulsion with external phase was achieved with ADVANTEC MIDGET mechanical stirrer attached with a four bladed propeller type shaft. UV-1800 SHIMADZU UV-Spectrophotometer was used for measuring the absorption intensity of the Indigo dye before and after the treatment (figure1).

Procedure

Stability analysis

Before emulsification of the W/O emulsion, both the aqueous and organic phases were separately prepared. Aqueous phase was prepared by dissolving an appropriate amount of H_2SO_4 in distilled water to make solutions of different molar strengths. Measured quantities of Hexane were mixed with Span-80 to make the organic phase. Hexane was used as organic diluent whereas Span-80 assurfactant. The solution was stirred and heated on WISE-STIR magnetic stirrer for 10 minutes at 30°C for a fixed stirring velocity of 700 rpm. To determine the emulsion stability, both these phases were initially mixed to make W/O emulsion under the varying speeds of ULTRA-Turrax T-25 Homogenizer from 3,000 to 10,000 rpm and then the prepared emulsion was filled in scaled test tubes. The test tubes were placed in test tube holder and kept for 24-hours at normal room temperature (25–30°C). After 24-hours, the phase separation ratio of the aqueous and oil was calculated using the following expression:

$$Stability\ \% = \frac{Vt - Vw}{Vt} \times 100$$

Where Vt is the total volume of the emulsion in the test tube, Vw – the separated volume of the aqueous phase in the test tube after 24 hours.

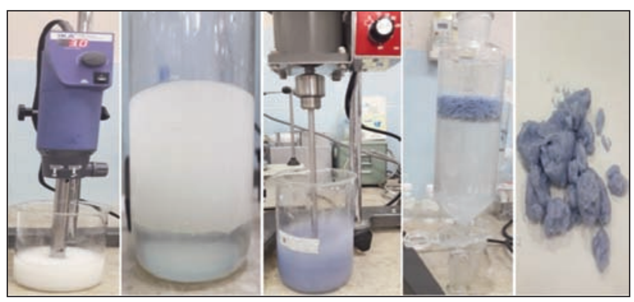
Extraction of Indigo dye

External feed phase was prepared by dissolving different quantities of Indigo dye in distilled water to make required dye concentrations. The prepared external phase contained in a PYREX glass beaker was placed under shaft of ADVANTEC MIDGET mechanical stirrer while pouring the W/O emulsion slowly into the beaker. The mechanical stirrer was rotated at different mixing speeds resulting in a Water/Oil/Water (W/O/W) double emulsion. After some definite time, contains of the beaker were transferred into a separating funnel and allowed for phase separation. The treated water was finally collected in a fresh beaker from the bottom of the funnel while the remainder in the funnel was collected separately for reuse of membrane after demulsification process.

RESULTS AND DISCUSSION

Parametric study

Parametric study on the behavior of formulated ELM with respect to stability and extraction efficiency was conducted by using conventional single factor design method. According to this method, all the parameters were initially set on one constant value except one parameter which was varied. Later this parameter was fixed at an optimum level varying the other parameter. This process continued till all the working parameters were individually optimized.



a b c d f

Fig. 1. Extraction process of Indigo dye by ELM process: *a* – preparation of W/O emulsion; *b* – stable emulsion; *c* – mixing of dye phase with W/O emulsion; *d* – separation of phases in separating funnel; *e* – dye extracted from aqueous solution

Effects of operational parameters on membrane stability

Effect of aqueous phase concentration

Concentration of the stripping agent in aqueous phase plays very vital role in the stability analysis of any ELM system. Experiments were conducted to determine the optimal concentration of aqueous phase to formulate an ELM with required stability. Figure 2 shows the effect of concentration of H_2SO_4 on the stability of ELM. Figure shows that the stability of emulsion is maximum at the lowest molar concentration of H_2SO_4. With the increase in concentration of H_2SO_4, the stability of the ELM is slightly decreased. This change in behavior can be attributed due to the partial hydrolysis of the surfactant which is catalyzed by protons. Surfactant present in the organic phase possesses some deteriorating properties also which results in the rupture of membrane consequently decreasing the stability.

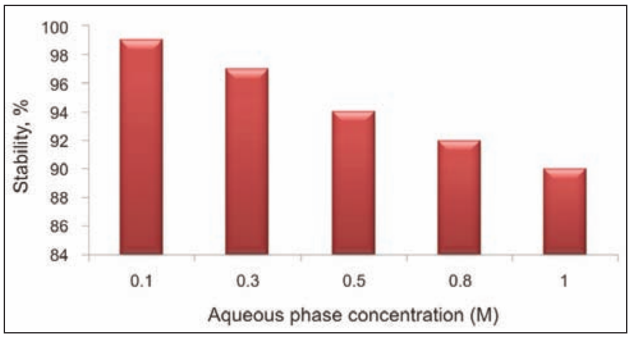


Fig. 2. Effect of aqueous phase concentration on stability of ELM

Effect of surfactant concentration

Surfactant acts as an emulsifier in any ELM system that reduces the interfacial tension between the phases of emulsion. In this study Sorbitanmonooleate, commonly known as Span-80, is used as non-ionic surfactant. The effect of Span-80 as surfactant on the stability of required emulsion is presented in figure 3. It is observed from the figure that stability is not good below 5% (w/v) of surfactant. This is due to the insufficient quantity of surfactant for making an adequate layer for surrounding all the aqueous phase. The maximum stability i.e. 100% is achieved at surfactant concentration of 5%, whereas the further increase in the concentration showed no any significant change and stability remained nearly constant.

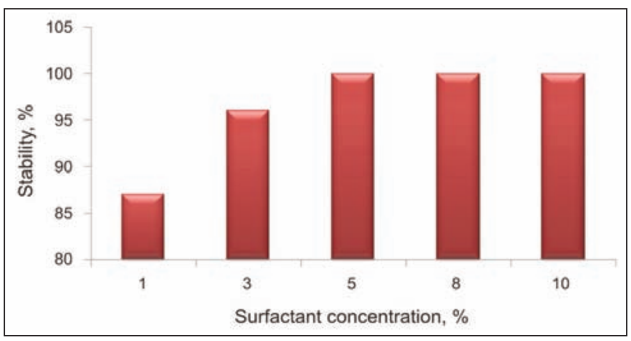


Fig. 3. Effect of surfactant concentration on stability of ELM

Effect of volume ratio of organic/aqueous phase

Figure 4 shows the effect of the volume ratio of the organic/aqueous phase on the stability of the required emulsion. From the figure it can be observed that the best maximum stability was achieved at the ratio of 1:2 (organic:aqueous). This can be explained by the fact that an increase in aqueous phase volume fraction shifts the internal drop size distribution toward larger sizes and causes an increase in the emulsion viscosity [21] and it is well known that high viscosity is generally favorable for the stability of the emulsion.

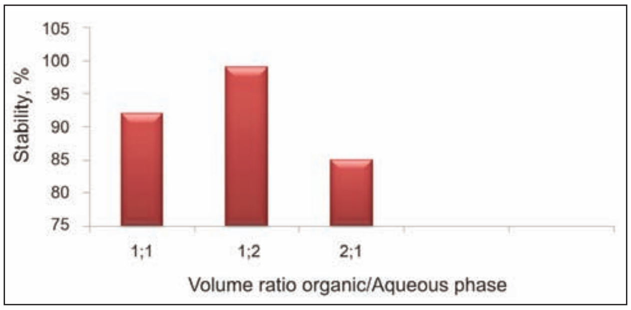


Fig. 4. Effect of volume ratio (organic/aqueous) on stability of ELM

Effect of emulsification time

Experiments were conducted to determine the effect of emulsification time on the stability of required emulsion. This effect is determinant from figure 5. It can be observed from the figure that stability was not good at lower emulsification time up to 5 minutes. Stability increased gradually and maximum stability was achieved at 10 minutes of emulsification time. Further increase above 10 minutes showed the reduction in membrane stability. This effect can be elucidated by understanding the phenomenon that the quantity of the emulsion droplets formed below the time of 5 minutes was very low in quantity while their size was relatively high. This behavior supported the property of coalescences to form bigger droplets thus destabilizing the emulsion. In contrast, for increased emulsification time above 10 minutes, the internal shearing for longer duration generate a high number of smaller droplets which increases the risk of emulsion breakage due to their high collision frequency.

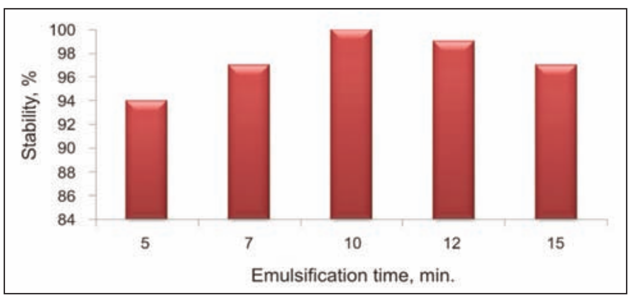


Fig. 5. Effect of emulsification time on stability of ELM

Effects of operational parameters on the extraction of Indigo dye

Effect of volume ratio of emulsion/feed phase

The extraction efficiency of the ELM system depends on different factors. Experiments were conducted to analyze these effects. Before analyzing the extraction efficiency, the stable membrane was developed according to optimized values of parameters previously observed. These optimum values include 0.1 M concentration of H_2SO_4 in aqueous phase, 5% Span-80 as concentration of surfactant, 8000 rpm emulsification speed and 10 minutes homogenization time.

For optimum extraction, volume ratio of emulsion to feed phase was experimented and analyzed. From figure 6 we can conclude the result by observing that the maximum extraction efficiency is achieved at the ratio of 1:5. Further increase in the ratio decreases the efficiency. This can be explained by the phenomena of swelling (water passage from external feed phase to internal aqueous phase), thereby decreasing the membrane film thickness resulting the emulsion become unstable, which intern decreasing the extraction of target solute.

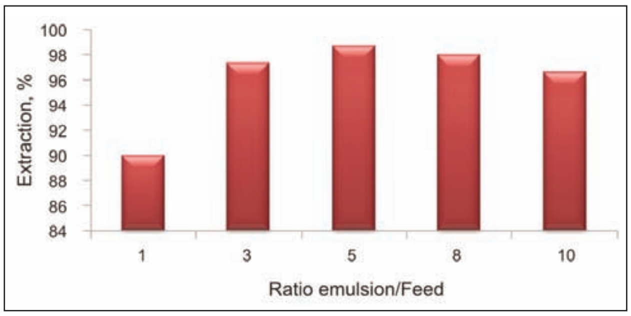


Fig. 6. Effect of volume ratio (emulsion/feed) on extraction of Indigo dye

Effect of dye concentration in feed phase

In separation processes, the quantity of the target is also one important factor to be considered. In this study, the effect of Indigo dye concentration in external feed phase was also observed by varying its concentration. Figure 7 shows that the maximum extraction efficiency is achieved at dye concentration of 50 ppm. For concentrations above 50 ppm, the extraction yield decrease which is due to the saturation of internal phase droplets by the target dye particles.

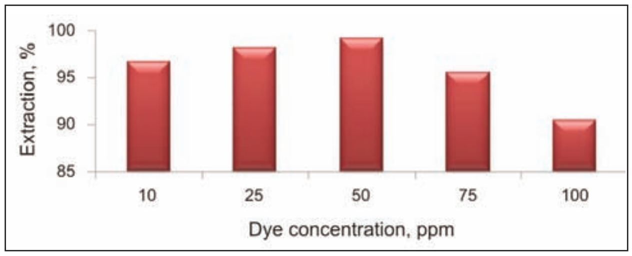


Fig. 7. Effect of dye concentration in feed on extraction of Indigo dye

Effect of stirring speed for mixing the emulsion and feed phases

The stirring speed plays a major role in the rate of extraction of any solute through emulsion liquid membrane. The effect of stirring/mixing speed in this study was also observed and produced in figure 9. From the graph in figure 8, it is observed that increasing the speed from 50 to 100 rpm, an increase in extraction efficiency is noticed. However, further increase in speed above 100 rpm gradually decreases the extraction efficiency. This can be attributed as lower stirring speed below 100 rpm is not adequate to form smaller sized emulsion droplets in maximum number for trapping the maximum quantity of dye particles. At optimal speed of 100 rpm, a good number of smaller sized emulsion droplets are formed leading to more surface area provided for better mass transfer. Further increase in speed increases

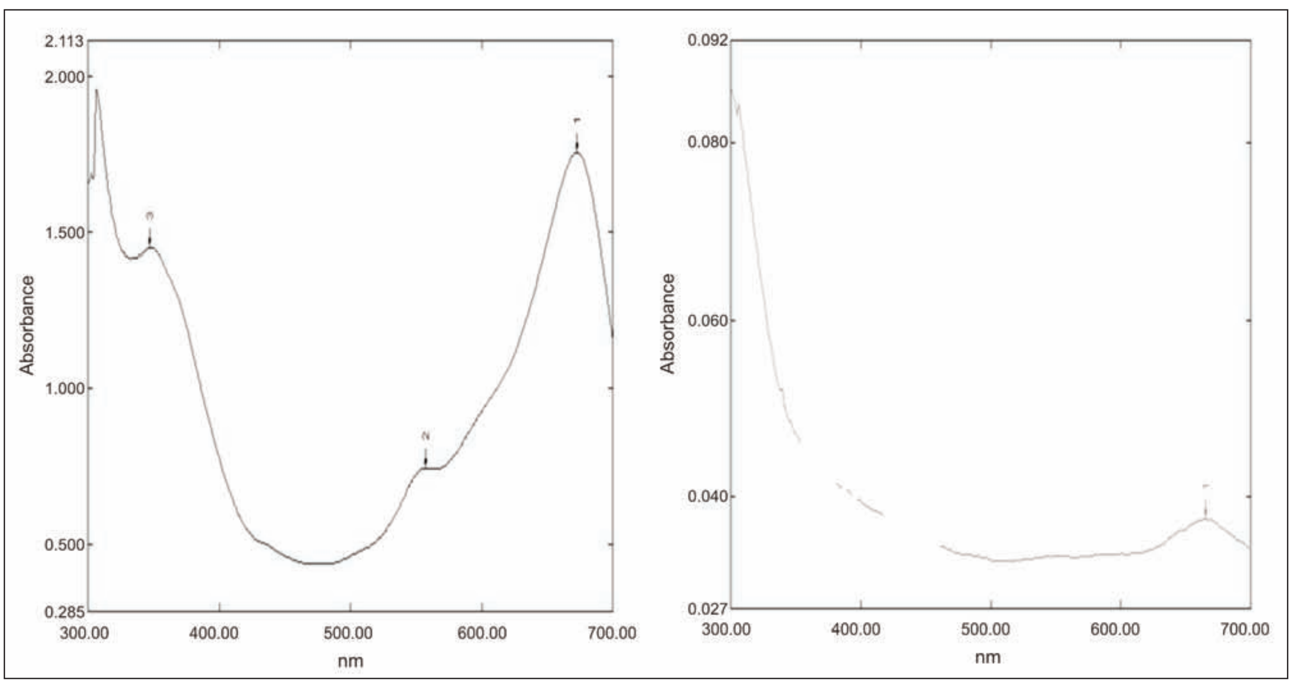


Fig. 8. Images showing difference in absorbance curves at same wavelength (left) absorbance of dye solution at 670 nm before ELM treatment 1.754% (right) absorbance of dye solution at 670 nm after ELM treatment 0.025%

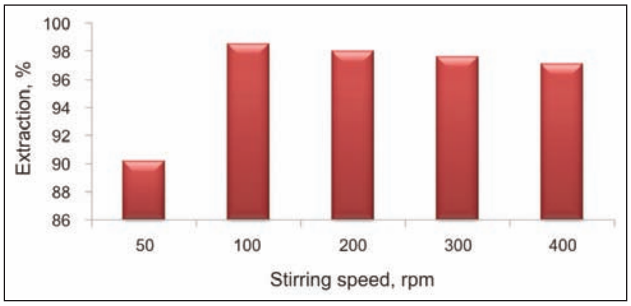


Fig. 9. Effect of stirring speed on extraction of Indigo dye

the shearing force on the system, thus by reducing the stability of membrane causing the emulsion rupture and diminishing the extraction efficiency.

Effect of contact time

Experiments were conducted to determine the effect of contact time of two phases (membrane and feed phases) on the extraction of Indigo dye. From the figure 10, it is noticed that the dye extraction increased with the increase of contact time from 3–5 min. This increase is evident up to this level, while as the further increase in contact time from 5–15 min results in a smaller reduction in percent extraction of Indigo dye. This indicates the similar behavior as previously discussed with stirring speed, i.e. increase in time of contact or mixing of emulsion and feed phase will also increase the time to resist the sheer force developed due to agitation by the system. This will adversely affect the emulsion stability resulting in rupture of liquid emulsion membrane leading to outflow of extracted dye back into the external phase, thereby decreasing the extraction efficiency.

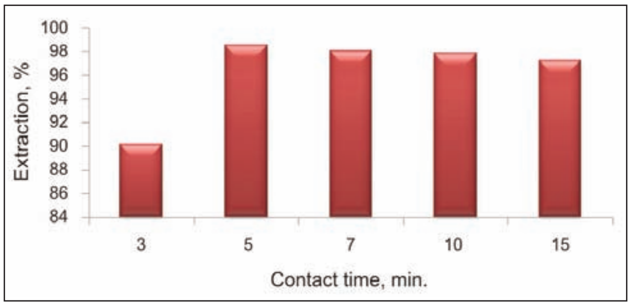


Fig. 10. Effect of contact time on extraction of Indigo dye

Fig. 11. Aqueous dye solution containing Indigo dye (left), water treated with ELM Process (right)

CONCLUSION

A study was carried out to remove an Indigo dye from aqueous solutions through ELM technique. Parameters affecting the stability of the emulsion were studied and a stable emulsion was formulated under optimum parameters for subsequent extraction process for Indigo dye. These optimum parameters include 0.1 M H_2SO_4 as concentration of aqueous phase, 5% as concentration of surfactant Span-80, 1:2 as volume ratio of organic to aqueous phase, 8000 rpm emulsification speed and 10 min as emulsification time. Different operating parameters affecting the extraction yield of the ELM system were also optimized to obtain maximum extraction efficiency. It was concluded that under optimum conditions of parameters, 99% extraction of Indigo dye from aqueous solution can be attained. Therefore, this study concludes that ELM technology has potential to remove Indigo dye from the textile cottage industry of Ajrak much efficiently.

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Advanced wastewater treatment stage for textile industry

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REZUMAT – ABSTRACT

Etapa avansată de tratare a apelor reziduale pentru industria textilă

Flotația cu aer dizolvat reprezintă o etapă importantă pentru tratarea apelor reziduale și a fost utilizată în ultimii șaizeci de ani pentru diferiți poluanți cum ar fi: solide în suspensie, grăsimi, uleiuri etc. În prezent, sistemele cu aer dizolvat sunt în general aplicate în stațiile de tratare a apelor reziduale industriale, acolo unde cantitatea de poluanți este mai mare decât media (industria textilă și pielărie). Membrii echipei de cercetare au dezvoltat o unitate inovatoare DAF și au realizat un demonstrator experimental de laborator. A fost testată instalația în laborator și a fost demonstrată eficiența tratării apelor reziduale. Ultimele cercetări au demonstrat că reactivii de flotație au un rol esențial în eliminarea diferiților poluanți. Literatura științifică demonstrează că acești reactivi pot fi utilizați pentru a elimina poluanții precum nămolul sau spuma. Reactivii sunt clasificați în modificatori, floculanți, depresante, colectori și agenți de spumare, în funcție de rolul lor în procesul de flotație. Utilizarea nanomaterialelor în tratarea apelor reziduale a devenit un subiect intens studiat. Reactivii colectori, pe bază de nanoparticule hidrofobe, pot absorbi o cantitate mai mare de poluanți datorită suprafețelor cu particule hidrofile care facilitează atașarea poluanților de bulele de aer generate de unitatea DAF. În studiul de față, cercetătorii susțin că rolul nanoparticulelor este de a facilita atașarea bule-particule și/sau de a minimiza detașarea. Scopul studiului este de a lua în considerare influența parametrilor nanoparticulelor asupra diferitelor etape ale flotației particulelor pentru a demonstra rolul-cheie al nanoparticulelor în eliminarea poluanților din apele reziduale din industria textilă.

Cuvinte-cheie: unitate de flotație cu aer dizolvat (DAF), tratarea apelor reziduale, nanomaterial, sedimentator

Advanced wastewater treatment stage for textile industry

Dissolved air flotation represents an important stage for wastewater treatment and was used during the last sixty years for different pollutants such as: suspended solids, greases, oils etc. Nowadays, the dissolved air systems are generally applied in industrial wastewater treatment plants, where the amount of pollutants is above the average (textile and leather industry). The research team members developed an innovative DAF unit and realized a laboratory demonstrator (figure 1). The laboratory installation was tested and the efficiency of wastewater treatment was demonstrated. The latest researches proved that flotation reagents have an essential role in the removal of different pollutants. The scientific literature demonstrates that these reagents can be used to remove the pollutants as sludge or foam, Reagents are divided into modifiers, flocculants, depressants, collectors and frothers, depending on their role the flotation process. Nanomaterial utilization in wastewater treatment has become an intensely studied topic. Collectors reagents, based on hydrophobic nanoparticles, can adsorb a larger quantity of pollutants due to the hydrophilic particle surfaces that facilitate the attachment of pollutants to air bubbles generated by the DAF unit. In the present paper, the researchers present that the role of nanoparticles is to facilitate particle-bubble attachment and/or to minimize detachment. The goal of the study is to consider the influence of nanoparticle parameters on the various stages of particle flotation to demonstrate the key role of nanoparticles in removal of pollutants from textile wastewaters.

Keywords: dissolved flotation unit (DAF), wastewater treatment, nanomaterial, settler

INTRODUCTION

Textile industry requires important quantities of water, and accordingly produces important quantities of wastewaters with high quantities of different pollutants. Depending on the textile finishing procedures the discharged wastewaters may contain: organic substances (COD, BOD_5), dissolved organic agents, surfactants, halogenated organic compounds, heavy metals, dyes, sulphates, suspended solids, etc. The biological compounds can be biologically removed from wastewater, if the largely lacking nutrients (nitrogen and phosphorous) are supplementary added [1]. Textile wastewater treatment requirements vary, accordingly to the quantities of textiles that are finished and the technological processes inside the textile factories. Due to the large diversity of the finishing processes and factories, the wastewater quality is determined for each application. In general, the textile discharged wastewaters are treated in local wastewater treatment plants (WWTPs), managed by the textile companies, or in some cases are treated in municipal WWTPs. In the cases of direct discharge into a receiving water, process combinations consisting of the following process steps have proven to be successful. The minimum wastewater treatment processes for the textile production and finishing include: mechanical wastewater pre-treatment; storage and homogenization; flotation; pH neutralization; chemical precipitation; biological (aerobic and anoxic) treatment; process automation.

Dissolved air flotation (DAF) is an effective technology for treating a variety of wastewaters including the ones discharged from the textile industry [2]. DAF systems are used for the removal of suspended solids including fibers, greases, oils. Due to oxygen presence in wastewater tanks, other types of pollutants can be removed.

DAF is a two-step process, the first being the pre-treatment process and the second being a flotation process [3]. During the pre-treatment process, chemicals are introduced within the wastewater to create light, floatable flocs in the tanks. After pre-treatment process, air bubbles are introduced into the reactors. The air bubbles will float the flocs, so the pollutants are rising to the water surface from where are separated with the help of a skimmer.

