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Multi-objective optimization of extraction of Tunisian Washingtonia filifera fibers for technical textile applications

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ABSTRACT – REZUMAT

Multi-objective optimization of extraction of Tunisian Washingtonia Filifera fibers for technical textile applications

The aim of this study is to investigate the effect of extraction treatment method on the properties of WPF (Washingtonia palm fibres). The employed treatment is a combined mechanical and chemical sodium hydroxide. The treatment processes was described and evaluated. The physical properties (linear density, diameter and extraction yield), and the mechanical properties (tenacity) of WPF were measured. The optimum extraction condition has been determined by a statistical study using desirability function. Obtained fibres under optimal conditions were characterized with morphological test (SEM), chemical tests (FT-IR spectra, X ray diffraction) and thermal test (TGA). Fibre obtained can be employed on technical textile applications and in particular drylaid nonwoven.

Keywords: *chemical properties, fibre extraction, factorial design, palm fibre, physical properties*

Optimizarea multi-obiectiv a extracției fibrelor de palmier Washingtonia filifera din Tunisia pentru utilizare în textile tehnice

Scopul acestui studiu este de a investiga influența metodei de tratament prin extracție asupra proprietăților WPF (fibrele de palmier Washingtonia). Tratamentul utilizat este unul combinat, mecanic și chimic cu hidroxid de sodiu. Procesele de tratare au fost descrise și evaluate. Au