UTILIZATION OF DISSOLVED AIR FLOTATION IN TEXTILE INDUSTRY

Dissolved air flotation is used for the removal of a wide range of pollutants and can be highly efficient if an uniform distribution of air bubbles is realised. The research team proposes a DAF unit for textile industry.

conditions, the dissolved air inside the water mass is transformed into micro air bubbles (20–100 microns). The air-water mixture is discharged inside a lamellar settler. The formed flocs are rising to the water surface and are removed with the help of a skimmer.

The DAF efficiency is dependent on the detention time and the contact surface area inside the capsule. The contact area can be increased by a very fine dispersion of the water and by small air bubbles inside the capsule. In this respect, the research team has made ample research on both air and water inlets. Figure 2,*A* presents the patented capsule [4] that was already tested for the wastewater treatment. The body of capsule has a cylindrical shape with 2 caps. Inside the pressure capsule water and air are introduced. The water feeding is located at the upper part of the capsule where treated/clean water is introduced through four sprinklers. So, the capsule is fed with very fine dispersed water drops and not with water jet. The air is introduced at the lower of the capsule. The air diffuser inside the capsule consists in a stainless-steel pipe with 1 mm apertures to introduce the air is small bubbles. In this way the contact

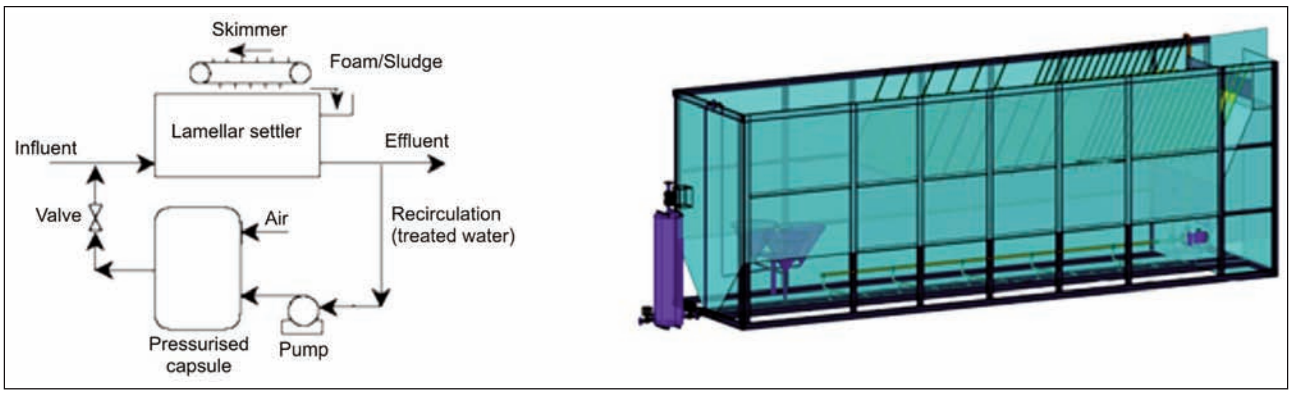
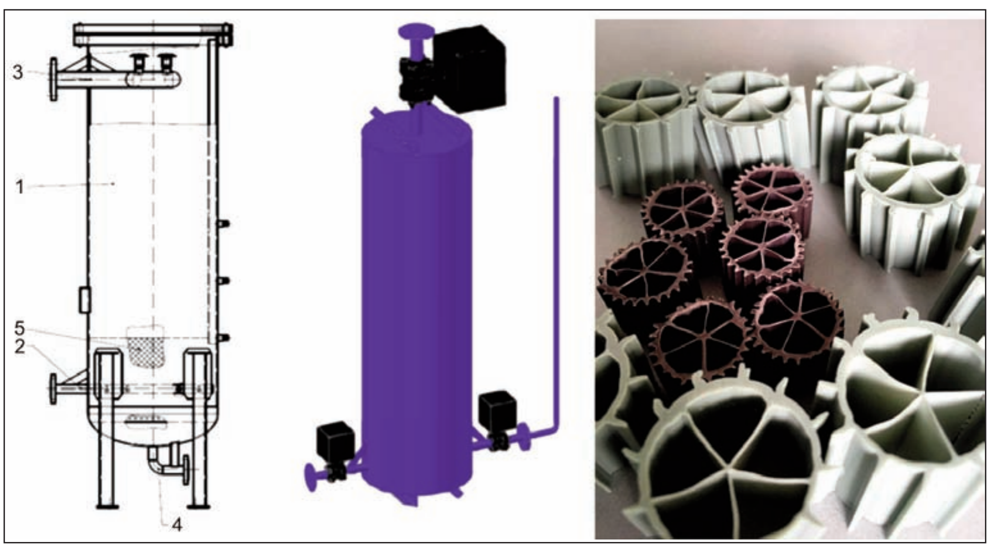


Fig. 1. Dissolved air flotation stage used in textile industry

The main components of the DAF technology consist in: a pressure capsule, a lamellar settler, a dosing system with nanomaterials for an increased pollutant removal efficiency (figure 1). The pressured capsule is feed with treated water and air. A pressure of 5 bar is created inside the capsule. The introduced air, under the pressure, is dissolved inside the water mass. This stage is followed by a depression to the atmospheric pressure. During the depression



A *B*

Fig. 2. Innovative pressure capsule proposed by the researchers:
A. *1* – pressure capsule; *2* – air inlet; *3* – water inlet; *4* – pressured water with dissolved air outlet; *5* – filling (small moving plastic elements, as shown in B); B. biofilm carriers inside the capsule

surface between air and water is maximized. To obtain a longer time contact between the air bubbles and water, the researchers introduced small plastic elements (figure 2, *B*) inside the capsule. This patented solution assures a better efficiency of small air bubble generation inside the lamellar settler.

LAMELLAR SETTER DESIGNING

Mathematical modelling processes and numerical simulations are starting to have a higher importance in the designing phase of various types of equipment. Using this tool, investors will save money and time.

In addition to engineering design calculations, numerical simulations have become a necessary activity in design. In the present study, the optimal shape for a lamellar clarifier was determined with the help of numerical simulations. The lamellar settles have an increased efficiency in settling solid suspensions relative to conventional longitudinal clarifiers.

In literature it is mentioned that for the sedimentation of granular particles, the low depth basins are economically preferable. These considerations have led to the emergence of lamellar decanters. The lamellar settler is highly efficient and does not require a very large space for the solid suspensions sedimentation. For such a lamellar clarifier, a series of mathematical modelling and numerical simulations were performed, as follows. These numerical simulations were necessary to avoid the preferential flows and currents inside the clarifier. To efficiently design the lamellar decanter, several types of lamellar decanters (with different dimensions, configurations and lengths of decanter plates) were analysed. Primarily, a decanter with a length of 2,000 mm, a useful height of 2,600 mm and a width of 3,000 mm was considered. A solid suspension concentration of 300 mg/l was also considered. The decanter plate package has a length of 1,500 mm (figure 3).

The discharge of the treated water outside the settler is performed at the top, i.e. the upper right corner of the images. It is noted that the lamellar settler provides high efficiency for the sedimentation process, yielding approximately 30 mg/l of solid suspensions. Forward the length of the decanter plates has been changed, and the results are shown in figure 4.

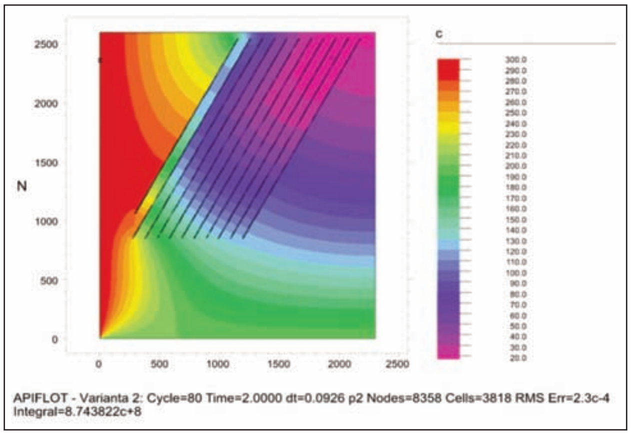


Fig. 4. Lamellar settler – variant 2. Sedimentation of solid suspensions

In comparison with the above-mentioned case, an improvement in the decanter efficiency is observed, which is in line with the results obtained by other researchers – increasing the length of the decanting plates provides greater efficiency. In the third option different lengths of decanting plates are considered (figure 5). As it can be seen in this case, the lamellar decanter is well-sized. The next step was increasing the number of decanter plates and the length of the decanter to 3,000 mm (figure 6).

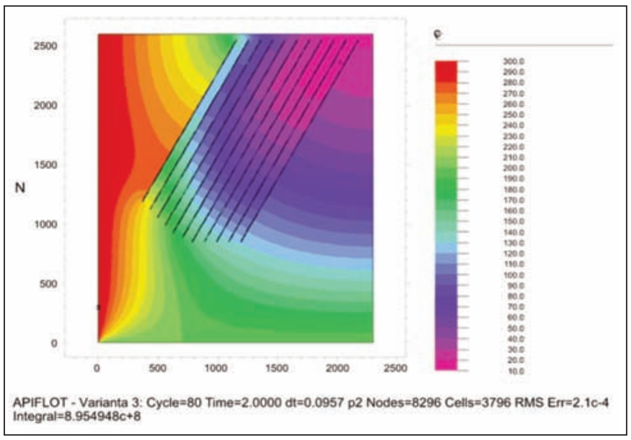


Fig. 5: Lamellar settler – variant 3. Sedimentation of solid suspensions

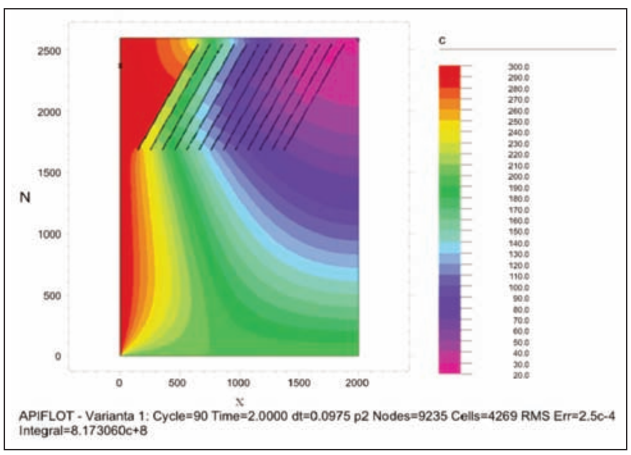


Fig. 3. Lamellar settler – variant 1. Sedimentation of solid suspensions

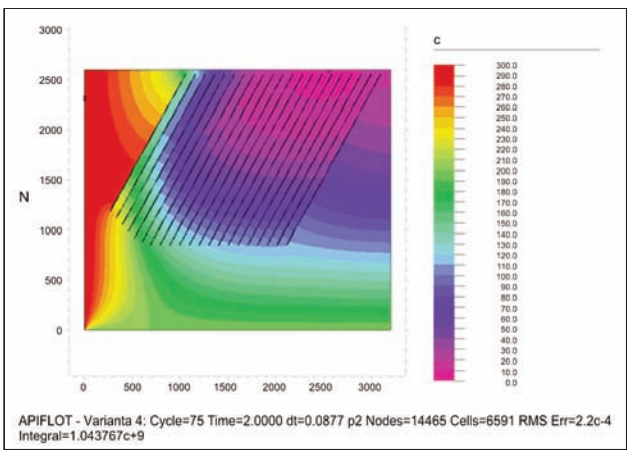


Fig. 6: Lamellar settler – variant 4. Sedimentation of solid suspensions

IMPROVEMENT OF THE DISSOLVED AIR FLOTATION SYSTEM

The treatment efficiency for the above presented DAF unit can be improved by adding a nanoparticle dosing system [5]. The nanoparticle introduced in DAF will have the role of stabilizing the foam. In this way more stable foam will be formed and evacuated from the system. The purpose of the dosing system is to allow a good dispersion of nanoparticles used as flotation agents in scrubbed wastewater. The component elements of the flotation agents dosing system are: metering pump; water tank with suspension particles; pipes; diffusion system inside the lamellar settler [6].
The flotation agents will be introduced in the tank where they will be uniformly incorporated in the water through the stirring system. From there, the floatation agents will be transported using a metering pump to the lamellar clarifier from where they will be injected into the residual water via the diffusion system. There they will adhere to colloidal particles or fat and froth. The foam will be collected so that through the particle recuperator, the flotation agents are recovered. Recovery further envisages the application of some methods for the regeneration of flotation agents from nanomaterials class. The metering pump will be protected from idle running with a float switch. The system diagram is presented in figure 7.

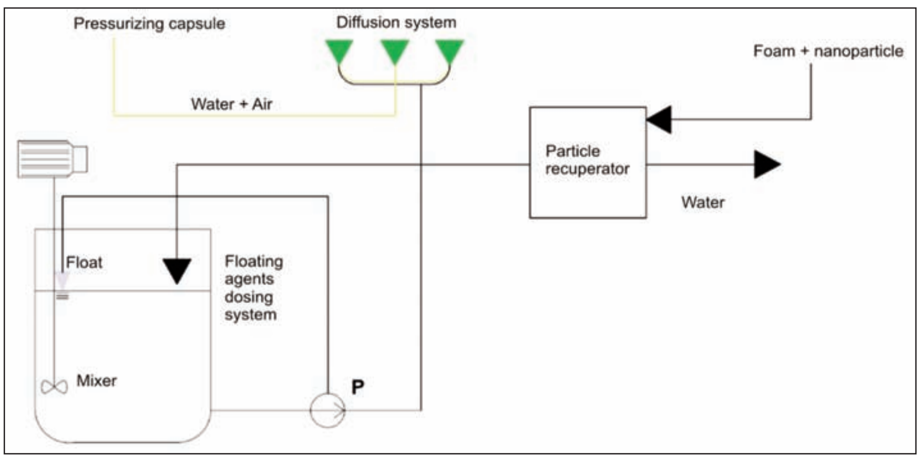


Fig. 7: Basic diagram for the flotation agents metering system

TYPES OF FLOTATION AGENTS THAT ARE USED IN DAF SYTEMS

The need to achieve a high efficiency in wastewater treatment, corroborated with environmental compliance, requires finding ways to improve and streamline the flotation process applied to heavily loaded waters. Flotation is a prerequisite for the purification of this type of highly loaded water intended to be purged within the system to be achieved in the present project.
The purpose of testing new types of nanoparticle collectors has been generated by finding new methods of removing and recovering materials-compounds which are found in a extremely low concentration in the water.

For example, for the purpose of separating/recovering valuable or pollutant particles (e.g. minerals), the flotation process is of particular importance. In the physico-chemical flotation process, the collector selectively binds the particles, increasing their hipprophobicity and thus promoting the attachment of particles to the air microbubbles [7].
Conventional collectors are low molecular weight surface active agents that promote adsorption on mineral surfaces [7]. According to Songtao Yang (2011) conventional water-soluble collectors can be partially or completely replaced by nanoparticulate hydrophobic colloidal collectors [7]. Songtao Yang et al. (2011) published the first report describing a new technology in which hydrophobic nanoparticles adsorb on much larger surfaces the hydrophilic mineral particles to improve the adsorption process at air bubble level. Songtao Yang et all. (2011) prepared by standard emulsion polymerization technique a series of nanoparticle suspensions, resulting in spherical particles with a very narrow dimensional distribution [8]. The major component of the nanoparticles was polystyrene, a rather hydrophobic plastic.
Nanoparticle collectors are likely to influence two important steps in the flotation mechanism: the adsorption of the beads to be separated from the water on the surface of the air bubble after collision and the desorption of unwanted particles from the surface of the bubble.
Understanding the mechanism by which nanoparticles make flotation more efficient is important because it is possible to find out what the role of nanoparticle size is in flotation.
A new idea for improving the process of flotation is introducing nanoparticles of inorganic nature (e.g. TiO_2, SiO_2, Al_2O_3, etc.) or organic (e.g. polystyrene etc.), which can increase the efficiency of wastewater pollutants removal. The role of nanoparticles in the flotation installation is to obtain high yields in removing organic pollutants from water, such as fats, dyes, oils, animal or vegetable waste.
Therefore, the following types of inorganic nanoparticles will be used for the purpose of flotation efficiency: SiO_2, TiO_2, Fe_2O_3 and Al_2O_3 which have already shown encouraging results in the flotation process, table 1 [9]. In the experiments to be performed, there will be tested 0.25 g/l of nanomaterial. By using the nanomaterials in the flotation process the following results are achieved: an increase in foam thickness and greater stability of micro-bubbles.
Particles of nanometric size stabilize the foam creating a barrier between the air bubbles so that they do not merge [10].

Table 1

Nanoparticles	Purity [%]	Particle size [nm]	PZC [pH]
TiO_2	99.5	15–30	3.4
SiO_2	99.9	15–20	-
γ-Al_2O_3	99.9	20	6.2
α-Fe_2O_3	99	20–40	7.6

CONCLUSIONS

From the data previously shown it can be noticed that the mathematical modelling has succeeded in highlighting the increased efficiency of the lamellar decanter. The lamellar clarifiers represent a very efficient equipment to be used for small-medium factories within the textile industry. The studies show that the lamellar decanter has numerous advantages over other decanting systems and can be successfully used in purification processes which include the flotation step.

In case of usage in the flotation steps, a system for removing the foam that forms on the free surface of the water will be required. In this way, a highly efficient wastewater treatment system will be developed to treat highly charged wastewater.

A new idea of improving the flotation process is the introduction into the equipment by means of a dosing system for flotation agents represented by nanoparticles of inorganic nature (ex. Al_2O_3, SiO_2, TiO_2, etc.) or organic (ex. polystyrene etc.), which can increase the pollutant removal efficiency from the discharged wastewaters. The role of nanoparticles in the flotation process is to obtain high yields for removing organic pollutants from water, such as fats, colloidal particles, dyes, oils, animal or vegetable waste as well for removing fine suspended solids in general.

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Textile & clothing clusters – sustainable development drive of the Romanian economy

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REZUMAT – ABSTRACT

Clustere din domeniul textile-confecții – motor de dezvoltare sustenabilă a economiei românești

Tendința, în rândul țărilor dezvoltate, este dezvoltarea de sisteme naționale cu interacțiuni internaționale complexe, numite de specialiști "triunghiuri ale cunoașterii". Triunghiul cunoașterii, constituit din educație, cercetare și inovare, se concretizează prin cooperarea dintre instituțiile de educație, organizațiile de cercetare și mediul de afaceri.
Importanța clusterelor privind creșterea competitivității regionale derivă din faptul că afacerile co-localizate cresc productivitatea companiilor, conduc la crearea de locuri de muncă, stimulează inovația, stimulează formarea de noi afaceri și sprijină supraviețuirea și dezvoltarea întreprinderilor mici. Această lucrare prezintă elemente pentru definirea clusterelor românești implicate în domeniul textile-confecții și analiza activității acestora. Conform Ministerului Economiei, în România, sunt înregistrate 4 clustere în domeniul textile-confecții, prezentate pe regiuni de dezvoltare.
Pentru o imagine detaliată privind activitatea clusterelor românești de textile-confecții, a fost realizată analiza indicatorilor economici ai acestora în perioada 2012-2016. Cifra de afaceri realizată de întreprinderile de textile-confecții din cadrul celor 4 clustere a fost, în 2016, de cca. 1,19 miliarde lei, angajând un personal de circa 7078 persoane. Clusterele au potențial de a crea ecosisteme favorabile inovării pentru întărirea grupurilor de IMM-uri în care nevoile acestora să fie mai bine exploatate, ca mijloc de promovare a creșterii economice.

Cuvinte-cheie: cluster, textile, confecții, sustenabilitate

Textile & clothing clusters – sustainable development drive of the Romanian economy

The tendency among developed countries is the development of national systems with complex international interactions, called by the specialists: "triangles of knowledge". The triangle of knowledge, consisting of education, research and innovation, is realized through cooperation between education institutions, research organizations and the business environment.
The importance of clusters to increase regional competitiveness comes from the fact that co-located businesses increase company productivity, lead to job creation, stimulate innovation, stimulate new business formation and support the survival and growth of small businesses.
This paper presents elements for defining the Romanian clusters involved in textile & clothing sector and their activity analysis.
According to the Ministry of Economy, in Romania there are 4 clusters in the textile & clothing sector, presented by development regions.
For a detailed view of the Romanian textile & clothingclusters activity, the analysis of their economic indicators during the period 2012-2016 was carried out. The turnover achieved by the textile & clothing enterprises part of the four clusters was in 2016 of 1.19 billionRON, employing a staff of about 7078 employees.
Clusters have the potential to create innovation-friendly ecosystems to strengthen SME clusters to better exploit their needs as a means of promoting economic growth.

Keywords: cluster, textile, clothing, sustainability

INTRODUCTION

The remarkable advances in technological development and innovation, which in recent years have occurred rapidly, influenced the organization and strategies in competitive environment.
The revolution of knowledge has been identified, a complex process of transition from the physical-driven economy to the intangible based one, intellectual resources (knowledge packages, human and informational capital). This approach plays an essential strategic role, being the engine of competitiveness.

It is known that, regardless of the field of activity, social welfare and added value is ensured through a systematic generation and efficient exploitation of knowledge. Thus, among developed countries, the trend is the development of national systems with complex international interactions, called by the specialists: "triangles of knowledge". The triangle of knowledge, consisting of education, research and innovation, is realized through cooperation between education institutions, research organizations and the business environment. Of these, the highest degree

of complexity, which raises the most problems (specific policies, the well prepared human resource, the financial resources needed to be allocated) is the innovation.
Innovation is a function of many variables due to the role it plays as a link element (bridge between research and industry). Reducing development time in the innovative products and services implemented in the industry is driving the acceleration of the economic circuit and thus increasing the satisfaction of the final user. Thus, the innovative process does not end with the implementation of new products and services in the industry, but it is continuously developing, step by step. Assimilation of the innovative process and ensuring cooperation between education institutions, research organizations and industry represent the environment of economic clusters.
Clusters appear naturally and reflect the unique assets and core competencies of a given region, that create unique competitive advantages for specific industries. Companies that are affiliated to a cluster structure have the benefit of visibility and sharing of tangible and intangible resources.
This paper presents elements for defining the Romanian clusters involved in textile & clothing sector and their activity analysis.

CLUSTER DEVELOPMENT FACTORS

The cluster concept means an organized, legally registered structure, made up of independent partners (enterprises, research organizations, universities, public authorities, nonprofit organizations, consultancy firms, commerce chambers, training centers, etc.), in order to increase the competitiveness of the group, by developing the production of innovative goods (technologies, products, processes) based on the cooperative innovation activities within the group, including through shared use of resources, as well as through the exchange and/or transfer of specialized knowledge [1].
Clusters include tightly linked and interconnected industrial operators operating in a certain geographic area. Companies operating in a cluster are connected through a common workforce, supply chain, customers or technology. Each cluster includes businesses and industry as well as companies that support them, which is a mutually beneficial business ecosystem.
The importance of clusters for increasing regional competitiveness stems from the fact that co-located businesses have the following attributes:
– increase company productivity;
– lead to job creation;
– stimulate innovation;
– stimulate new business formation;
– support the survival and growth of small businesses.
Clusters create synergies, and they lead to the creation of competitive advantages best illustrated by economist Michael Porter [2–3], stating that the economic success of a cluster depends on the complex interaction of factors such as enterprise demand, strategy and competition, production factors, supply chains, and horizontal integration, interconnected into a structure known as Porter's Diamond (figure 1).
The Porter's Diamond factor conditions are: material resources; human resources (labour costs, qualifications and commitment); knowledge resources; infrastructure; quality of research; liquidity on stock market; natural resources [4–5].
The relation between the related and supporting industries (suppliers) leads to sharing of know-how and encouraging each other by producing complementary products.
The demand conditions depend on the home demands (buyer needs, composition); size of the market (sophistication of the demands); early saturation. These generate a pressure that constantly improves the enterprise competitiveness [4–5].
The enterprise strategy, structure and right balance between benefits and cost associated with globalization are dynamic conditions, whichon actual direct market competition, impels the enterprise to work for increasing its productivity and innovation [4–5].
The government acts as a catalyst and challenger stimulating early demands for advanced products and services. The chance provides many advantages for the enterprises ready to start up new operations [5].

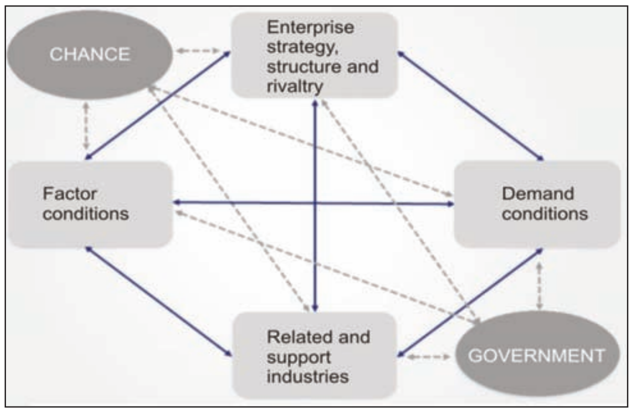

Fig. 1. The main factors that determine the competitive advantage – Porter's Diamond [4–5]

This model plays a critical role in driving innovations and improving the competitive advantage of companies, in terms of internationalization [6].
Clusters are catalysts for economic growth by providing a framework to organize disparate local and regional public policies and investment oriented towards economic development. Achieving this goal requires a number of factors that are closely linked (figure 2) [7].
Small and medium-sized enterprises (SMEs) provide crucial industrial links to trigger a broad-based industrial chain reaction. Without these SMEs, as contributors, industrial growth in developing countries may not be able to maintain an increase in domestic value, employment, productivity and industrial linkages [8]. In this context, innovative regional clusters

Fig. 2. Strategic framework for cluster development [7]

are a superior step because they ensure economic growth at regional and national level by interlinking cluster companies to a high level, leading them to functioning in an integrated system [9].

Under these circumstances, increasing the competitiveness of SMEs is a critical issue. Increasing the competitiveness and attractiveness of clusters and poles of competitiveness is a key element that can only be achieved by attracting investment. In many countries, cluster-oriented policies and programs have been successfully introduced to strengthen competitiveness and address the challenges of structural issues [10].

In Europe, more than 2000 clusters are active (of which 150 are the world's largest scale, in terms of number of jobs, concentration and specialization). These clusters operate together on regional markets and European consortia, integrating around 38% of the European workforce [11]. At the level of the European Union, the creation of added value and the development of clusters is a topical issue, handled responsibly, with an average of 3% of GDP in the RDI sector, given the threat of a new economic crisis [12].

The national industry is formed, in particular, from large, medium and small companies with private capital and a growing number of SMEs. Under these circumstances, Romania tends to align with this European allocation of additional funds to support RDI activity, adopting strategies aimed at increasing innovation performance in large companies and SMEs, encouraging partnerships between key institutional, economic and educational actors. In addition, the funds for research, development and innovation in clusters and centers of excellence (human resources, technology, infrastructure, managerial skills and abilities) must be increased in order to enhance the competitiveness of the Romanian economy at European and world level [13].

CONSIDERATIONS CONCERNING THE CONTRIBUTION OF TEXTILE – CLOTHING CLUSTERS TO SUSTAINABLE DEVELOPMENT OF ROMANIA

According to the Ministry of Economy, in Romania 72 clusters are registered, of which 52 clusters have been certified by the ESCA-European Secretariat for Cluster Analysis [14]. Among these are the four clusters in the textile-clothing sector, presented by development regions.

The four existing Romanian clusters in the textile-clothing domain were composed of the partnerships created within the stakeholders (enterprises, research organizations – National R&D Institute for Textiles and Leather, technical/economical/arts universities, public authorities, nonprofit organizations, consultancy firms, commerce chambers), with the support of national authorities and in the framework of specific national funding programs. The synergy of different actors involved in this same sector led to the creation of T&C clusters and generates future paths to realize other clusters.

The ROMANIAN TEXTILE CONCEPT CLUSTER – RTxC cluster [15] concentrates 61 actors (36 manufacturers), especially from the Bucharest-Ilfov, South-Muntenia, South-East Regions. The cluster was created as a common platform of cooperation between the members, aiming to support and consolidate their position within the industry by implementing innovative services, products and technologies, thus supporting the sustainable development of the textile industry and of the sector related services (footwear and leather, transport, media, education). RTxC cluster won the SILVER LABEL for cluster management, awarded by ESCA (European Secretariat for Cluster Analysis).

The ASTRICO NORD-EST CLUSTER – ASTRICO NE cluster [16] concentrates 31 members (28 companies) from the North-East Region of Romania. ASTRICO NORD-EST cluster is a powerful industrial production and marketing group based on RIFIL SA Company, a prestigious spinning mill in Europe that produces yarns for garments and industrial use. ASTRICO NORD-EST owns BRONZE LABEL for all managerial activity.

The TRADITIONS MANUFACTURE FUTURE CLUSTER – TMV cluster [17] concentrates 37 members (32 SMEs), especially in the South-East region of Romania, being a national landmark for creativity and technology. The TMV cluster aims to increase consumer consciousness and interest towards the phenomenon of fashion, the stabilization and improvement of the workforce in the field, the attraction of new companies and, last but not least, the creation of a regional brand. TMV cluster owns BRONZ LABEL for all managerial activity.

The TRANSYLVANIA TEXTILE & FASHION CLUSTER – TT&F cluster [18] concentrates 40 members (19 SMEs), especially from the central area of Romania. TT&F cluster aims to identify all the opportunities to achieve added value products through technology

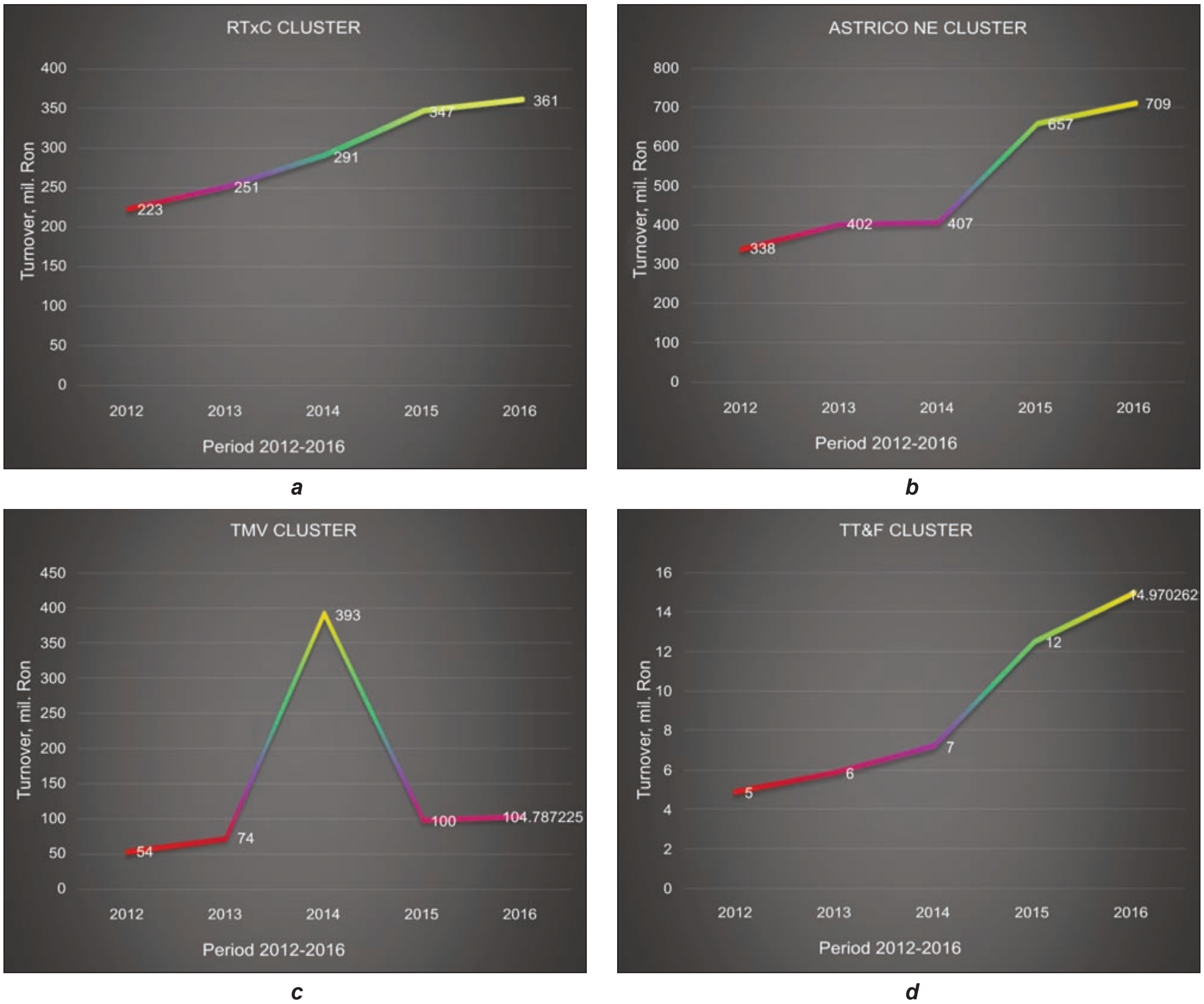

Fig. 3. Turnover evolution in RON during 2012-2016: *a* – RTxC; *b* – ASTRICO NE; *c* – TMV; *d* – TT&F

transfer and applied research. The TT&F cluster owns BRONZ LABEL for all managerial activity.

For a detailed view of the activity of the Romanian clusters involved in textile & clothing sector, the analysis of their economic indicators during the period 2012–2016 was carried out. Figure 3 shows the evolution of the turnover indicator for each of the Romanian textile & clothing clusters (figure 3, *a* – RTxC cluster, figure 3, *b* – ASTRICO NE cluster, figure 3, *c* – TMV cluster and figure 3, *d* – TT&F cluster). The values presented in the figure 3 represent the aggregate value of the turnover only for the producing enterprises, representing the business environment.

Depending on the economic evolution of the members, the clusters record different values for the turnover during the analyzed period.

It is worth mentioning that these clusters, which are a reaction to the market demands and the capitalization of the interconnections between the companies in the "activity area", can be considered central pillars of the local development.

It is noted that the highest value of this indicator is recorded by the ASTRICO NE cluster, over the entire period considered for the analysis (2012–2016).

The total turnover (of the 4 Romanian textiles & clothing clusters) has a positive evolution, with a maximum of 49.8% in 2014, compared to 2013 (figure 4). The turnover of the enterprises within the four Romanian textile & clothing clusters was 1.19 billion RON in 2016.

In terms of the number of employees, the RTxC cluster recorded a minimum in 2014 of 2754 people, in

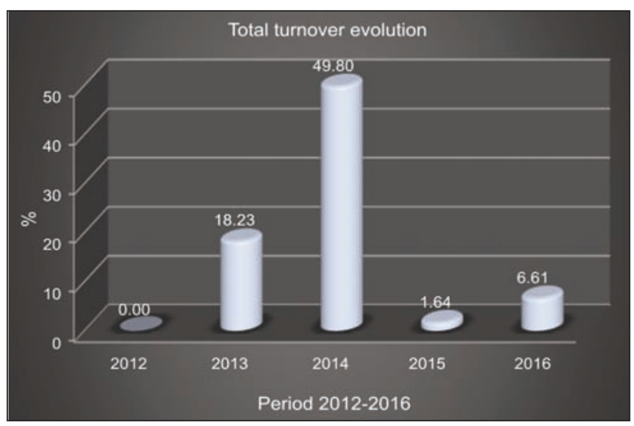

Fig. 4. Turnover evolution for the 4 Romanian textile & clothing clusters

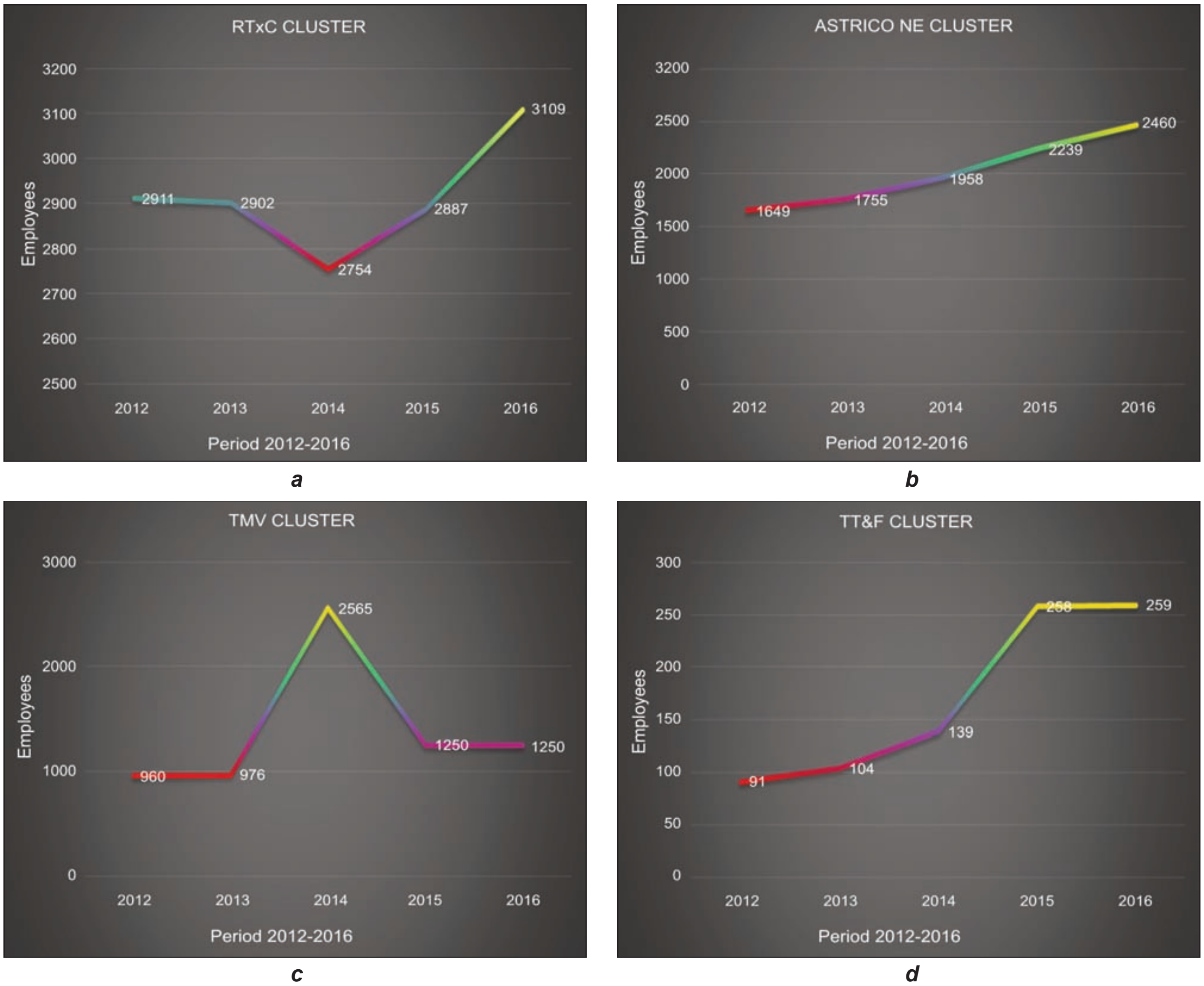

Fig. 5. Average number of employees evolution, during 2012–2016:
a – RTxC cluster; *b* – ASTRICO NE cluster; *c* – TMV cluster; *d* – TT&F cluster

order to reach 3109 in 2016. In the case of TMV cluster, in 2014 there was a maximum number of employees.

In the case of ASTRICO NE and TT&F clusters, the number of employees registered a trend of growth from 2012 to 2016 (figure 5).

The average total number of employees of the Romanian textile & clothing clusters had the following evolution in the period 2012–2016: 5611 persons were employed in 2012, the number increased to 5737 persons in 2013 (by 2.25%). The total average number of employees shows a maximum increase of 29.27% in 2014, compared to 2013, strongly influenced by the increase in the TMV cluster's number of employees in that period (figure 6). The total average number of employees decreased in 2015 to 6634 people (by 10.56%), and in 2016 it increased to 7078 people (by 6.71%).

In 2017, there was a turnover increase compared to 2016 for the RTxC, TT&F and ASTRICO NE clusters. Regarding the average number of employees, this indicator had a positive evolution in 2017 compared to 2016 for the RTxC and ASTRICO NE clusters, and a negative evolution for TT&F and TMV, respectively.

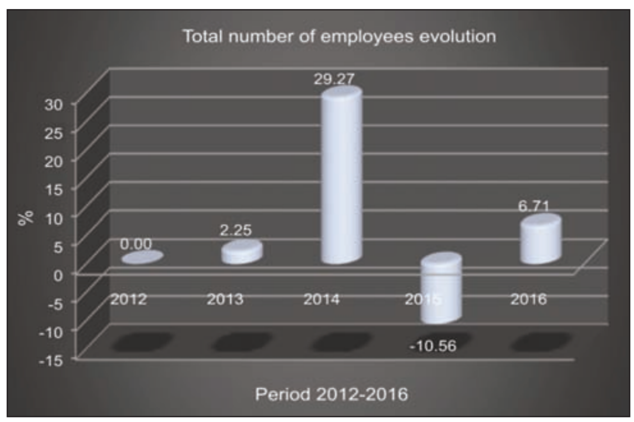

Fig. 6. Total number of employees' evolution for the Romanian textile & clothing clusters

The values of the elements of analysis (turnover, number of employees) are correlated with the dynamics of the local context accentuated by the local competitiveness ("the diamond of competitiveness").

CONCLUSIONS

In their area of activity, clusters have the potential to create innovation-friendly ecosystems to strengthen

SME groups, in order to better exploit their needs as a means of promoting economic growth. Cluster integrated companies are more competitive, more innovative, and cooperate more than single ones. The objectives of the national clusters in the field of textiles & clothing are in line with the strategic objective of the textile sector in Romania, namely to increase the competitiveness of the products under the conditions of the market economy, with minimal material and social costs and maximum efficiency.

The turnover of the Romanian textile& clothing enterprises within the four Romanian clusters was in RON 1.19 billion in 2016, employing a staff of about 7078 people.

In order to increase the economic indicators, textiles & clothing enterprises need support and information, joint development strategies, joint access to European funds, and the desideratum that is achieved through clustering. It is appreciated that the economic benefits generated by the clusters serve both the cluster members and the public interest, because efficiency, innovation and training levels reach higher odds. Thus clusters are perceived as a success story in the current world dominated by change.

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The evaluation of websites in the textile industry by applying ISO/IEC 9126-4 standard and the EDAS method

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REZUMAT – ABSTRACT

Evaluarea site-urilor web din industria textilă prin aplicarea standardului ISO/IEC 9126-4 și a metodei EDAS

În zilele noastre, companiile moderne realizează cea mai mare parte a comunicării cu consumatorii lor pe Internet, de obicei pentru a-și promova propriile produse și servicii. În prezent, nu există nicio companie care să nu își promoveze produsele și serviciile prin intermediul internetului și al site-urilor web. Prin urmare, măsurarea calității unui site web este semnificativă din punctul de vedere al companiei, pentru a menține avantajul competitiv pe termen lung; astfel, calitatea site-ului web a devenit un aspect de mare importanță. Lucrarea urmărește prezentarea unei noi abordări de luare a deciziilor cu mai multe criterii, împreună cu criteriile standardului de calitate ISO/IEC 9126-4 dedicate evaluării calității site-urilor web din industria textilă. Abordarea propusă se axează pe utilizarea noii metode de Evaluarea Bazată pe Distanța de la Soluția pe Termen Mediu (EDAS) pentru clasarea alternativelor, adică în cazul nostru site-urile web, în timp ce în scopul determinării ponderii, a fost aplicată metoda Analiza Raportului de Evaluare a Ponderii în Etape (SWARA). Pentru a demonstra utilitatea, eficiența și simplitatea, a fost realizat un exemplu numeric al evaluării site-urilor web ale industriei textile din Serbia.

Cuvinte-cheie: calitatea site-ului web, industria textilă, evaluare, EDAS, MCDM

The evaluation of websites in the textile industry by applying ISO/IEC 9126-4 standard and the EDAS method

Nowadays, modern companies perform the largest part of their communications with their consumers over the Internet, usually in order to promote their own products and services. There are almost no companies today that do not promote their products and services through the Internet and websites. Therefore, measuring the quality of a website is significant from the company's point of view in order to maintain the competitive advantage in the long run; thus, the quality of a website has become an area of great importance. This paper aims to present a new multiple-criteria decision-making approach, together with the "quality in use" ISO/IEC 9126-4 criteria devoted to the evaluation of the quality of websites in the textile industry. The proposed approach is based on the use of the newly-developed Evaluation Based on Distance from Average Solution (EDAS) method for the ranking of alternatives, i.e. in our case websites, whereas for the purpose of determining the weights, the adapted Step-wise Weight Assessment Ratio Analysis (SWARA) method is applied. In order to demonstrate usability, efficiency and simplicity a numerical example of the evaluation of the websites of the textile industry in Serbia is conducted.

Keywords: website quality, textile industry, evaluation, EDAS, MCDM

INTRODUCTION

The textile industry represents an important branch of the processing industry and is significant for the economy of a country. In the new era, the textile industry began to expand faster in the 18th century. The textile industry in Serbia has a long tradition and is one of the most important branches of the processing industry [1]. It belongs to the traditional branches of the processing industry. As a rule, it employs a large number of low-cost and low-skilled, mostly female laborers, whose work is paid much less than in the other branches of the processing industry. The social aspect of this branch is, therefore, extremely important for all countries. The textile industry is the most global industry in the world, with as many as 26 million employees, which amounts to 15% of the world's industrial workforce. The share of the social product of the textile industry in industry in 1990 was 10.06%, and in 1999, it was 6.8%. In the global context, this branch has undergone major changes since 1970, which coincides with the structural crises in developed countries, the globalization process and the accelerated liberalization of world trade [2]. The period of the development of the textile industry in the former Yugoslavia is referred to as the "golden age of the textile industry". At that time, more than 250,000 workers in the branch of the Republic of Serbia were employed in over a hundred factories [1]. The difficult political situation of the 1990s and the sanctions led to a fall in the share of Serbian textile factories in the market. After 2000, a very important branch of industry remained neglected. With the unsuccessful privatization process, almost all of the former textile giants were closed. For many years now, the unfavorable aspects of the textile enterprises market have reflected in a considerably low position on the world markets, unattainable competitiveness, obsolete equipment and technology, a drastic reduction in educated human resources and the insufficient training of the existing employees [3]. Also, Bratucu et al. point out that strong competition in this industry has forced companies to redirect their production to developing countries, which provide advantages from the aspect of legislative regulations, the policy, environmental protection regulations and, most importantly, labor costs [4].

An increasing and wider use of the Internet in everyday business has contributed to the development of the technological environment supportive of the integration of computer resources into business and manufacturing [5]. Today, the Internet represents a global multimedia distributed information system because it includes practically the whole world and allows not only access to the multimedia content distributed into space, but also the generation of a certain multimedia content based on the specific requirements of the users in the interactive mode [6]. Therefore, the Internet, as a global network, allows consumers to create an image of the actual value of a particular product and its benefits, which was impossible in earlier times in the case of the dominance of the one-way media. Today, the Internet offers companies a variety of web services, such as websites, to promote different content, products and services. Also, Hodge and Cagle point out that, since the introduction of the Internet and e-commerce in the mid-1990s, there has been a great deal of interference with the impact it will have on how companies operate and the changes in the global economy as a whole [7]. Lee and Kozar emphasize the fact that companies, due to increasing competition, are paying special attention to the importance of the quality of their websites in order to promote and/or sell their products and services [8]. Thus, the quality of the websites has become crucial for the acquisition of new consumers, as has been confirmed in numerous studies, such as: Al-Manasra et al. [9], Lin [10], Kim and Stoel [11], and so on.

The quality of websites has become an area of great importance. The quality of services, consumer services and customer satisfaction play an important role in the success and survival of websites, and these are the key elements a website should have in order for it to achieve good results. Therefore, the quality of websites is significant from a company's point of view, in order for a company to maintain the competitive advantage in the long run. So far, the WebQual model has been most frequently used to measure the quality of the website service [12], which is based on the principles of the SERVQUAL model [13]. On the other hand, official institutions in charge of standards and standardization, such as the ISO (International Organization for Standardization), are very seriously addressing the issue of quality and define the same as "the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs". It is also important to state that the ISO and the International Electrotechnical Commission have developed a metric for measuring and evaluating a software product. Within the above organizations, Working Group 6 have developed ISO/IEC 9126-1 (the quality model), 9126-2 (the external metrics), 9126-3 (the internal metrics), and 9126-4 (the quality-in-use metrics). These standards provide pragmatic guidance when it comes to the evaluation of software products [14–15].

Multiple-criteria decision-making methods (MCDM), as a part of operational research, are increasingly being used to solve a variety of problems. In due course of time, many MCDM methods have been proposed, such as: the AHP, the ANP, COPRAS, ARAS, SWARA, and so on [16]. Also, MCDM methods were successfully applied when the evaluation of websites is concerned [17–21].

Based on the previously stated, the newly-developed EDAS method and SWARA method will be used in this paper in order to evaluate websites in the textile industry in accordance with the ISO/IEC 9126-4 "quality-in-use" criteria, namely: Effectiveness; Efficiency; Satisfaction; Freedom from risk, and Context coverage. Therefore, the paper is organized as follows: Section 1 of this paper is the introduction. The methodology applied in the paper, more precisely the EDAS method, is presented in Section 2 and the SWARA method, is presented in Section 3. In Section 4, a numerical example of a website evaluation is shown. Finally, the conclusions are given in Section 5.

THE EDAS METHOD

The EDAS (Evaluation Based on Distance from Average Solution) is developed by Keshavarz Ghorabaee et al. [22]. The EDAS method has largely found its application, which is confirmed by various extensions [23–36].

The basic concepts of the EDAS method are the use of two distance measures, namely the Positive Distance from Average (PDA) and the Negative Distance from Average (NDA), and that the evaluation of alternatives is performed according to the higher values of the PDA and the lower values of the NDA.

Based on Stanujkic et al. [25], the computational procedure of the EDAS method for a decision-making problem with m criteria and n alternatives can be presented as follows:

***Step* 1.** Select the available alternatives, the most important criteria that describe the alternatives, and construct the decision-making matrix X, shown as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{1n} & x_{2n} & \dots & x_{mn} \end{bmatrix}, \quad (1)$$

where x_{ij} denotes the performance rating of the alternative i on the criterion j.

***Step* 2.** Determine the average solution according to all of the criteria, shown as follows:

$$x_j^* = (x_1, x_2, \dots, x_n), \quad (2)$$

where

$$x_j^* = \frac{\sum_{i=1}^{m} x_{ij}}{m}. \quad (3)$$

Step **3.** Calculate the positive distance from the average d_{ij}^+ and the negative distance from the average d_{ij}^-, according to the type of the criteria (the benefit and the cost), shown as follows:

$$d_{ij}^+ = \begin{cases} \dfrac{\max(0,(x_{ij} - x_j^*))}{x_j^*}; & j \in \Omega_{max} \\ \dfrac{\max(0,(x_j^* - x_{ij}))}{x_j^*}; & j \in \Omega_{min} \end{cases}, \quad (4)$$

$$d_{ij}^- = \begin{cases} \dfrac{\max(0,(x_j^* - x_{ij}))}{x_j^*}; & j \in \Omega_{max} \\ \dfrac{\max(0,(x_{ij} - x_j^*))}{x_j^*}; & j \in \Omega_{min} \end{cases}, \quad (5)$$

where Ω_{max} and Ω_{min} denotes the set of the benefit criteria and the cost criteria, respectively.

Step **4.** Determine the weighted sum of the PDA, Q_i^+, and the weighted sum of the NDS, Q_i^-, for all of the alternatives, as follows:

$$Q_i^+ = \sum_{j=1}^{n} w_j d_{ij}^+, \quad (6)$$

$$Q_i^- = \sum_{j=1}^{n} w_j d_{ij}^-. \quad (7)$$

Step **5.** Normalize the values of the weighted sum of the PDA and the weighted sum of the NDA for all of the alternatives, shown as follows:

$$S_i^+ = \frac{Q_i^+}{\max_i Q_i^+}, \quad (8)$$

$$S_i^- = 1 - \frac{Q_i^-}{\max_i Q_i^-}, \quad (9)$$

where S_i^+ and S_i^- denote the normalized weighted sum of the PDA and the NDA, respectively.

Step **6.** Calculate the appraisal score S_i for all of the alternatives, as follows:

$$S_i = \frac{1}{2}(S_i^+ + S_i^-). \quad (10)$$

Step **7.** Rank the alternatives according to the decreasing values of the appraisal score. The alternative with the highest S_i is the best choice among the candidate alternatives.

THE SWARA METHOD

The Step-wise Weight Assessment Ratio Analysis (SWARA) method was proposed by Kersuliene et al. [37]. The usability of the SWARA method has been proven in solving many MCDM problems, of which only several are mentioned [38–42].

The SWARA method has a certain similarity with the prominent AHP method. However, the computational procedures of the SWARA and the AHP methods significantly differ from one another.

The requirement that evaluation criteria should be sorted in descending order according to their expected significances can be mentioned as the weakness of the SWARA method, when it is compared with the AHP method. Therefore Stanujkic et al. proposed the use of the following equation for determining the importance of criteria as follows [43]:

$$s_j = \begin{cases} > 1 & \text{when } C_j \succ C_{j-1} \\ 1 & \text{when } C_j = C_{j-1} \\ < 1 & \text{when } C_j \prec C_{j-1} \end{cases}. \quad (11)$$

where: s_j denotes the comparative importance of the criterion j, and $C_j \Theta C_{j-1}$ denotes the significance of the criterion j in relation to the j–1 criterion.

Because of the above mentioned, the computational procedure of the adapted SWARA method, used in this article, could be precisely expressed by using the following steps:

Step **1.** Choose the criteria on the basis of which an evaluation of alternatives will be carried out.

Step **2.** Set the value of the relative importance of the criteria by using Eq. (11), starting from the second criterion. For the first criterion, the value of the relative importance of the criteria should be set to 1.

Step **3.** Calculate the coefficient k_j for the criterion j as follows:

$$k_j = 2 - s_j. \quad (12)$$

Step **4.** Calculate the recalculated weight q_j for the criterion j as follows:

$$q_j = \begin{cases} 1 & \text{if } j = 1 \\ \dfrac{q_{j-1}}{k_j} & \text{when } j > 1 \end{cases}. \quad (13)$$

Step **5.** Calculate the weights of the criteria as follows:

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k}. \quad (14)$$

where w_j denotes the weight of the criterion j.

A NUMERICAL EXAMPLE OF the WEBSITE EVALUATION IN THE TEXTILE INDUSTRY

In order to verify the proposed approach, a research study related to the quality of the websites of the four textile companies in Serbia was conducted.

In this case, the evaluation of the four websites was performed, namely: A_1 – http://www.spartan.rs/; A_2 – http://edi.rs; A_3 – http://www.elipsa.rs/ and A_4 – http://www.panter.co.rs/.

On the other hand, the evaluation of the above websites was carried out in relation to the following “quality-in-use” criteria: C_1 – Effectiveness; C_2 – Efficiency; C_3 – Satisfaction; C_4 – Freedom from risk, and C_5 – Context coverage.

The evaluation of the alternatives, i.e. websites in our case, in relation to the selected criteria was carried out by a domain expert. At the very beginning of the evaluation, the domain expert assigned weights to the selected criteria. The weights of the criteria were determined by using the adapted SWARA method. The weights of the criteria are shown in table 1.

After determining the weights of the evaluation criteria, the domain expert performs an evaluation of the alternatives in relation to the selected criteria. Table 2 shows the result of the evaluation of the alternatives in relation to the evaluation criteria.

After that, the average solution is determined for each criterion by using Eq. (3). The obtained results are displayed in table 3.

Table 1

THE SIGNIFICANCE OF THE CRITERIA ASSIGNED BY THE DOMAIN EXPERT

Criteria	E_1
C_1	0.28
C_2	0.24
C_3	0.18
C_4	0.16
C_5	0.14
	1

Table 2

THE RESULTS OF THE EVALUATION OF THE ALTERNATIVES, OBTAINED FROM THE DOMAIN EXPERT

Alternatives \ Criteria	C_1	C_2	C_3	C_4	C_5
A_1	4	5	5	4	4
A_2	3	3	3	2	3
A_3	4	3	4	3	4
A_4	2	2	1	2	1

Table 3

THE AVERAGE SOLUTION OF EACH EVALUATION CRITERION

Criteria	C_1	C_2	C_3	C_4	C_5
x_j^*	3.25	3.25	3.25	2.75	3.00

In the next step, the positive distance from the average d_{ij}^+ and the negative distance from the average d_{ij}^- are determined by using Eq. (4) and Eq. (5), respectively. The obtained results are accounted for in tables 4 and 5.

The weighted sum of the positive distance from the average, Q_i^+, and the weighted sum of the negative distance from the average, Q_i^-, are calculated by using Eq. (6) and Eq. (7), respectively, after which their normalized values, S_i^+ and S_i^-, are determined by using Eq. (8) and Eq. (9). The mentioned values are shown in table 6.

Finally, the appraisal score S_i of the considered alternatives is calculated by using Eq. (10). As can be seen from table 6, the best-ranked alternative is the alternative denoted as A_1.

Table 4

THE POSITIVE DISTANCE FROM THE AVERAGE

Alternatives \ Criteria	C_1	C_2	C_3	C_4	C_5
A_1	0.75	1.75	1.75	1.25	1.00
A_2	0.00	0.00	0.00	0.00	0.00
A_3	0.75	0.00	0.75	0.25	1.00
A_4	0.00	0.00	0.00	0.00	0.00

Table 5

THE NEGATIVE DISTANCE FROM THE AVERAGE

Alternatives \ Criteria	C_1	C_2	C_3	C_4	C_5
A_1	0.00	0.00	0.00	0.00	0.00
A_2	0.25	0.25	0.25	0.75	0.00
A_3	0.00	0.25	0.00	0.00	0.00
A_4	1.25	1.25	2.25	0.75	2.00

Table 6

THE APPRAISAL SCORE AND THE RANKING ORDER OF THE CONSIDERED ALTERNATIVES

Alternatives	Q_i^+	Q_i^-	S_i^+	S_i^-	S_i	Rank
A_1	1.28	0.00	1.00	1.00	1.00	1
A_2	0.00	0.30	0.00	0.79	0.40	3
A_3	0.53	0.06	0.41	0.96	0.68	2
A_4	0.00	1.45	0.00	0.00	0.00	4

CONCLUSIONS

In modern organizations, there have been major changes in the way of business doing. The rapid development of the Internet and information and communication technologies has influenced change in the way of trading. Thus, trade from classical stores is moving towards online trade. Therefore, due to the numerous advantages offered by e-commerce, an increasing number of customers decide to purchase online. Online shopping is becoming an increasingly common way of shopping, and in order for a website to succeed, it has to meet many customers' needs and expectations. Websites are being attributed a vital role by organizations in order for organizations to promote their products and services; for companies to be competitive, they will have to combine online sales and traditional sales channels, thus taking advantage of both.

A new approach to the evaluation and ranking of websites in the textile industry is the subject matter of consideration in this paper. The proposed approach is based on the use of the EDAS method for the selection of the alternative, i.e. websites, whereas the "quality-in-use" ISO/IEC 9126-4 criteria were used to evaluate the websites. After the presented numerical example of the evaluation of the websites in the textile industry, the alternative denoted as A_1 is the best-ranked in terms of the evaluation criteria. The usability, effectiveness, simplicity, applicability and adaptivity of the proposed approach is tested and verified in the considered numerical example regarding the evaluation of the websites in the textile industry.

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A framework of consumer perceived value on fashion products for female college students of France

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REZUMAT – ABSTRACT

Cadrul valoric perceput de consumator asupra articolelor de modă pentru studentele din Franța

În ultimul timp, valoarea percepută de consumator este din ce în ce mai mult în atenția experților în marketing și branding. Cercetările actuale existente referitoare la valoarea percepută de consumator sunt lipsa de analiză a dimensiunilor interioare ale cadrului valoric perceput de consumator. În acest studiu, cercetarea noastră se concentrează asupra dezvoltării cadrului valoric perceput de consumator. Pentru a demonstra aplicarea cadrului propus, a fost dezvoltat un cadru valoric perceput de consumator pentru articolele de modă destinate studentelor din Franța. Pentru a obține cadrul dorit, o ipoteză bazată pe cunoaștere a fost inițial efectuată de un grup de manageri de marketing în domeniul modei pentru a genera un set de dimensiuni și indicatori corespunzători pentru valoarea percepută de consumator, care conține 4 dimensiuni și 26 de indicatori. Cadrul de ipoteze a fost validat și adaptat printr-un proces de analiză statică bazat pe rezultatele experimentale ale colectării datelor de la 350 de studente din Franța. În cele din urmă, a fost obținut un cadru valoric perceput de consumator pentru studente, care conține 7 dimensiuni și 26 de indicatori. Cadrul propus a fost validat printr-un set de analize. Rezultatele experimentale conexe au demonstrat că poate fi aplicat în continuare cadrul final pentru analiza comportamentală a consumatorului, strategia de marketing și planificarea design-ului noilor produse și dezvoltarea produsului.

Cuvinte-cheie: valoarea percepută de consumator, analiza comportamentală a consumatorului, modelare, ipoteză, proces bazat pe cunoaștere, structură ierarhică

A framework of consumer perceived value on fashion products for female college students of France

Consumer perceived value is paid attention by marketing and branding experts recently. Current existing researches related to consumer perceived value are lack of analysis of inner dimensions of the consumer perceived value framework. In this study, our research focuses on the development of the consumer perceived value framework. To demonstrate the application of the proposed framework, a fashion-based consumer perceived value framework for French female college students is developed. In order to obtain the desired framework, a knowledge-based conjecture is firstly performed by a group of professional fashion marketing managers to generate a set of dimensions and corresponding indicators of consumer perceived value, which contains 4 dimensions and 26 indicators. After that, the conjecture framework is validated and adapted through a process of statics analysis based on experimental results of collecting data from 350 female college students in France. Finally, we obtained a framework of consumer perceived value for French female college students, which contains 7 dimensions and 26 indicators. The proposed framework is validated though a set of analysis. Related experimental result has demonstrated that the final framework can be further applied to consumer behavior analysis, marketing strategy and new product design and development planning.

Keywords: consumer perceived value, consumer behaviour analysis, modelling, conjecture, knowledge-based process, and hierarchical structure

INTRODUCTION

Consumer perceived value is a concept related to marketing and branding strategy [1–2]. Based on the theory of consumer perceived value, the success of a product is largely relied on whether customers believe it can satisfy their needs [3]. Consumer perceived value emphasizes the importance of developing a market driven product development and marketing strategy, in which customers ultimately determine how to interpret and react to marketing messages [4–5]. Existing research on consumer perceived value focuses on services in purchasing such as tourism, shopping mall service, tourism, mobile shopping [6–7]. In this study, we focuses on the development of a framework of consumer perceived value on fashion purchasing.

The concept of consumer perceived value was put forward as a strategic imperative for producers and retailers in the 1990s [8]. Evolution of this concept has two phases. First, Zeithaml pointed out that consumer perceived value should be obtained from the comparisons between expectations and perceptions [9]. She has suggested that perceived value could be regarded as "consumer's overall assessment of the utility of a product (or service) based on perceptions of what is received and what is given" [10]. After that, Monroe put forward that consumer perceived value should be defined as the ratio or trade-off between quality and price, which is a value-for-money conceptualization [11]. Clearly, there are two dimensions involved in consumer perceived value: quality and price. Based on the definition of consumer perceived value, Woodruff have demonstrated that the framework of consumer perceived value follows a hierarchical structure [12], in which the consumer perceived value can be found on the root, dimensions of consumer perceived value are on the branches, and the indicators affecting these dimensions are on the leaves. These dimensions and indicators are independent to each other. However, existing studies on consumer perceived value are too general, especially about the content of the dimensions of consumer perceived value. More specific dimensions of consumer perceived value should be defined.

In this study, in order to overcome the current limitations of the consumer perceived value, we develop a new framework with a hierarchical structure, capable of defining the dimensions of consumer perceived value in fashion products purchasing. The rest of this study is organized as follows. In Section 2, the general framework of the proposed consumer perceived value is outlined. Two experiments are presented to explain how to define the dimensions of the proposed framework and their relative weights. Experiment subjects are female college students from France. Section 3 discusses the experiment results and provides suggestions for fashion brands. Section 4 concludes this paper.

METHODOLOGY AND EXPERIMENTS

Experiment I: Knowledge-based conjecture of the proposed consumer perceived value framework

The collection of the raw data has been carried out in two steps. A group of experienced fashion marketing managers have been invited for the identification of the dimensions of the proposed consumer perceived value framework (figure 1). The invited marketing managers have met the following three requirements: (1) he/she work in fashion marketing for more than 10 years; (2) the selected people are top managers or high-level managers in the company; (3) the selected people are specialists in consumer behavior analysis. Finally, 20 fashion-marketing managers were selected. Prior to data collection, a training section was carried out to avoid cognitive confusions and better understanding of the purpose of the research by the involved fashion-marketing managers. First, each of the invited fashion-marketing managers was asked to give in-depth interviews on an exhaustive list of the relevant dimensions of consumer perceived value framework for fashion, based on their professional knowledge and experience. The dimensions should satisfy the several requirements, including: (1) the selected dimensions must be the key of the consumer perceived value related to fashion; (2) only the quantifiable (measurable) dimensions can be selected; (3) the definition and the measurement method of these dimensions must be stable. Secondly, a screening was performed by a "round table" discussion among all the invited fashion-marketing managers, to select the most appropriate dimensions. Finally, a set of 4 dimensions was selected. Using the same method, 26 indicators were selected.

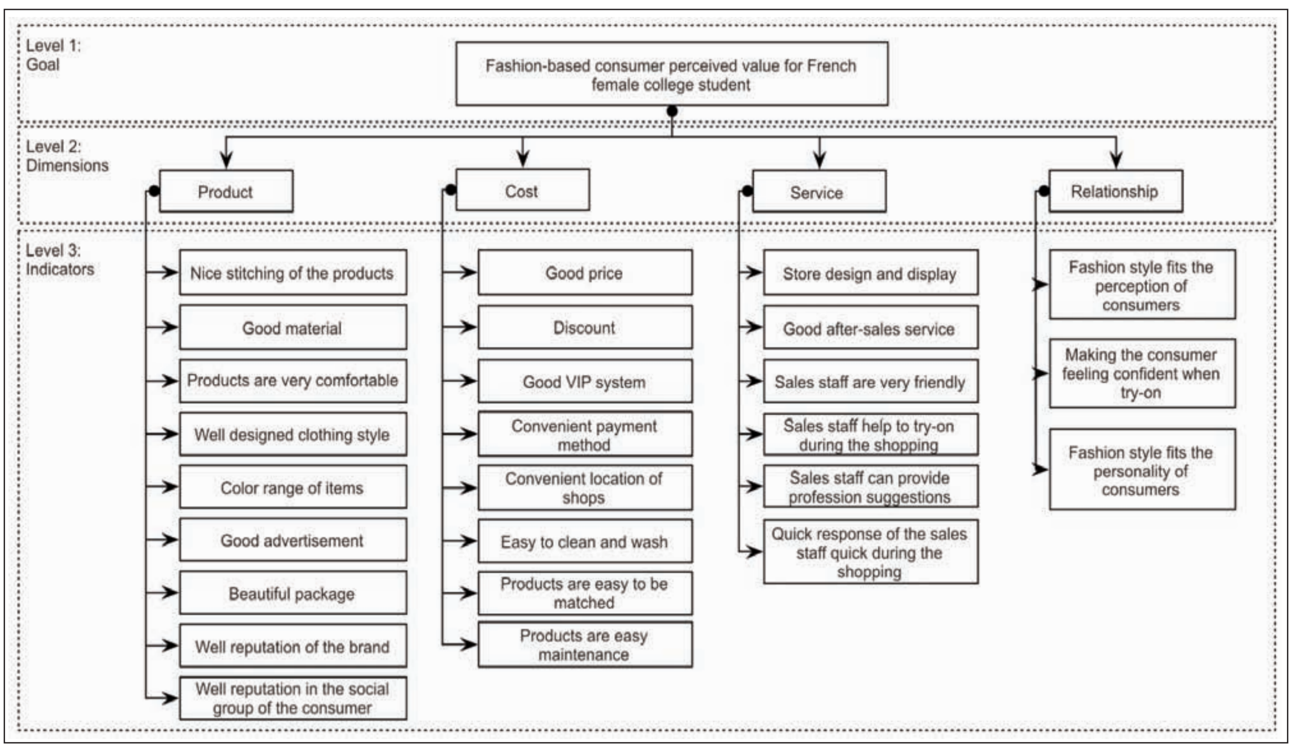

Fig. 1. Knowledge-based conjecture of the proposed consumer perceived value framework

Experiment II: Demonstration and adaptation of the conjecture

In Experiment II, a questionnaire concerning the importance of the selected 26 indicators was released to 350 female college students from 15 different cities in France. The questionnaire was made from the 26 indicators and uses the SD method to describe each indicator. In order for the participants to answer in a more assertive way, an importance on a 5-point bipolar adjective scale with a neutral point at the middle (quite unimportant, slightly unimportant, normal, slightly important, quite important) was employed. Besides, education background, average monthly living expense and average monthly fashion expense were also collected in the questionnaire. After the survey, 325 (92.3% of the whole 350 answers) proper answers were obtained.

Verification of the selected indicators

In order to verify if the selected 26 indicators are efficient, calculations of Common Factor Variance (CFV) were performed. Common Factor Variance has been verified for its potential in identifying if one indicator is relied on the common factor among all the indicators or not. If the CFV value of one certain indicator is too small, it should be considered to be an unreasonable indicator. Normally, the value of CFV of one indicator should be higher than 0.4. After the calculation of the CFV values, the whole 26 selected indicators are proved to be reasonable, which demonstrate the conjecture about the selection of 26 indicators is reasonable.

Verification of the selected consumer perceived value dimensions

In order to verify the selected value dimensions, Principal Component Analysis (PCA) was performed. PCA is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components [13]. Since indicators of consumer perceived value has been verified, this section was designed to verify if principal components obtained from PCA will support the previous conjecture gained by experts based on their experience.

After the analysis, there are seven principles whose Initial Eigenvalue is greater than 1. It means there are seven principle components can be selected. Figure 2 presents the result of the PCA. From figure 2, we can find out that, the first principal components have the largest eigenvalue. From the second principal component to the seventh component, the value of eigenvalue reduces gradually. From the eighth principle component, the rest eigenvalues are rather small. In this condition, we define seven principle components based on the static analysis, which is different from the conjecture.

In order to validate the independence of the selected seven principle components, Component Score Covariance (CSC) of these principle components were analyzed [13]. Using CSC analysis, it found that

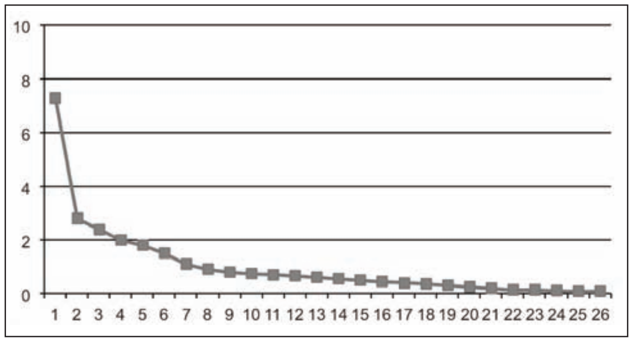

Fig. 2. PCA of the selected indicators

there is no linear correlation among the selected seven principle components. It can be concluded that all these principle components are independent. Let F_1, F_2, F_3, F_4, F_5, F_6 and F_7 be the new dimensions of the proposed consumer perceived value.

Adaptation of the structure of the proposed framework

Since the branch of the proposed hierarchical framework is modified, belongings of different indicators to different dimensions should be modified.

Table 1 presents Ingredient matrix composed of the capacity factor, which means the relationship between all the indicators and the selected principle components. When the value of one indicator on one certain principle component is higher, it means that this indicator is more greatly influenced by this principle component. For example, F_3 strongly influences the indicator *"Good price"*, *"Discount"*, *"Store design and display"*, *"Well reputation of the brand"*, *"Well reputation in the social group of the consumer"*, *"Good advertisement"* and *"Convenient payment method"*. However, F_4 also has impacts on *"Discount"*, *"Good VIP system"*, *"Sales staff can provide profession suggestions"*, *"Well reputation of the brand"*, *"Fashion style fits the perception of consumers"* and *"Good price"*. One indicator can be greatly influenced by two or more principle components. In this situation, Maximum Variance Rotation Method was applied to solve this problem [14]. After that, the whole 26 indicators are distributed to the seven principle components. Based on the distribution of the indicators, it is possible to redefine the seven principle components, as presented in table 2.

F_1 refers to 8 indicators: *"Convenient payment method"*, *"Convenient location of shops"*, *"Sales staff help to try-on during the shopping"*, *"Sales staff can provide profession suggestions"*, *"Beautiful package"*, *"Quick response of the sales staff quick during the shopping"*, *"Good after-sales service"* and *"Sales staff are very friendly"*. All of these indicators are related to the service provided in store. In this condition, F_1 is named as *"Service"*. F_2 refers to 5 indicators: *"Making the consumer feeling confident when try-on"*, *"Fashion style fits the personality of consumers"*, *"Color range of items"*, *"Fashion style fits the perception of consumers"*, and *"Well designed clothing style"*. All of these indicators are related to

Table 1

Selected indicators	Capacity factor of each indicator on each principle components						
	F_1	F_2	F_3	F_4	F_5	F_6	F_7
Good after-sales service	0.70	0.02	0.00	–0.14	0.04	–0.16	0.09
Quick response of the sales staff quick during the shopping	0.65	–0.12	0.08	–0.10	0.13	–0.02	0.09
Products are easy to be matched	0.64	0.01	0.00	–0.12	0.18	–0.16	–0.54
Beautiful package	0.62	–0.39	–0.19	0.15	–0.25	–0.16	0.18
Products are easy maintenance	0.60	–0.29	–0.19	–0.04	0.29	–0.23	–0.24
Sales staff help to try-on during the shopping	0.60	–0.42	–0.63	0.04	–0.30	–0.05	0.14
Nice stitching of the products	0.60	0.21	–0.27	–0.16	0.34	–0.14	0.29
Convenient location of shops	0.58	–0.39	0.17	–0.09	–0.17	–0.05	–0.04
Fashion style fits the perception of consumers	0.57	0.22	0.16	–0.35	–0.30	0.15	–0.13
Good material	0.57	0.27	–0.24	–0.04	0.31	–0.15	0.26
Fashion style fits the personality of consumers	0.56	0.31	–0.04	–0.08	–0.42	0.17	–0.15
Products are very comfortable	0.55	0.25	–0.23	0.06	0.41	–0.14	0.06
Convenient payment method	0.55	–0.29	0.31	–0.12	–0.14	–0.26	0.00
Making the consumer feeling confident when try-on	0.54	0.54	0.06	–0.10	–0.23	0.20	–0.12
Sales staff are very friendly	0.53	–0.04	0.21	–0.27	0.17	0.10	0.08
Good VIP system	0.51	–0.14	0.13	0.51	–0.09	–0.24	0.07
Good advertisement	0.51	–0.44	–0.32	0.24	0.03	0.39	0.02
Sales staff can provide profession suggestions	0.46	–0.22	0.33	–0.40	0.03	–0.04	0.21
Store design and display	0.46	-0.23	–0.45	0.37	–0.10	0.36	0.00
Color range of items	0.51	0.58	–0.15	0.11	–0.13	0.10	0.09
Well designed clothing style	0.42	0.54	–0.22	0.06	–0.23	–0.07	0.20
Good price	0.24	0.39	0.53	0.30	0.00	–0.11	–0.05
Discount	0.27	0.17	0.49	0.64	0.04	–0.20	–0.02
Well reputation of the brand	0.39	0.55	0.34	0.10	0.37	0.05	0.14
Well reputation in the social group of the consumer	0.38	–0.19	0.48	0.02	0.25	0.46	0.05
Easy to clean and wash	0.54	0.35	–0.22	0.09	0.17	0.05	–0.57

the emotional needs of the consumers. As this one doesn't exist in the conjecture, based on the context, F_2 is named as *"Emotion need"*. F_3 refers to 3 indicators: *"Nice stitching of the products"*, *"Good material"* and *"Products are very comfortable"*. All of these indicators are related to the internal properties of the product. In this condition, F_3 is named as *"Product internal properties"*. F_4 refers to 2 indicators: *"Store design and display"* and *"Good advertisement"*. All of these indicators are related to the visual image of the brand. In this condition, F_4 is named as *"Brand visual image"*. F_5 refers to 3 indicators: *"Easy to clean and wash"*, *"Products are easy maintenance"* and *"Products are easy to be matched"*. All of these indicators are related to if the products of the brand can save time and energy for the consumer. In this condition, F_5 is named as *"Non-monetary costs"*. F_6 refers to 3 indicators: *"Discount"*, *"Good price"* and *"Good VIP system"*. All of these indicators are related to the price of products. In this condition, F_6 is named as *"Price"*. F_7 refers to 2 indicators: *"Well reputation of the brand"* and *"Well reputation in the social group of the consumer"*. All of these indicators are related to the reputation.

RESULT DISCUSSIONS AND SUGGESTION

Result discussion

The final seven principle components, namely the dimensions of the proposed consumer perceived value framework, extracted by factor analysis are service, emotion need, product internal attribute, brand visual image, non-monetary cost, price and brand reputation. After empirical research, compared with the conjecture model, the final obtained model are more precise in the dimension division. Then final model can be regarded as the extension of the conjecture model.

The dimension of *"Service"* has not been changed. The dimension of "*Product*" is refined into "*Product internal attribute"* and *"Brand visual image"*. The dimension of *"Relationship"* has been changed to *"Emotion need"*, which better reflects the relationship between consumer and product. The dimension of

Table 2

Dimensions	Selected indicators of consumer perceived value	Capacity factor of each indicator on each principle components						
		F_1	F_2	F_3	F_4	F_5	F_6	F_7
F_1: Service	Convenient payment method	0.72						
	Convenient location of shops	0.68						
	Sales staff help to try-on during the shopping	0.66						
	Sales staff can provide profession suggestions	0.64						
	Beautiful package	0.61						
	Quick response of the sales staff quick during the shopping	0.55						
	Good after-sales service	0.50						
	Sales staff are very friendly	0.41						
F_2: Emotion need	Making the consumer feeling confident when try-on		0.78					
	Fashion style fits the personality of consumers		0.74					
	Color range of items		0.67					
	Fashion style fits the perception of consumers		0.64					
	Well designed clothing style		0.61					
F_3: Product internal properties	Nice stitching of the products			0.79				
	Good material			0.76				
	Products are very comfortable			0.69				
F_4 : Brand visual image	Good advertisement				0.82			
	Store design and display				0.78			
F_5: Non-monetary costs	Easy to clean and wash					0.77		
	Products are easy to be matched					0.74		
	Products are easy maintenance					0.57		
F_6: Price	Good price						0.87	
	Discount						0.65	
	Good VIP system						0.60	
F_7: Brand reputation	Well reputation in the social group of the consumer							0.78
	Well reputation of the brand							0.74
Eigenvalues		7.4	2.5	1.8	1.5	1.4	1.2	1.1
Explained variance		14.2	11	10	8.7	7.2	6.8	6.7
Cumulative variance		14.2	25	35.2	44	51	58	64.6

"Budget" is refined into *"Price"* and *"Non-monetary costs"*. Although the results of empirical research and the conjecture are different, but they both grasp the same understanding customer perceived value. The result affirms that conjecture is reasonable.

Suggestions to fashion brands

Based on the hierarchical model of fashion-based consumer perceived value for female college students in France, this section puts forward the corresponding marketing strategy for fashion brands from the aspects of service, product and price.

Service strategy

"Service" is the most influential dimension of female college students on fashion-based consumer perceived value. Indicators related to *"service"* can be classified into two groups: one is related to the convenience of consumption, another is related to the sales staff. For the aspect of the convenience of consumption, fashion brands should try to provide products in a fast and convenient manner.

On the other hand, regarding the sales staff, a professional training of the sales staff should be carried out especially about the professional skill and manner in service. In this context, fashion brands should provide good services to improve their consumers' perceived value. For example, carefully select the location of shops and try-to provide O2O service.

Product strategy

Based on the experiment data, *"product"* is also a dimension, which is very influential in consumer perceived value. In fashion marketing, "product" cannot be simply understood as "sell products". It refers to the product itself, but also has the extension of the promotion of the brand. Currently, French brands are strong in product design and development, but some

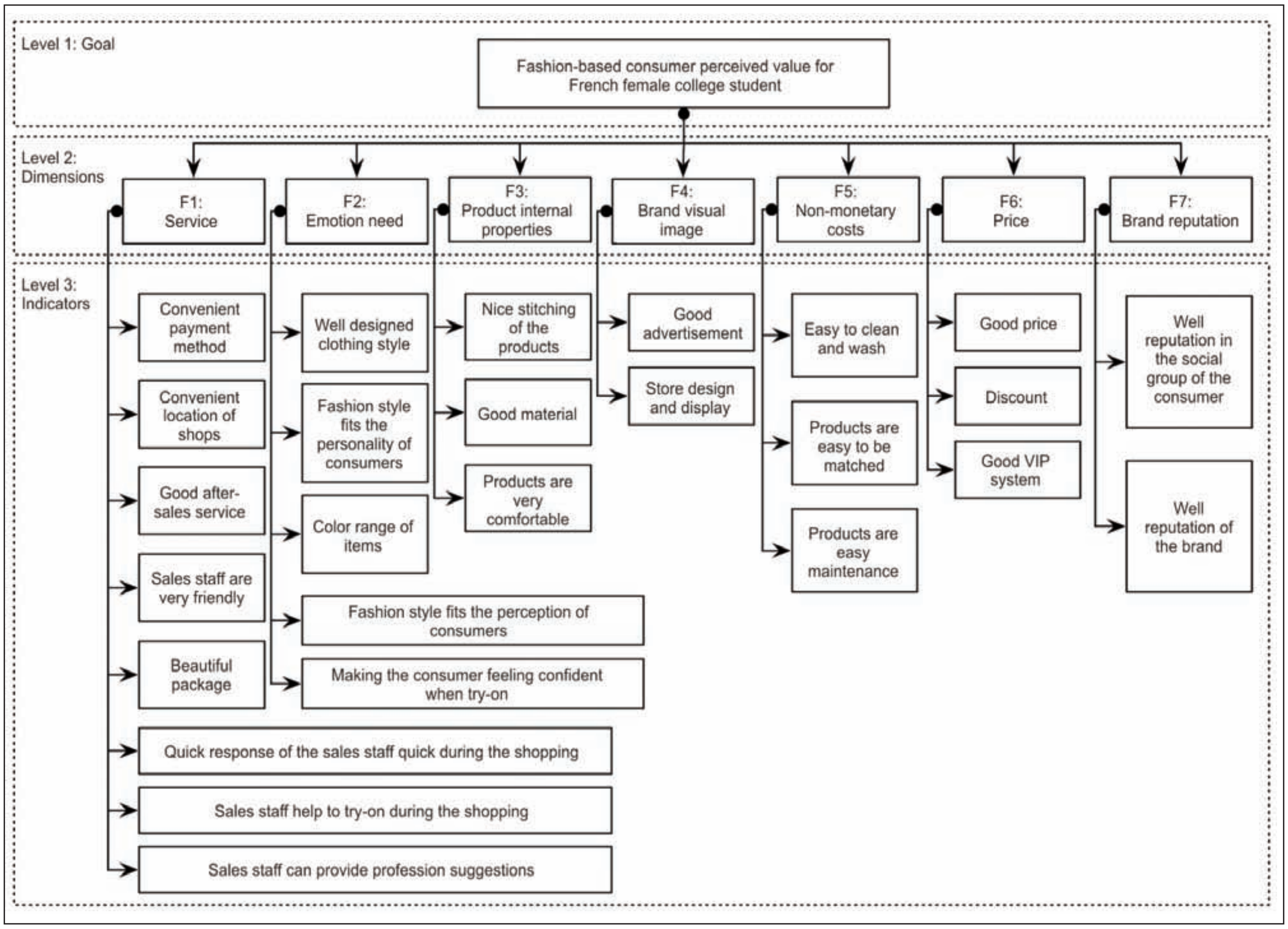

Fig. 3. Final consumer perceived value framework

of the local French brands have the problem of ambiguity of brand position and style. The relationship between “design” and “brand position” is not clearly verified. In this context, fashion brands should focus not only product development, but also built up good brand image. For example, seize the advantage of local culture, and promoting cultivates innovative design talents.

Price strategy

Due to the increasing competition, the market share of the female college students should be well captured by fashion brands. In the final obtained model, perceived value about *“price”* of female university students includes monetary cost and non-monetary cost. Different female university students’ perceptions of non-monetary cost are different. At the same time, monetary cost becomes the main factor, which has a direct impact on the purchase decision of female college students. In this situation, developing a reasonable price range should be well considered by fashion brands. Discount promotion can also be considered.

CONCLUSION

This paper analyzes the framework of fashion-based customer perceived value of French female college students. The analysis begins with knowledge-based theoretical conjecture, realized by experts based on their professional knowledge and experience. The conjecture framework is then validated and modified by experimental results.

Finally, we obtained a framework of consumer perceived value for French female college students, which contains 7 dimensions and 26 indicators. The proposed framework can be future applied to consumer behavior analysis, marketing strategy and product development planning.

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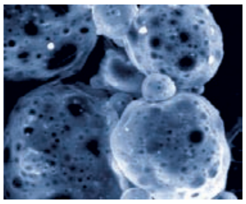

SWOT analysis of Pakistan's textile and clothing industry

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REZUMAT – ABSTRACT

Analiza SWOT a industriei textile și de îmbrăcăminte din Pakistan

Industria textilă și de îmbrăcăminte din Pakistan este unul dintre jucătorii importanți ai comerțului global de textile și îmbrăcăminte, fiind, de asemenea, o piatră de temelie pentru economia națională. Deși industria textilă și de îmbrăcăminte din Pakistan posedă resurse abundente de materii prime (bumbac) și de forță de muncă ieftină și abundentă, aceasta s-a confruntat cu multe probleme în ultimii ani. În acest moment, analiza SWOT este una dintre metodele care pot fi utilizate pentru analiza situației curente. Acest studio urmărește să prezinte situația actuală a industriei textile și de îmbrăcăminte din Pakistan prin analiza SWOT. Astfel, poate fi completat un decalaj în care studiile academice sunt inadecvate. În plus, studiul contribuie la dezvoltarea strategiei companiilor pakistaneze de textile și îmbrăcăminte și a oficialilor guvernamentali. În conformitate cu scopul cercetării, au fost determinate în primul rând punctele forte și dezavantajele industriei textile și de îmbrăcăminte din Pakistan. Ulterior, au fost analizate oportunitățile și amenințările comerțului național și internațional cu produse textile și de îmbrăcăminte. În cele din urmă, datele obținute au fost analizate și evaluate și au fost elaborate sugestii pentru viitorul industriei.

Cuvinte-cheie: industria textilă și de îmbrăcăminte din Pakistan, analiza SWOT, competitivitate, comerțul cu produse textile și îmbrăcăminte

SWOT analysis of Pakistan's textile and clothing industry

Pakistan's textile and clothing industry is one of the significant players of global textile and clothing trade as well as being a corner stone for its national economy. Although Pakistan's textile and clothing industry possesses abundant raw material resources (cotton) and cheap and abundant labour, it has confronted with many issues in recent years. At this point, SWOT analysis is one of the methods which can be used for the analysis of current situation. This research aims to reveal the present situation of Pakistan's textile and clothing industry with SWOT analysis. Thus, a gap can be filled in which academic studies are inadequate. Besides, the study contributes to the strategy development of Pakistan's textile and clothing companies and government executives. In accordance with the aim of the research, the strengths and weakness of Pakistan's textile and clothing industry are determined primarily. Afterwards, opportunities and threats, which can be faced within national and international textile and clothing trade are analyzed. Finally, the obtained data are analyzed and evaluated and suggestions are made for the future of the industry.

Keywords: Pakistan's textile and clothing industry, SWOT analysis, competitiveness, textile and clothing trade

INTRODUCTION

Asian countries have recently become the rising stars of global textile and clothing trade. Pakistan, which is one of these countries, is a leading global textile exporter. Pakistan textile and clothing industry, which is a locomotive of Pakistan economy, attracts attention with increasing export ratios. However, the academic studies within the literature, which analyze and scrutinize Pakistan's textile and clothing industry, which is one of the significant actors of global textile and clothing trade, in all aspects, are inadequate and lack of current information. Therefore, a current situation evaluation study, which can analyze the current situation of Pakistan textile and clothing industry and which can be helpful for developing future strategies, is needed. In this context, primarily, current situation of Pakistan's textile and clothing industry is analyzed in detail.

As known, textile is the basic industry of Pakistan. It is accorded as the backbone of Pakistan's economy as it is the remarkable source of Pakistan's export earnings. Textile industry is the single largest determinant for the economic growth of the country due to its share in the economy as well as its contribution to exports, employment, foreign exchange earnings, investment and revenue generation [1]. Textile and clothing industry approximately constitutes 62% of Pakistan's exports by 2016 (table 1).

Pakistan's textile industry provides approximately %40 of industrial labour force, 40% of manufacturing sector's banking credits, 8% of gross domestic product. According to the International Cotton Advisory Committee, Pakistan is the fourth largest cotton producer and third largest cotton consumer in the world. In addition, Pakistan is the world's second largest cotton yarn exporter and third largest cotton cloth manufacturer and exporter [3].

Easily available cheap labour and basic raw material (cotton) has played a primary role in the growth of Pakistan's textile industry. Pakistan's textile industry, which is the leading sector of industrial manufacturing, is based on abundant supply of indigenous cotton. In other words, it depends on cotton agriculture.

Table 1

SHARE OF TEXTILE AND CLOTHING INDUSTRY IN PAKISTAN'S GLOBAL TRADE (MILLION US DOLLAR) [2]						
	2011	**2012**	**2013**	**2014**	**2015**	**2016**
Pakistan's total exports	25,383	24,567	25,121	24,706	22,188	20,435
Pakistan's textile and clothing exports	13,632	12,919	13,890	14,068	13,255	12,783
Share of textile and clothing in exports (%)	53.71	52.59	55.29	56.94	59.74	62.55
Pakistan's total imports	44,012	44,105	44,647	47,434	44,219	47,155
Pakistan's textile and clothing imports	1,332	1,148	1,313	1,631	1,724	1,821
Share of textile and clothing in imports (%)	3.03	2.60	2.94	3.44	3.90	3.86

Therefore, whatever affects the cotton crop is likely to affect the performance of the textile industry [4].
Today, Pakistan has an integrated textile industry which comprises cotton spinning, cotton weaving, cotton fabric, fabric processing, home textiles, towels, hosiery, knitwear and clothing. These are manufactured both on large scale units and small and medium cottage units [5]. The major concentration of the industry is in the Karachi, Hyderabad, Multan, Lahore, Gujranwala and Faisalabad [1].
Since 2000, Government of Pakistan has been emphasizing the value added production in textile industry. For this purpose, comprehensive Textile Vision-2000 policy was formulated in order to bring innovations, implement market driven strategies and encounter the challenges of World Trade Organization. However, the progress of value added production in weaving and spinning has not been satisfactory [6].
In the mid of 2000s, Pakistan's textile production has seen a sharp increase in investment, which coupled with Pakistan's pool of inexpensive labour. It has attracted global brands, particularly in the manufacture of sportswear. Nevertheless, the industry's performance has been undermined recently by increased international competition, particularly after the phase-out of the Multifibre Agreement in December 2004. In addition, numerous infrastructure bottlenecks, particularly in the energy sector, crippled textiles production and squeezed the profit margins of textile and clothing producers [7].
In spite of these disadvantages, Pakistan's share in global textile exports is %2,7 by 2016 and it is the-seventh biggest textile exporter of the world [8]. Textile and clothing export and import figures of Pakistan and its shares within world textile trade are shown in table 2.
Textile and clothing exports of Pakistan according to product segments are shown in table 3 whereas the imports figures according to product segments are shown in table 4. As it can be seen, Pakistan mostly exports cotton (fibre, yarn and fabric), other made-up textile articles, knitted apparel and clothing accessories and woven apparel and clothing accessories. The biggest shares within cotton belong to cotton yarn other than sewing thread (containing >= 85% cotton by weight) and woven fabrics of cotton (containing >= 85% cotton by weight and weighing > 200 g/m²), whereas lion's share within other made-up textile articles belongs to bed linen, table linen, toilet linen and kitchen linen of all types of textile materials.
If the imported textile and clothing items of Pakistan are analyzed, it can be seen that Pakistan mostly imports cotton (fibre, yarn and fabric), man-made filaments (fibre, yarn and fabric) and man-made staple fibres (fibre, yarn and fabric). The lion's share within cotton belongs to neither carded nor combed cotton, whereas the biggest shares within man-made filaments and staples belong to synthetic filament yarn (including synthetic monofilaments of < 67 decitex) and artificial staple fibres (not carded or combed).

Table 2

	2011	**2012**	**2013**	**2014**	**2015**	**2016**
World textile export	293,844	283,430	303,503	313,621	290,519	284,064
Pakistan's textile export	9,082	8,705	9,341	9,077	8,232	7,680
Pakistan's share in world textile export	3.09	3.07	3.08	2.89	2.83	2.70
World textile import	311,299	301,950	324,505	335,258	308,108	303,934
Pakistan's textile import	1,245	1,077	1,245	1,545	1,621	1,716
Pakistan's share in world textile import	0.40	0.36	0.38	0.46	0.52	0.56
World clothing export	418,523	421,554	462,005	490,168	453,894	444,444
Pakistan's clothing export	4,550	4,214	4,549	4,991	5,023	5,103
Pakistan's share in world clothing export	1.09	1.00	0.98	1.02	1.11	1.14
World clothing import	438,190	457,034	502,610	525,977	498,525	468,793
Pakistan's clothing import	87	71	68	86	103	105
Pakistan's share in world clothing import	0.02	0.02	0.01	0.02	0.02	0.02

Table 3

	2012	2013	2014	2015	2016
50-Silk (fibre, yarn, fabric)	686	1,825	1,375	1,823	1,577
51-Wool and animal hair (fibre, yarn, fabric)	12,203	16,093	14,166	9,332	6,795
52-Cotton (fibre, yarn, fabric)	5,225,694	5,333,784	4,731,369	4,040,271	3,497,374
53-Other vegetable textile fibres (fibre, yarn, fabric)	5,629	2,140	1,282	3,046	3,119
54-Man-made filaments (fibre, yarn, fabric)	34,127	30,349	33,423	25,656	30,336
55-Man-made staple fibres (fibre, yarn, fabric)	449,180	418,173	417,658	302,343	220,487
56-Wadding, felt, nonwovens and special yarns	16,569	27,340	87,828	113,957	89,055
57-Carpets and other textile floor coverings	121,380	128,302	123,268	105,242	88,773
58-Special woven fabrics, lace and embroidery	25,959	21,917	22,067	18,916	22,784
59-Laminated textile fabrics	13,284	12,663	10,376	8,942	6,369
60-Knitted fabrics	36,085	32,565	35,969	41,862	36,064
61-Knitted apparel and clothing accessories	2,006,290	2,105,321	2,402,619	2,359,608	2,347,471
62-Woven apparel and clothing accessories	1,694,386	1,854,926	1,984,656	2,127,462	2,253,021
63-Other made-up textile articles	3,285,353	3,685,485	3,906,465	3,759,721	3,803,987

Table 4

	2012	2013	2014	2015	2016
50-Silk (fibre, yarn, fabric)	33,949	24,640	38,866	50,416	52,265
51-Wool and animal hair (fibre, yarn, fabric)	13,885	11,681	19,803	18,072	20,025
52-Cotton (fibre, yarn, fabric)	683,983	1,046,709	741,596	662,978	719,254
53-Other vegetable textile fibres (fibre, yarn, fabric)	53,230	50,524	48,426	48,058	42,159
54-Man-made filaments (fibre, yarn, fabric)	529,861	527,170	676,963	720,153	721,791
55-Man-made staple fibres (fibre, yarn, fabric)	539,396	532,440	766,145	782,754	687,043
56-Wadding, felt, nonwovens and special yarns	50,122	55,711	86,725	112,254	119,426
57-Carpets and other textile floor coverings	24,434	15,596	17,566	20,958	21,742
58-Special woven fabrics, lace and embroidery	45,625	44,932	46,017	30,979	36,791
59-Laminated textile fabrics	69,654	62,775	82,661	88,216	107,067
60-Knitted fabrics	33,365	41,016	74,884	122,101	171,495
61-Knitted apparel and clothing accessories	23,641	25,019	33,440	44,129	53,363
62-Woven apparel and clothing accessories	26,815	22,254	33,311	41,384	30,116
63-Other made-up textile articles	197,537	198,162	230,203	280,988	314,334

New strategies should be developed in order to increase Pakistan's textile and clothing exports. But before strategic development, it is necessary to identify the internal capabilities and weaknesses of Pakistan's textile and clothing industry. SWOT analysis is the one of the self-evaluating tools for measuring internal capabilities and weaknesses.

SWOT analysis method falls back upon four research directions as; strengths, weaknesses, opportunities and threats. The phases of SWOT analysis encompass three stages: the identification of strengths, weaknesses, opportunities and threats; the analysis of strengths, weaknesses, opportunities and threats and the formulation of the strategic alternatives [11]. It is a good tool for understanding the current situation of a company/industry/country and also helps to improve the status of company/industry/country. It also devises a plan for the future; one that employs the existing strengths, present and future opportunities and defends against the threats. The SWOT analysis of Pakistan's textile and clothing industry will help to identify the weaknesses of the present industry and also will help to rectify those weaknesses by using strengths and opportunities. The SWOT analysis will help to find solutions for threats, so that the industry will grow and become competitive against the rivals like China and India and also against the new growing countries like Bangladesh and Vietnam.

THE PURPOSE AND THE METHOD OF THE RESEARCH

Pakistan's textile and clothing industry has made significant progresses in recent years. These progresses are reflected well on country's economic development and industry's international trade. Thus, it is the seventh biggest textile exporter of the world. Abundant raw material resources, cheap and abundant labour force and preferential trade agreements with USA and European Union have significantly contributed to this rapid progress. Besides, textile and

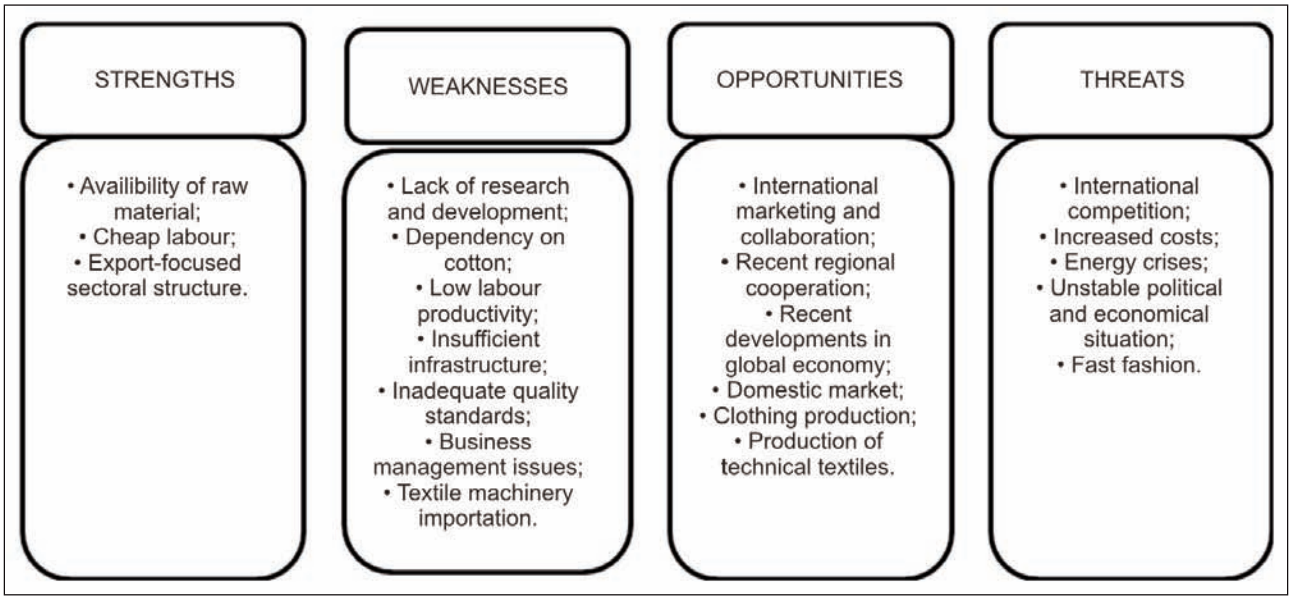

Fig. 1. SWOT analysis of Pakistan's textile and clothing industry

clothing cluster within South Asia has also contributed to this development.

This research aims to reveal the present situation of Pakistan's textile and clothing industry with SWOT analysis. Thus, a gap can be filled in which academic studies are inadequate. Besides, the study contributes to the strategy development of Pakistan's textile companies and government executives, supplier companies and countries and rival companies and countries.

In accordance with the aim of the research, the strengths and weakness of Pakistan's textile and clothing industry are determined primarily. Afterwards, opportunities and threats, which can be faced within national and international textile trade, are analyzed. Finally, the obtained data are analyzed and evaluated and suggestions are made for the future of the industry.

SWOT ANALYSIS OF PAKISTAN'S TEXTILE AND CLOTHING INDUSTRY

SWOT analysis of Pakistan's textile and clothing industry is summarized in figure 1.

Strengths of Pakistan's Textile and Clothing Industry

Availability of raw material

Pakistan has high self-sufficiency in raw material. According to Cotton Incorporated [12], Pakistan takes the 13 place within the leading cotton exporters of the world. However, it takes the fourth place within the biggest cotton producers of the world (table 5). Cotton is the main crop of Pakistan and textile industry mainly depends on cotton. In order to benefit from abundant cotton resources, Pakistan's textile industry has moved towards industrialization. Cotton (fibre, yarn and fabric) export and import figures of Pakistan throughout the years are shown in table 6.

Table 5

Country	2013/14	2014/15	2015/16	2016/17
India	31.0	29.5	26.4	27.0
China	32.8	30.0	22.0	22.8
USA	12.9	16.3	12.9	17.2
Pakistan	9.5	10.6	7.0	7.7
Brazil	8.0	7.0	5.9	6.8
Australia	4.1	2.3	2.9	4.2
Uzbekistan	4.1	3.9	3.8	3.7
Turkey	2.3	3.2	2.7	3.2
Burkina Faso	1.3	1.4	1.1	1.3
Turkmenistan	1.6	1.5	1.5	1.3
Mali	0.9	1.0	1.0	1.2
Mexico	0.9	1.3	0.9	0.8
Greece	1.4	1.3	1.0	1.0

Table 6

	2012	2013	2014	2015	2016
52-Cotton (fibre, yarn, fabric) export	5,225,694	5,333,784	4,731,369	4,040,271	3,497,374
Annual % change	-	2,07	–11,29	–14,61	–13,44
52-Cotton (fibre, yarn, fabric) import	683,983	1,046,709	741,596	662,978	719,254
Annual % change	-	53.03	–29.15	–10.60	8.49
Foreign trade balance of cotton	4,541,711	4,287,075	3,989,773	3,377,293	2,778,120

Table 7

Occupation	Wages per month (for 26 working days) (US$)	Wages per day (for 8 hours shift) (US$)
Technical manager Production manager Spinning/weaving/dyeingmaster	Wages alter due to the mutual bargaining between employers and employees	Wages alter due to the mutual bargaining between employers and employees
Head jobber Production supervisor Shift in charge Assistant spinning/weaving master	88.54	3.41
Highly skilled in printing, dyeing and finishing	79.92	3.07
Semi skilledin printing, dyeing and finishing	68.82	2.65
Unskilled in printing, dyeing and finishing	66.41	2.55

Cheap labour

Pakistan's textile industry provides approximately %40 of industrial labour force [3]. Cheap labour is the major strength of Pakistan's economy. Cheap labour supply strengthens the textile industry's position and at the same time it helps to increase the number oforders from USA and European markets. The wages of Pakistan's textile industry workers are given in table 7.

Export-focused sectoral structure

As it is mentioned before, Pakistan's textile and clothing industry approximately constitutes 62% of Pakistan's exports by 2016. Also Pakistan's share in global textile exports is %2,7 by 2016 and it is the seventh biggest textile exporter of the world. As it can be seen, the sector is focused on exportation and this situation strengthens sector's structure.

Weaknesses of Pakistan's Textile and Clothing Industry

Lack of research and development

There is lack of efficient research and development and training in Pakistan's textile and clothing sector [14]. The lack of research and development in the cotton sector of Pakistan has resulted in low quality of cotton in comparison to rest of Asia. Due to the low profitability in cotton crops, farmers are shifting to other crops such as sugar cane. It is the lack of proper research and development that has led to such a state [15].

Dependency on cotton

As discussed earlier, Pakistan's textile industry is dependent on cotton and cotton production. Therefore, Pakistan's textile industry is diminished due to the decreasing cotton production. As discussed in the introduction part, Pakistan mostly imports man-made filaments and staples (fibres, yarns and fabrics). In other terms, it imports synthetic fibres, yarns and fabrics which are widely used inclothing and technical textile production. Therefore, dependency on cotton restricts diversification of Pakistan's textile export. Every year Pakistan spends million dollars on synthetic fibres imports (table 8).

Low labour productivity

It is concluded that, lack of qualified skilledand educated labour force is a big constraint for textile and clothing exports of Pakistan [1, 5, 16]. Although Pakistan is labour abundant country, its labour productivity is remarkably lower than rivals due to

Table 8

SYNTHETIC FIBRES EXPORT AND IMPORT FIGURES OF PAKISTAN (THOUSAND US DOLLAR) [9]

	2012	2013	2014	2015	2016
54-Man-made filaments (fibre, yarn, fabric) export	34,127	30,349	33,423	25,656	30,336
Annual % change	-	–11.07	10.13	–23.24	18.24
54-Man-made filaments (fibre, yarn, fabric) import	529,861	527,170	676,963	720,153	721,791
Annual % change	-	–0.51	28.41	6.38	0.23
Foreign trade balance of man-made filaments	–495,734	–496,821	–643,540	–694,497	–691,455
55-Man-made staple fibres (fibre, yarn, fabric) export	449,180	418,173	417,658	302,343	220,487
Annual % change	-	–6.90	–0.12	–27.61	–27.07
55-Man-made staple fibres (fibre, yarn, fabric) import	539,396	532,440	766,145	782,754	687,043
Annual % change	-	–1.29	43.89	2.17	–12.23
Foreign trade balance of man-made staple fibres	–90,216	–114,267	–348,487	–480,411	–466,556

unqualified and unskilled labour force. Labour productivity can be improved by proper training and education. Therefore, redundant raw material usage can be reduced and product quality can be increased.

Insufficient infrastructure

Adequate infrastructure consists of sufficient water resources, continuous electricity and gas supplies, efficient logistics and transportation, proper tax structure and abundant raw material. These are the basic requirements for industry development. However, Pakistan is deficient in terms of adequate infrastructure. Nowadays, Pakistan textile industry faces with increasing electricity and gas prices which directly affect the production costs [4].

industry. Therefore, Pakistan cannot be able to fulfil orders on time. However, customers demand their orders on time in order to launch their own products on time. Consequently, Pakistan loses customers [4].

Textile machinery importation

Pakistan has given foreign trade deficit in textile machinery trade over the past five years (table 9). Its textile and leather machinery import has approximately increased %22 for the last five years. Therefore, Pakistan's textile and clothing sector is dependent on imported machineries.

The textile machinery used in Pakistan is imported mainly from countries like Japan, Switzerland, Germany, China and Belgium [14].

Table 9

	2012	2013	2014	2015	2016
724-Textile and leather machinery export	14,539	13,958	9,073	10,006	8,010
Annual % change	-	–4.00	–35.00	10.28	–19.95
724-Textile and leather machinery import	439,315	498,101	584,915	515,227	537,486
Annual % change	-	13.38	17.43	–11.91	4.32
Foreign trade balance of textile and leather machinery	–424,776	–484,143	–575,842	–505,221	–529,476

Moreover, critics argue that the textile industry has obsolete equipment and machinery. The inability to timely modernize the equipment and machinery has led to the decline of Pakistan's textile competitiveness. Due to obsolete technology, the production costs are higher in Pakistan as compared to other countries like India, Bangladesh and China [15].

Inadequate quality standards

Pakistan textile industry is currently facing several challenges. There is a need for the industry to improve the quality of its products [14]. Some of the large scaled Pakistani textile companies produce according to the standards whereas most of the small and medium sized companies do not focus on quality standards. Most of the small and medium sized companies purchase second-hand textile machines from China, India and South Korea. However, their machinery buying criteria only consist of cheapness and workableness. Consequently, these old machines are very poor in terms of quality and textile products which are produced by these machines possess low quality [5]. This situation usually ends with international customer and market loss. If an industry wants to be successful in international markets, it has to provide best quality. Therefore it has to produce according to the quality standards which are accepted globally.

Business management issues

Pakistan misses many opportunities due to the lack of professionalism, which is the basic requirement of today's business life. In addition, supply chain management is the key factor of successful business. However, supply chain management is rarely implemented in Pakistan's textile industry. This situation is resulted in disorganized, disconnected and distorted

Opportunities for Pakistan's Textile and Clothing Industry

International marketing and collaboration

Marketing can be defined asan art of product and service presentation. Marketing techniques are used in order to build good relationships with customers, present products and services outstandingly and take advantage of opportunities. If Pakistan invests in marketing techniques and marketing employees, it can easily increase its share within global textile and clothing trade.

Pakistani textile companies must reduce production costs, improve labour efficiency, apply quality standards, produce high value-added products, use marketing techniques successfully and penetrate into foreign markets. In this context; collaboration with other successful foreign companies can be useful, because a company can learn lots of things from its partners (suppliers, rivals, collaborators etc.).

Recent regional cooperation

The Shanghai Cooperation Organisation is a permanent intergovernmental international organisation, the creation of which was announced on 15 June 2001 in Shanghai (China) by the Republic of Kazakhstan, the People's Republic of China, the Kyrgyz Republic, the Russian Federation, the Republic of Tajikistan, and the Republic of Uzbekistan. It was preceded by the Shanghai Five mechanism [19]. For the first time since its 2001 inception, the Shanghai Cooperation Organization has a pair of new members. By simultaneously adding Pakistan and India to the organization in June 2017, now it represents nearly half of the global population, as well as significant economic and geographic heft [20]. Therefore, this regional cooperation is a huge opportunity for Pakistan's textile and clothing industry.

Recent developments in global economy

Global economic activity is picking up with a long-awaited cyclical recovery in investment, manufacturing, and trade. World growth is expected to rise from 3.1 percent in 2016 to 3.5 percent in 2017 and 3.6 percent in 2018 [21]. According to the latest projections by the World Bank, in emerging and developing economies, growth is projected to accelerate to 4.2 percent in 2017 from 3.4 percent in 2016 [22]. Pakistan's textile and clothing industry can find new markets and increase its exportation due to these recent developments in global economy.

Domestic market

In addition to increasing global demand, Pakistan also enjoys a huge domestic demand owing to its huge population size [14]. Domestic demand is raised due to the recent migration of the population from the agrarian society to the urban areas, increased income levels and population growth [16].

Clothing production

Pakistani textile and clothing companies should produce and sell high value-added products in order to compete with their rivals and increase their market share. In this context, selling clothes instead of raw cotton would be better in terms of earning profit. Therefore, Pakistani textile and clothing companies should be focused on clothing production.

Production of technical textiles

Technical textiles gain more importance from day to day. Therefore, Pakistan must give great importance to this segment. However, neither government nor the textile companies pay attention to this segment. Pakistan spends excessively every year during technical textile (aerospace, military, marine and medical products) importation. Although textile is the backbone of Pakistan's economy, the sector only focuses on conventional products. Therefore, Pakistani textile and clothing companies should be focused on technical textile production.

Threats for Pakistan's Textile and Clothing Industry

International competition

Textile industry is one of the oldest industries in Pakistan and in spite of its inherent strengths; it loses its competitiveness to other countries, especially in South East Asian countries [14]. Bangladesh, India and China are rivals of Pakistan in its major export markets (European Union and USA) in terms of textile industry. Also the recessions in the West has resulted in a slowdown in demand for textile products. Due to all the other problems faced by the textile industry, its production capacity and quality continues to decrease. Therefore, Pakistan is lagging behind its competitors and it is a huge threat for Pakistan's textile industry [5].

Increased costs

Pakistan textile industry possesses higher labour costs, longer labour hours, higher electricity and transportation costs (table 10). In addition to these building costs in Pakistan are extremely high according to its rivals. Therefore, total production costs are increased due to high input costs.

In addition to these, shortage of electricity, high interest rates, double digit inflation and descending value of Pakistani rupee also increase the production costs because the production of textile industry is decreased due to these challenges whereas its fixed costs are remained same. Besides, cotton and other raw material prices fluctuate rapidly in Pakistan [15, 24]. Therefore, Pakistan textile and clothing industry should find a way for cost reduction in order to gain competitiveness.

Table 10

Cost category	1 (lowest)	2	3	4	5 (highest)
Labour cost	Bangladesh	Cambodia	Pakistan	India	China
Labour hours	Bangladesh	China	Pakistan	India	Cambodia
Electricity cost	Bangladesh	China	Pakistan	India	Cambodia
Ocean transport cost	China	Bangladesh/Cambodia	Pakistan	India	-
Land transport cost	Bangladesh	Pakistan	India	China	Cambodia
Building cost	China	Bangladesh	Cambodia	India	Pakistan

Energy crises

Energy prices vary from country to country. In this context, Pakistan possesses higher electricity prices than its rivals (table 11). In this context, production costs are increased due to the increasing energy prices.

Currently in Pakistan, there is an acute shortage of energy and it is indeed facing one of the worst energy scenarios since its birth back in 1947. The shortfall of electricity, natural gas and petroleum products

Table 11

Country	Average price (US$/KWh)
Bangladesh	0.0418
China	0.0650
India	0.0433
Pakistan	0.0491

has greatly affected the daily life of almost every Pakistani. Presently, industrial and agricultural growth are on the decline due to the shortage of energy which gave birth to many vices like inflation, unemployment, unrest, everyday strikes, street crimes, intolerance in the society and increase of the poverty level in the country [25].

Unstable political and economic situation

Unstable political situation and corrupt system in the country are one of the major reasons of industrial decline. Industrial activities cannot be performed in a disturbance and fear atmosphere. Besides, Pakistan is a country where policies are rapidly changed even in days and weeks. Moreover, the recent terrorist attacks within the country results in high freight costs. Therefore, textile industry cannot develop properly without long-termed and consistent policies [5].

Fast fashion

Nowadays, product life cycles within the clothing sector are shortened due to the rapid alterations and fashion concept. Companies frequently present new collections to their customers in order to comply with fast fashion. In this context, fast fashion poses a threat to Pakistan's textile and clothing industry because Pakistan is lack of new machines, fast and efficient production and qualified labours. Therefore, customers prefer Pakistan's rivals even at higher costs due to the deadline issues.

CONCLUSIONS, GENERAL EVALUATION AND SUGGESTIONS

Pakistan's textile and clothing industry has recently gone through serious and strategic processes. Global developments also seriously affect these strategic processes. However, textile and clothing industry is mostly affected by internal issues such as high electricity prices, frequent power cuts, devaluation of Pakistani rupee, high production costs, political uncertainties, low labour productivity, inadequate quality standards, insufficient infrastructure and absence of research and development activities. These issues negatively affect competitiveness and exportation of textile and clothing industry.

In spite of these issues, Pakistan's textile and clothing industry has an important place in Pakistan's economy. Also it is the seventh biggest textile exporter of the world. Therefore, significant precautions should be taken in order to improve and enhance this industry. As a consequence, some suggestions are made for Pakistan's textile and clothing industry.

1. Short, medium and long term policies and incentive implementations of government must be reviewed and activated.
2. Pakistan's textile and clothing industry is dependent on cotton and cotton production. However, the industry must be focused on clothing and technical textile production. In other words, it should produce and sell high value added products. Thus, exportation amounts and values can be increased.
3. Although Pakistan is labour abundant country, it lacks for qualified labour force. Its labour productivity is remarkably lower than its rivals. Labour skills and productivity should be improved by proper training and education.
4. Pakistan possesses higher energy prices than its rivals. Production costs are increased due to the increasing electricity and gas prices. Besides, power cut (electricity and natural gas cuts) is the main problem of Pakistan's textile and clothing industry. Therefore; continuous, adequate and cheaper power should be supplied.
5. All Pakistani textile and clothing companies should pay attention to international quality standards. The products must be manufactured according to these standards.
6. All Pakistani textile and clothing companies should invest in technology. High technology is helpful in terms of product quality and customer satisfaction.
7. Pakistan is dependent on textile machinery importation. Therefore, companies should invest to this segment.
8. Pakistan's textile and clothing industry should pay attention to accurate business management in order to prevent from disorganized, disconnected and distorted industry.

To sum up, textile and clothing industry's share and efficiency within Pakistan economy should be increased progressively and permanently.

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Statistical study of the effect of metallic mordants on tensile strength of wool

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REZUMAT – ABSTRACT

Studiul statistic al efectului mordantului metallic asupra rezistenței la tracțiune a lânii

În ciuda varietății mari de studii în domeniul efectului diferiților mordanți asupra proprietăților de vopsire și de rezistență a culorii lânii cu coloranți naturali, nu există o investigație aprofundată a efectului mordantului metallic asupra proprietăților de tracțiune a lânii. În acest studiu s-au aplicat cinci tipuri diferite de săruri metalice pe lână: sulfatul de potasiu, de aluminiu, clorura de staniu, dicromatul de potasiu, sulfatul de cupru și sulfatul feros, cu concentrații cuprinse între 1 %owf și 20 %owf. Rezistența la tracțiune a probelor a fost măsurată și a fost utilizat software-ul SPSS pentru a evidenția efectul diferitelor concentrații de mordanți asupra rezistenței la tracțiune a firelor de lână, comparativ cu proba netratată. Rezultatele au arătat că sulfatul de potasiu, de aluminiu și sulfatul feros nu au avut un efect semnificativ statistic asupra rezistenței firelor, în timp ce clorura de staniu a prezentat cel mai mare effect și a redus în mod semnificativ rezistența firelor. Sulfatul de potasiu, de aluminiu și sulfatul feros au redus tenacitatea la maximum 4,2 %owf și respectiv 4,4 %owf, în timp ce proba tratată cu clorură de staniu a fost complet distrusă atunci când s-a aplicat mai mult de 5 %owf din mordant.

Cuvinte-cheie: mordant, tenacitate, lână, formare complex, alaun, SPSS

Statistical study of the effect of metallic mordants on tensile strength of wool

Despite the vast variety of studies in the field of effect of different mordants on dyeing and fastness properties of wool with natural dyes, there is no thorough investigation on the effect of metal mordants on tensile properties of wool. In this study, five different metallic salts namely aluminum potassium sulfate, tin chloride, potassium dichromate, copper sulfate, and ferrous sulfate were applied on wool with concentrations ranging from 1 %owf to 20 %owf. The tenacity of the samples was measured and SPSS software was employed to investigate the effect of different concentrations of various mordants on tensile strength of woolen yarn compared with raw sample. The results showed that aluminum potassium sulfate and ferrous sulfate had no statistically significant effect on the tenacity of the yarns while tin chloride showed the highest inverse effect and lowered the yarn strength significantly. Aluminum potassium sulfate and ferrous sulfate reduced the tenacity for maximum of 4.2 %owf and 4.4 %owf respectively while the tin chloride treated sample was completely destroyed when applying higher than 5 %owf of the mordant.

Keywords: mordant, tenacity, wool, complex formation, alum, SPSS

INTRODUCTION

Metal mordants are usually used in combination with various synthetic and natural mordant dyes in order to improve the fastness and depth of shade or obtain different hues when using a single dye [1–2]. Various transition metals can act as mordants and their salts can be applied on wool by three different application routes namely, pre-mordanting, meta-mordanting and after-mordanting depending on whether the mordant is applied before, together with or after the dyeing procedure. However, the use of mordant dyes has declined in recent years, owing to their negative environmental impacts and eco-toxicity [1, 3–4].

Recently, a great tendency to the use of natural products has been arisen specially when speaking about the coloration of textiles. This renewed interest is mainly due to the increased awareness of the environmental and health risks that synthetic dyes produce in the synthesis, processing and application stages [5–6]. Most of the natural dyes possess low affinity towards the textile fibers, therefore high amounts of the dyeing material and prolonged dyeing times are usually needed to dye a textile product using natural dyeing plants satisfactorily. To improve the exhaustion of natural dyes onto textile fibers, different techniques have been employed. Several pretreatments like cationization [7], plasma treatment [6, 8–9], enzyme treatment [10], gamma treatment [11–12], and microwave treatment [13] are examples of techniques which have been studied to overcome this drawback.

However, the most usual way to enhance the dyeing of textile fibers with natural dyes is still mordanting with metal salts. Examples of the most common mordants are the salts of chromium, tin, iron, copper and aluminum and several studies have been published on the optimization of natural dyeing and mordanting of fibers with different mordants [14–19]. When applying mordants on wool fibers, the main action of mordanting is to increases the interaction between the amine groups of protein molecules of wool fibers and hydroxyl and carbonyl groups of dye molecules. Figure 1 shows the mechanism of complex formation between wool protein, aluminum ion, and juglone as a model natural dye molecule [20–21].

Recently the use of binary and ternary metal salt combinations has been reported with the aim of obtaining new shades using annatto and walnut bark as natural dyesand their colorimetric and fastness properties have been studied [22–23]. The main concern in the previous studies have been about the improvement of exhaustion, color strength and fastness properties besides achieving different shades or

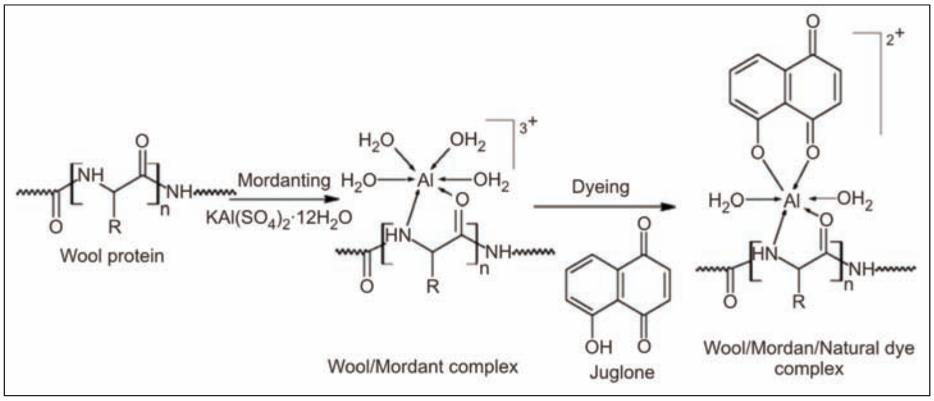

Fig. 1. Mechanism of complex formation between wool, aluminum mordant and juglone dye [20–21]

Independent samples t-test for equality of means was performed to compare the average tenacity of samples mordanted with various amounts of different mordants with the raw sample. The hypotheses to be tested were determined as follows:

H_0: There is no significant difference between average tenacity of mordanted and raw yarns.

H_1: There is a significant difference between average tenacity of mordanted and raw yarns.

functional properties when using a specific natural dye [20, 24–30]. However, there is no research published on the effect of different mordants on physical properties of fibers. In this study the effect of mordanting process with several common mordants in various concentrations on tensile strength of wool fibers have been studied and compared with the raw sample.

EXPERIMENTAL WORK

Materials and methods

Woolen yarn (Nm = 400, 2 ply) was purchased from a local spinning mill and used for the experiments after scouring and drying [1% non-ionic detergent (Triton X-100, Sigma-Aldrich, USA), 50 ºC, for 30 min]. All other chemicals used in this study were analytical grade reagents obtained from Merck, Germany.

Mordanting: The mordanting bath was prepared using the required amount (1, 2, 5, 10, 20 %owf) of mordant (aluminum potassium sulfate, tin chloride, potassium dichromate, copper sulfate, and ferrous sulfate) according to the experimental design. The liquor to goods ratio (L:G) was 50:1 and the mordanting was done at boil temperature for 1 hour.

Tensile strength measurement: The tenacity of raw and different mordantedwoolen yarns was measured according to ASTM D 2256 test method. Gauge length was 25 cm and crosshead speed was 30 cm/min. The samples were chosen randomly and the average of five measurements was reported for each sample. To evaluate the difference between the tensile strength of samples mordanted with various amounts of each mordant, the test results were analyzed for significant differences using one way analysis of variance (ANOVA) and the Tukey post hoc test at a 95% level of confidence using SPSS software version 16.0 (IBM, USA).

The hypotheses to be tested were determined as follows:

H_0: There is no significant difference between average tenacity of mordanted yarns with different amounts of mordant.

H_1: There is a significant difference between average tenacity of mordanted yarns mordanted with different amounts of mordant.

RESULTS AND DISCUSSION

Effect of mordants on tensile strength of yarns

Figures 2–6 show the effects of various amounts of different mordants on the tenacity of the woolen yarn. The mean tenacity of the raw woolen yarn was 8.53 cN/Tex. The highest effect on the tenacity of yarns was observed in the case of stannous chloride mordant specially when using concentrations higher than 2 %owf. $SnCl_2$ is a reducing agent and causes breaking of disulfide bonds which are present between wool protein chains and are sensitive to reducing agents. These covalent bonds are very important for

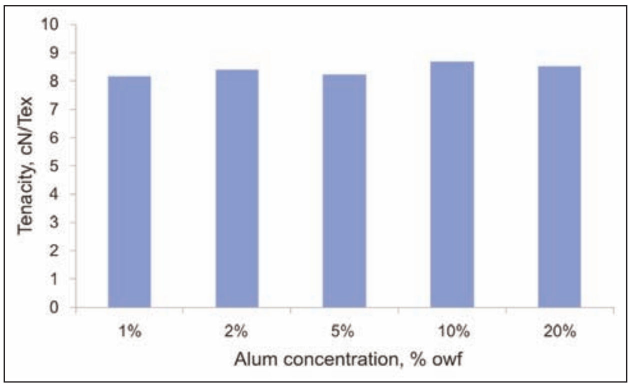

Fig. 2. The effect of concentration of alum on tenacity of woolen yarn

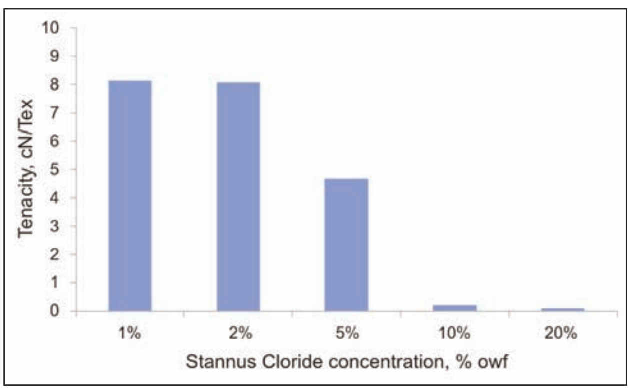

Fig. 3. The effect of concentration of stannous chloride on tenacity of woolen yarn

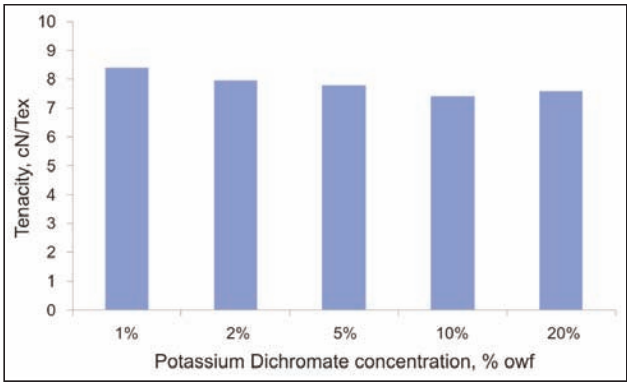

Fig. 4. The effect of concentration of potassium dichromate on tenacity of woolen yarn

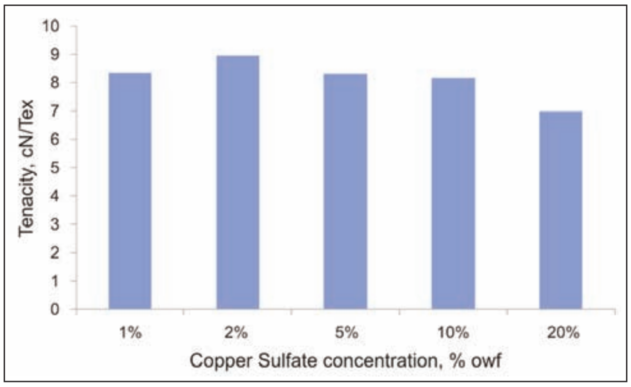

Fig. 5. The effect of concentration of copper sulfate on tenacity of woolen yarn

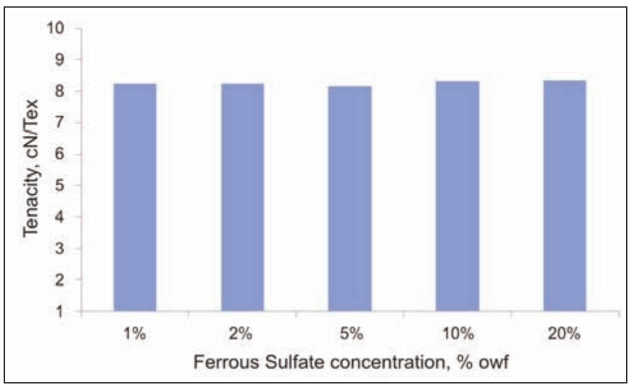

Fig. 6. The effect of concentration of ferrous sulfate on tenacity of woolen yarn

strength of wool fibers as they are the only offered covalent bonds between protein chains of wool and therefore the decrease in tensile strength due to mordanting with stannous chloride has been observed. The changes of the tenacity of alum and ferrous sulfate mordanted samples were negligible. More detailed discussion will be made in the statistical analysis section.

Statistical analysis

The one-way analysis of variance (ANOVA) is used to determine whether there are any statistically significant differences between the means of two or more independent groups. One-way ANOVA requires the homogeneity assumption which states that the population variances are equal for all groups. Table 1 shows the results of the Levene's test with the null hypothesis of "All compared groups have similar population variances". It can be concluded that the variances are not equal if "Sig." < 0.05. As can be seen in table 1, Levene's test showed that the variances of the tenacity of all compared groups are equal.

Table 1

TEST OF HOMOGENEITY OF VARIANCES				
	Levene statistic	df1	df2	Sig.
Al	.735	4	20	.579
Sn	1.186	3	16	.346
Cr	.040	4	20	.997
Cu	.273	4	20	.892
Fe	1.031	4	20	.416

Table 2 shows the output of the ANOVA analysis. If "Sig." < 0.05 for a specific mordant, it means that there is a statistically significant difference in the tenacity between the samples treated with different concentrations of that mordant. Here it can be seen that the tenacity of samples mordanted with Al and Fe salts, does not significantly change when the amount of the mordant was varied between 1 %owf up to 20 %owf but the tenacity of samples mordanted with Sn, Cr and Cu salts, significantly change when

Table 2

ANOVA RESULTS						
		Sum of squares	df	Mean square	F	Sig.
Al	Between groups	.839	4	.210	.545	.705
	Within groups	7.696	20	.385		
	Total	8.535	24			
Sn	Between groups	198.282	3	66.094	199.503	.000
	Within groups	5.301	16	.331		
	Total	203.583	19			
Cr	Between groups	4.154	4	1.038	6.467	.002
	Within groups	3.212	20	.161		
	Total	7.365	24			
Cu	Between groups	10.242	4	2.561	11.515	.000
	Within groups	4.447	20	.222		
	Total	14.690	24			
Fe	Between groups	.123	4	.031	.071	.990
	Within groups	8.574	20	.429		
	Total	8.697	24			

applied on wool in this range of concentration. Multiple Comparisons table which contains the results of the Tukey post hoc test shows which of the specific groups differed (tables 3, 4, and 5).

As can be seen in table 3, only the tenacity of samples mordanted with 1 %owf and 2 %owf of stannous chloride are equal and the other samples showed statistically significant difference in tensile strength ("Sig." < 0.05).

According to the data presented in table 4, the tenacity of samples mordanted with 1 %owf and 2 %owf of sodium dichromate statistically differ with samples mordanted with 10 %owf and 20 %owf of the same mordant. There is no significant difference between

Table 3

MULTIPLE COMPARISONS FOR DIFFERENT CONCENTRATIONS OF $SNCL_2$

(I) $SnCl_2$ %	(J) $SnCl_2$ %	Mean difference (I–J)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
1	2	.06000	.36403	.998	–.9815	1.1015
	5	3.43000*	.36403	.000	2.3885	4.4715
	10	7.69000*	.36403	.000	6.6485	8.7315
2	1	–.06000	.36403	.998	–1.1015	.9815
	5	3.37000*	.36403	.000	2.3285	4.4115
	10	7.63000*	.36403	.000	6.5885	8.6715
5	1	–3.43000*	.36403	.000	–4.4715	–2.3885
	2	–3.37000*	.36403	.000	–4.4115	–2.3285
	10	4.26000*	.36403	.000	3.2185	5.3015
10	1	–7.69000*	.36403	.000	–8.7315	–6.6485
	2	–7.63000*	.36403	.000	–8.6715	–6.5885
	5	–4.26000*	.36403	.000	–5.3015	–3.2185

* The mean difference is significant at the 0.05 level.

Table 4

MULTIPLE COMPARISONS FOR DIFFERENT CONCENTRATIONS OF $K_2Cr_2O_7$

(I) $K_2Cr_2O_7$ %	(J) $K_2Cr_2O_7$ %	Mean difference (I–J)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
1	2	.06000	.25344	.999	–.6984	.8184
	5	.62000	.25344	.144	–.1384	1.3784
	10	1.02000*	.25344	.005	.2616	1.7784
	20	.82000*	.25344	.030	.0616	1.5784
2	1	–.06000	.25344	.999	–.8184	.6984
	5	.56000	.25344	.217	–.1984	1.3184
	10	.96000*	.25344	.009	.2016	1.7184
	20	.76000*	.25344	.049	.0016	1.5184
5	1	–.62000	.25344	.144	–1.3784	.1384
	2	–.56000	.25344	.217	–1.3184	.1984
	10	.40000	.25344	.527	–.3584	1.1584
	20	.20000	.25344	.931	–.5584	.9584
10	1	–1.02000*	.25344	.005	–1.7784	–.2616
	2	–.96000*	.25344	.009	–1.7184	–.2016
	5	–.40000	.25344	.527	–1.1584	.3584
	20	–.20000	.25344	.931	–.9584	.5584
20	1	–.82000*	.25344	.030	–1.5784	–.0616
	2	–.76000*	.25344	.049	–1.5184	–.0016
	5	–.20000	.25344	.931	–.9584	.5584
	10	.20000	.25344	.931	–.5584	.9584

* The mean difference is significant at the 0.05 level.

Table 5

MULTIPLE COMPARISONS FOR DIFFERENT CONCENTRATIONS OF $CUSO_4$						
(I) $CuSO_4$ %	(J) $CuSO_4$ %	Mean difference (I–J)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
1	2	–.60000	.29824	.296	–1.4924	.2924
	5	.05000	.29824	1.000	–.8424	.9424
	10	.18000	.29824	.973	–.7124	1.0724
	20	1.36000*	.29824	.002	.4676	2.2524
2	1	.60000	.29824	.296	–.2924	1.4924
	5	.65000	.29824	.228	–.2424	1.5424
	10	.78000	.29824	.105	–.1124	1.6724
	20	1.96000*	.29824	.000	1.0676	2.8524
5	1	–.05000	.29824	1.000	–.9424	.8424
	2	–.65000	.29824	.228	–1.5424	.2424
	10	.13000	.29824	.992	–.7624	1.0224
	20	1.31000*	.29824	.002	.4176	2.2024
10	1	–.18000	.29824	.973	–1.0724	.7124
	2	–.78000	.29824	.105	–1.6724	.1124
	5	–.13000	.29824	.992	–1.0224	.7624
	20	1.18000*	.29824	.006	.2876	2.0724
20	1	–1.36000*	.29824	.002	–2.2524	–.4676
	2	–1.96000*	.29824	.000	–2.8524	–1.0676
	5	–1.31000*	.29824	.002	–2.2024	–.4176
	20	–1.18000*	.29824	.006	–2.0724	–.2876

* The mean difference is significant at the 0.05 level.

the tenacity of the samples mordanted with 5 %owf of sodium dichromate with samples treated with the lower or higher amounts. However the tenacity of the samples mordanted with 10 %owf and 20 %owf of sodium dichromate differ with the samples treated with 1 %owf and 2 %owf and is statistically equal with the tenacity of the samplemordanted with 5 %owf of sodium dichromate.

Table 5 shows that when using copper sulfate as a mordant on wool, there is no statistically significant difference between the samples mordanted with 1 %owf, 2%owf, 5 %owf and 10 %owf, but the tenacity was changed significantly when 20 %owf of $CuSO_4$ was used.

Table 6 displays the results of the independent samples t-test. In the "Levene's Test for Equality of Variances" column, Sig. is the p-value corresponding to this test statistic. If "Sig." < 0.05 we should look at the "Equal variances not assumed" row for the t-test results. Sig (2-tailed) is the p-value corresponding to the given test statistic and degrees of freedom. Mean Difference is the difference between the sample means and is calculated by subtracting the mean of the second group from the mean of the first group. The group means are statistically significantly different if the value in the "Sig. (2-tailed)" row is less than 0.05. As seen in table 6, the equality of the variances is assumed for all samples. So the "Sig. (2-tailed)" of the first row will be considered for comparison of each mordanted sample with the raw sample.

As can be seen there is no significant difference between the mean tenacity value of all samples mordanted with alum or ferrous sulfate and the raw wool sample. It means that thesemordants can be applied on wool without any significant change in the tensile strength of the yarns.

About the samples mordanted with stannous chloride, there is no significant decrease in tenacity when using 1 %owf and 2 %owf of the mordant but the tenacity significantly changes when using higher amounts of the stannous chloride mordant. When using 20 %owf of this mordant, the fibers were completely destroyed and it was impossible to measure the tenacity of the yarn.

About the samples mordanted with chromium, the tenacity significantly changes when using higher than 5 %owf of the mordant, but the decrease in the tenacity of the chromium mordant is much lower than the stannous chloride mordanted samples.

When mordanting with copper sulfate, there was a statistically significant change in the tenacity compared with the raw sample only when 20 %owf of the mordant was applied.

CONCLUSION

In this study, the effect of five different mordants on wool tensile strength was statistically analyzed using "independent samples t-test" and "one-way ANOVA" by SPSS software. The concentration of all mordants

Table 6

INDEPENDENT SAMPLES TEST

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference	
									Lower	Upper
Al 1%	Equal variances assumed	.022	.885	–1.214	8	.259	–.36200	.29821	–1.04968	.32568
	Equal variances not assumed			–1.214	7.892	.260	–.36200	.29821	–1.05132	.32732
Al 2%	Equal variances assumed	.018	.896	–.449	8	.666	–.12000	.26756	–.73699	.49699
	Equal variances not assumed			–.449	7.925	.666	–.12000	.26756	–.73800	.49800
Al 5%	Equal variances assumed	.102	.758	–.938	8	.376	–.30000	.31980	–1.03747	.43747
	Equal variances not assumed			–.938	7.591	.377	–.30000	.31980	–1.04444	.44444
Al 10%	Equal variances assumed	.000	1.000	.490	8	.638	.14000	.28596	–.51943	.79943
	Equal variances not assumed			.490	7.987	.638	.14000	.28596	–.51961	.79961
Al 20%	Equal variances assumed	1.269	.293	–.041	8	.968	–.02000	.48637	–1.14158	1.10158
	Equal variances not assumed			–.041	5.532	.969	–.02000	.48637	–1.23497	1.19497
Sn 1%	Equal variances assumed	.179	.684	–1.661	8	.135	–.41000	.24679	–.97911	.15911
	Equal variances not assumed			–1.661	7.382	.138	–.41000	.24679	–.98751	.16751
Sn 2%	Equal variances assumed	.132	.726	–1.431	8	.190	–.47000	.32838	–1.22725	.28725
	Equal variances not assumed			–1.431	7.450	.193	–.47000	.32838	–1.23709	.29709
Sn 5%	Equal variances assumed	.825	.390	–8.459	8	.000	–3.84000	.45395	–4.88682	–2.79318
	Equal variances not assumed			–8.459	5.784	.000	–3.84000	.45395	–4.96090	–2.71910
Sn 10%	Equal variances assumed	1.334	.281	–37.249	8	.000	–8.10000	.21746	–8.60146	–7.59854
	Equal variances not assumed			–37.249	5.568	.000	–8.10000	.21746	–8.64225	–7.55775
Cr 1%	Equal variances assumed	.002	.963	–.437	8	.674	–.12000	.27480	–.75369	.51369
	Equal variances not assumed			–.437	7.987	.674	–.12000	.27480	–.75387	.51387
Cr 2%	Equal variances assumed	.109	.750	–.729	8	.487	–.18000	.24679	–.74911	.38911
	Equal variances not assumed			–.729	7.382	.488	–.18000	.24679	–.75751	.39751
Cr 5%	Equal variances assumed	.012	.915	–2.751	8	.025	–.74000	.26896	–1.36021	–.11979
	Equal variances not assumed			–2.751	7.942	.025	–.74000	.26896	–1.36101	–.11899
Cr 10%	Equal variances assumed	.053	.824	–4.398	8	.002	–1.14000	.25922	–1.73776	–.54224
	Equal variances not assumed			–4.398	7.778	.002	–1.14000	.25922	–1.74074	.53926
Cr 20%	Equal variances assumed	.001	.974	–3.304	8	.011	–.94000	.28453	–1.59613	–.28387
	Equal variances not assumed			–3.304	7.993	.011	–.94000	.28453	–1.59623	–.28377
Cu 1%	Equal variances assumed	.004	.949	–.627	8	.548	–.18000	.28725	–.84241	.48241
	Equal variances not assumed			–.627	7.981	–.548	–.18000	.28725	–.84268	.48268
Cu 2%	Equal variances assumed	.006	.942	1.441	8	.188	.42000	.29151	–.25222	1.09222
	Equal variances not assumed			1.441	7.954	.188	.42000	.29151	–.25289	1.09289
Cu 5%	Equal variances assumed	.072	.795	–.749	8	.476	–.23000	.30727	–.93857	.47857
	Equal variances not assumed			–.749	7.780	.476	–.23000	.30727	–.94207	.48207
Cu 10%	Equal variances assumed	.142	.716	–1.128	8	.292	–.36000	.31924	–1.09617	.37617
	Equal variances not assumed			–1.128	7.600	.294	–.36000	.31924	–1.10297	.38297
Cu 20%	Equal variances assumed	.549	.480	–6.574	8	.000	–1.54000	.23426	–2.08020	–.99980
	Equal variances not assumed			–6.574	6.746	.000	–1.54000	.23426	–2.09819	–.98181
Fe 1%	Equal variances assumed	.043	.841	–.935	8	.377	–.29000	.31031	–1.00559	.42559
	Equal variances not assumed			–.935	7.737	.378	–.29000	.31031	–1.00985	.42985
Fe 2%	Equal variances assumed	1.172	.311	–1.397	8	.200	–.31000	.22198	–.82189	.20189
	Equal variances not assumed			–1.397	5.914	.213	–.31000	.22198	–.85507	.23507
Fe 5%	Equal variances assumed	.105	.754	–1.196	8	.266	–.38000	.31766	–1.11252	.35252
	Equal variances not assumed			–1.196	7.625	.267	–.38000	.31766	–1.11884	.35884
Fe 10%	Equal variances assumed	1.129	.319	–.401	8	.699	–.22000	.54801	–1.48371	1.04371
	Equal variances not assumed			–.401	5.177	.704	–.22000	.54801	–1.61436	1.17436
Fe 20%	Equal variances assumed	.001	.973	–.643	8	.538	–.18000	.27975	–.82509	.46509
	Equal variances not assumed			–.643	8.000	.538	–.18000	.27975	–.82510	.46510

was varying between 1 %owf and 20 %owf. The results showed that alum and ferrous sulfate had no significant effect on the tensile strength of wool and there was no statistically significant difference between the tenacity of samples mordanted with different concentrations of these mordants. Samples mordanted with 20 %owf of sodium dichromate and copper sulfate exhibited statistically significant decrease in tensile strength while the sample mordanted with 20 %owf of stannous chloride was completely destroyed. The loss of tensile strength for samples mordanted with stannous chloride having concentrations higher than 2 %owf was statistically significant.

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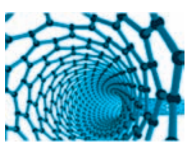

Impacts of female body shapes on patternmaking

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NEZLA ÜNAL EMİNE UTKUN

REZUMAT – ABSTRACT

Impactul formelor corpului feminine asupra creării tiparelor

Îmbrăcămintea potrivită este unul dintre cei mai importanți factori care determină comportamentul cumpărătorilor și confortul mișcării corpului.

Acest studiu își propune să examineze efectele diferitelor forme de corp feminin asupra modelului de îmbrăcăminte. În acest scop, au fost prelevate și clasificate în funcție de forma și dimensiunile corpului măsurătorile corpului a 231 de femei cu vârsta cuprinsă între 18 și 25 de ani. Impactul formelor corpului a fost investigat pe modelul de bază de îmbrăcăminte cu standard de ajustare pregătit în sistemul de creare a tiparelor Müller & Sohn.

Modelele de bază ale rochiilor de damă ajustate pe corp cu măsura 36 și cu formă a corpului dreptunghiulară și tip pară au fost ajustate, iar aceste ajustări au fost comparate. În timp ce ajustările de model s-au efectuat în funcție de forma corpului dreptunghiuluară și de cea tip pară, modificările necesare au fost făcute pe întreaga înălțime, circumferința sânilor, talie, șold și partea frontală și au fost efectuate măsurători de lungime medie în partea din față și spate.

Cuvinte-cheie: potrivirea îmbrăcămintei, ajustări ale modelului, forme ale corpului, confortul mișcării corpului

Impacts of female body shapes on patternmaking

Clothing fit is one of the most important factors that affect consumers' purchasing behaviour and body movement comfort.

This study aims to examine the effects of different female body shapes on clothing pattern design. For this purpose, body measurements of 231 women aged between 18 and 25 were taken and classified according to body shapes and sizes. Then the impacts of body shapes were investigated on basic dress pattern drawing with standard dart prepared in Müller&Sohn patternmaking system.

Darted basic dress patterns of women who had a body size of 36 and piled up in pear and rectangle body shapes were adjusted, and these adjustments were compared. While pattern adjustments were carried out according to the rectangle and pear body shape, necessary changes were made on the full height, the girths of breasts, waist, hip and front, back and front average length measurements.

Keywords: fitting, pattern adjustments, body shapes, body movement comfort

INTRODUCTION

Clothing fit is one of the most important factors that affect consumers' purchasing behaviour and body movement comfort. In order for a garment fitting to the body, the patterns must be compatible with the body sizes and shapes of the person. Fabrication clothing that can fit the body is one of the most important competitive advantages for companies that manufacture by using mass production-based measurements.

A lot of research is present in the international literature on patternmaking of different body types, body sizes, and garment groups. Some of the studies conducted can be summarized as follows.

Connell et al. (2003) noted that body-type analysis is theoretically the basis of body size measurement. In their work, the researchers examined the body types of women in America [1].

Schofield et al. (2006) published a study, which explored fitting pantsof 176 women aged 55 and olderto be able to see the relation between sizing, body and pattern shape in clothes. According to the results of the study, body shapes have been presented as subsetgroups and the personalized productions were recommended as a solution to the problem of clothing fit to the body [2].

Cho et al. (2006) stated that consumers demand personal clothing and variety in their study. The researchers emphasized that not only body sizes but also body shapesmust be taken into account during the preparation of the patterns of personal clothes [3].

In their study, Connell et al. (2006) developed a new tool called the Body Shape Assessment Scale (BSAS) ©, which analyses female body shapes and explained how it works [4].

Lee et al. (2007) compared the body shapes of American and Korean women by race and age in their study. The study found that the largest shape category was the rectangle shape in both countries, but the distribution within each shape category for Korean women was different from that of USA women. More body shape categories were found in the USA women than in Korean women. They pointed out that body shape is one of the main factors in clothing fit and clothing comfort [5].

In their study, Shin et al. (2007) revealed that ethnic groups had different fit problems and significant body shape differences [6].

Faust and Carrier (2009) suggested that body shapes should be added to the clothing labels as well as body sizes, and they made experiments in this direction. The researchers indicated that labels did not inform the consumers adequately and that the consumers had fitting problems with the clothes [7].

Çileroğlu (2010), examined the size distribution of Turkish women between the ages of 18–50, identified their body shapes and analyse the relation between their body measurements and body shapes in terms of the ready-to-wear industry. Results showed that, 37% of Turkish women had hourglass, 31% had triangle, 19% had rectangle and 13% had an inverted triangle body shape [8].

Manuel et al. (2010) categorized the body shapes of African-American women in their study and examined how these body shapes affected women's clothing preferences [9].

Vuruşkan and Bulgun (2011) asserted that the methods used currently to determine the female body shapes generally depended on subjective and visual decision-making approaches. In their work, they developed a numerical method to identify the female body shape [10].

Mason et al. (2012) investigated and classified the body shapes of Kenyan women [11].

Özeren (2012) stated that the competitive conditions in the market today cause the enterprises to make a difference and to produce personal products especially for ready-to-wear industry. People's bodies are different, so clothing productionshould be done according to body sizes and body shapes. In this study, a basic body pattern drawing without dartswas developed according to triangle and hourglass female body shapes. At the end of the study it was suggested that the developed pattern drawing system could be used for both body shapes [12].

Vuruşkan and Bulgun (2013) assessed garment fitting between made-to-measure garments and standard body garments by taking the most common female body shapes as an example. The researchers emphasized the importance of personalized production for oversize bodies and non-standard body shapes [13].

Tama and Öndoğan (2014) prepared patterns in Contec, Metric, Müller&Sohnand Basic Block patternmaking systems in order to evaluate the fit of the basic skirt pattern and compared them with clothing programs. Patterns were designed with the help of the CAD system and body sizes as well as different body shapes (hourglass, triangle, rectangle) were considered. Based on the results of the study, the researchers stated that different patternmaking systems were more successful in designing the pattern of each body shape [14].

The Contec Pattern Making system is suitable for computer applications and hand drawing. Dress patterns can be easily prepared using very few assistant lines in Metric system. The basic measurements are taken from the body directly and auxiliary measurements are calculated in Müller&Sohn System. Patterns are drawnby the combination of simple blocks in The Basic Blocks System [14].

Petrak et al. (2015) examined the effects of male body posture and shape on clothing design and garment fit. In the scope of the study, 50 male subjects were scannedwith 3D body scanning system. At the end of the study, the researchers developed a new parametric garment pattern design by considering body dimensions, posture and shape [15].

Eryazıcı and Çoruh (2015) examined the dress preferences of working women according to body shapes. They detected that women's dress styles did not show any difference according to their body shapes [16].

If clothing pattern is prepared suitable for the body, clothing does not restrict body movements and also adapt itself to these movements [17].

In the light of the literature review and the advancements that occur in the sector, it can be stated that it is insufficient to consider only body sizes in patternmaking, and that body shapes should also be taken into account. In this study, the impacts of different female body shapes on the dress pattern design were investigated.

MATERIALS AND METHODS

Within the scope of the study, firstly basic body measurements (full height, chest, waist and hip girths) were obtained by tape measure from 231 women aged between 18 and 25 in Turkey. They wore their underwear while measuring. Then, auxiliary measures (armhole and hip depth, back and front length, back neckline, chest drop, back, armhole and front girth) were calculated by using "Body Size Calculator" [18]. The positions of the front and back body measurementsare displayed in figure 1 and the explanations are presented in table 1.

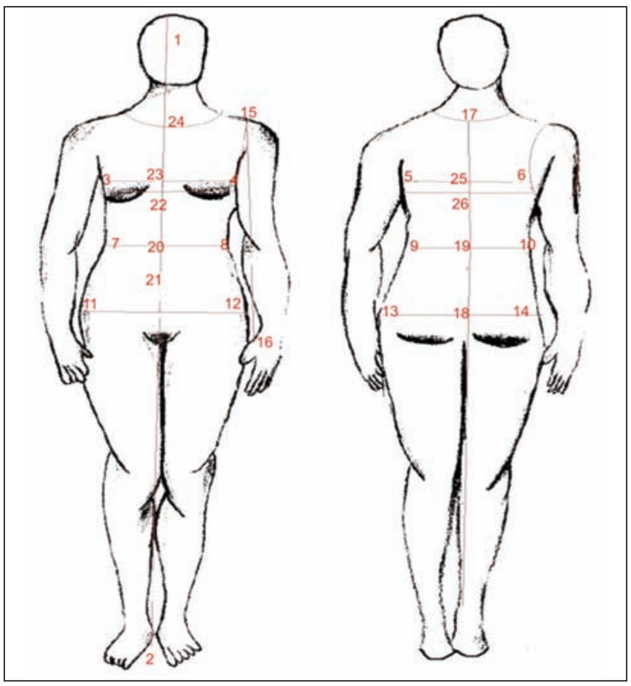

Fig. 1. Women's body measurements parts

Table 1

Basic measurements	Line	Auxiliary measurements	Line	Auxiliary measurements	Line
Full length	1–2	**Armhole depth**	17–26	**Front length I**	24–21
Breasts girth	3–4 & 5–6	**Back neckline**	17	**Front length II**	20–24
Waist girth	7–8 & 9–10	**Hip drop**	17–18	**Back girth**	5–6
Hip size	11–12 & 13–14	**Breasts drop I**	22–24	**Armhole width**	3–5/4–6
Sleeve length	15–16	**Breasts drop II**	23–24	**Front girth** **Back length**	3–4 17–19

Table 2

Breasts girth	Size no.
Between 80 and 83 cm	34
Between 84 and 87 cm	36
Between 88 and 91 cm	38
Between 92 and 95 cm	40
Between 96 and 99 cm	42
Between 100 and 103 cm	44
Between 104 and 109 cm	46
Between 110 and 115 cm	48
Between 116 and 121 cm	50
Between 122 and 127 cm	52
Between 128 and 133 cm	54

The body sizes of the women were determined according to the Müller&Sohn pattern making system by using data in table 2.

After establishing body size, women were classified according to body shapes. These shapes have been classified using geometric figures, rods, lines or fruit formsin the literature.

In this study, Rosen's classification was used. Rosen (2005) namedthe seven groups representing female body shapes as proportioned, rectangle, pear, apple, hourglass, diamond, and round [19].

While female body shapes are classified:

- Pear body type; women whose chest girthisat least 8 cm less than their hip girth;
- Apple body type; women whose chest girth is at least 9 cm more than their hip girth;
- Rectangle body type; women who have a difference of 7 cm or less between their chest and hip girths;
- Hourglassbody type; women whose chest girthis at least 37 cm larger than their waist girth [20, 21, 22, 23].

Finally, the impacts of body shapes on pattern drawing were investigated on basic body pattern drawing with standard darts prepared in Müller&Sohn patternmaking system, pattern adjustments were made and these adjustments were compared. These adjustments were madewith the help of the data obtained by calculating the arithmetic mean of the basic and auxiliary body measurements of 36-size women with pear and rectangle body shapes where piling upwasdetermined.

In this study, in order for the dress pattern drawings to be done, first 36-body size, darted basic body pattern with standard posture and expansion drawings were made. Later on, based on the measurements obtained, adjustments were made on the 36-body-size, darted basic dress pattern drawings according to pear and rectangle body shapes.

FINDINGS

Table 3 illustrates the distribution of the women by body shape and size.

Table 3

Body size	Body shapes (n)			
	Pear	Apple	Rectangle	Total
34	10	0	11	21
36	31	0	28	59
38	8	1	22	31
40	10	1	18	29
42	14	1	7	22
44	1	5	12	18
46	7	0	8	15
48	8	3	11	22
50	1	4	4	9
52	0	0	3	3
54	0	0	2	2
Total	90	15	126	231

According to the data obtained from 231 women it was determined that 90 women had pear, 126 women had rectangle and 15 women had apple body shape.

A total of 31out of 90 women with pear and 28 out of 126 women with rectangle body shape were of 36-body size. It was revealed that the piling upin both body shapes was in 36-body size.

A comparison of the differences in 36-sized female body measurements according to rectangle and pear body shapes is displayed in table 4.

Figures 2 and 3 show pattern adjustments applied according to the rectangle and pear body shapes according to Müller&Sohn pattern making system.

CONCLUSION

Existing patternmaking systems mostly take into account body measurements of the standard body shape and posture. Within the scope of this study, the

Table 4

Body shape with 36-Size Standard Posture		36-Size Rectangle Body Shape		36-Size Pear Body Shape	
Measurements		Measurements	Differences	Measurements	Differences
Full height	160 cm	162 cm	2 cm lengthened	163 cm	3 cm lengthened
Chest girth	84 cm	86 cm	2 cm enlarged	85 cm	1 cm enlarged
Waist girth	68 cm	67 cm	1 cm taken in	69 cm	1 cm enlarged
Hip girth	90 cm	89 cm	2 cm taken in	96 cm	6 cm enlarged
Armhole depth	19 cm	19 cm	No difference	19 cm	No difference
Back length	40 cm	41 cm	1 cm lengthened	41cm	1 cm lengthened
Hip depth	60 cm	60 cm	No difference	60 cm	No difference
Back neckline	6 cm	6 cm	No difference	6 cm	No difference
Breastsdepth I	31 cm	31 cm	No difference	31 cm	No difference
Breast depth II	25 cm	25 cm	No difference	25 cm	No difference
Front length I	44 cm	44 cm	No difference	44 cm	No difference
Front length II	50 cm	50 cm	No difference	51 cm	1 cm lengthened
Back girth	16 cm	16 cm	No difference	16 cm	No difference
Armhole width	9 cm	9 cm	No difference	9 cm	No difference
Front girth	17 cm	18 cm	1 cm enlarged	17.5 cm	0.5 cm enlarged

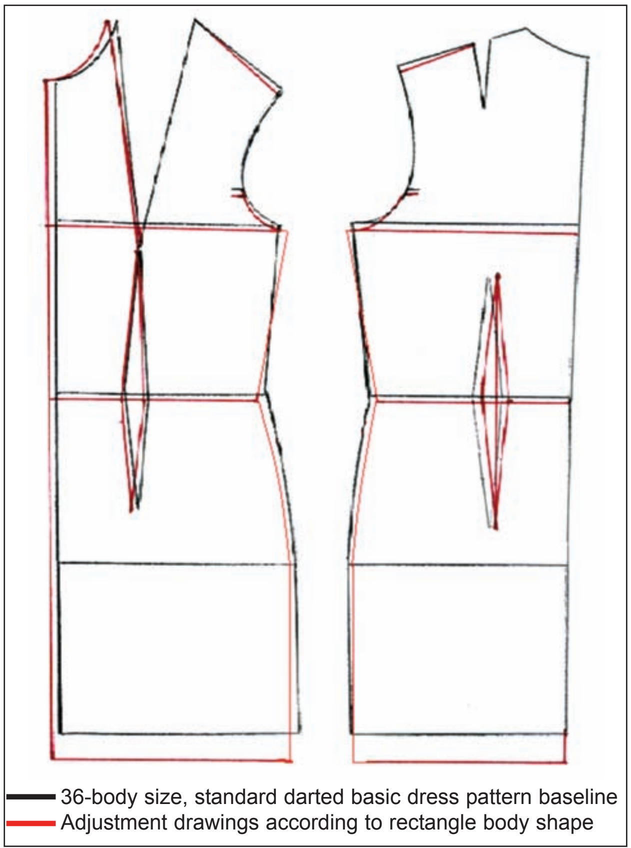

Fig. 2. 36-body size, darted basic dress pattern adjustments according to the rectangle body

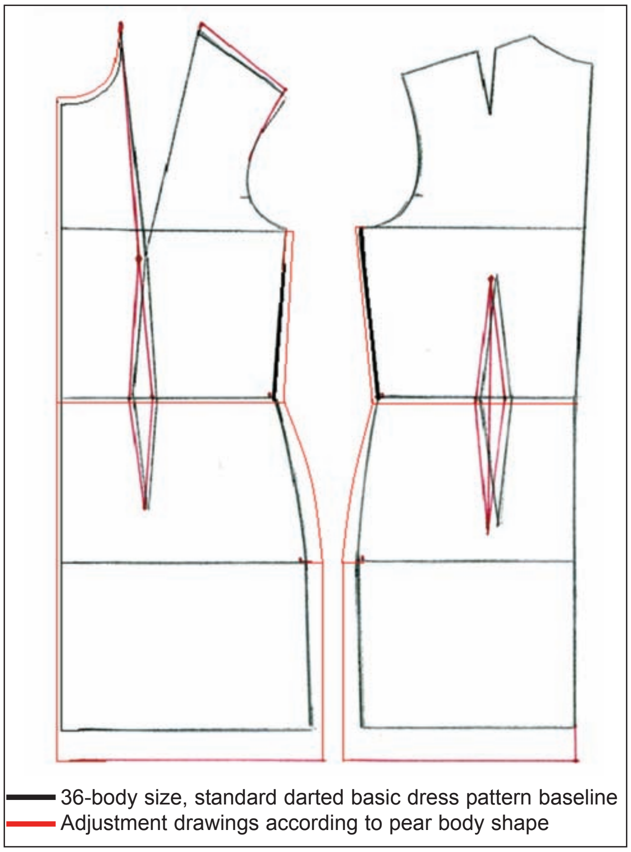

Fig. 3. 36-body size, darted basic dress pattern adjustments according to the pear body shape

effects of different female body shapes on the patternmakingwere examined and the patternmaking stages of different body shapes were compared.

While pattern adjustments were carried outaccording to the rectangle body shape; necessary changes were made on the fullheight, breasts, waist,front and hip girths, back average length measurements.

When pattern adjustments were carried out according to the pear body shape; necessary changes were made on the full height, breasts, waist and hip girth, back average length and front average length measurements.

When pattern adjustments were carried out according to the rectangle and pear body shapes, it was revealed that there were no changes in hollow forearm depth, hip drop, back neckline, breasts drop 1, breasts drop 2, front average length 2, back girth, and hollow forearm girth, and no adjustments were made.

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Contents, pp. 419-421 – The translation in Romanian language is:

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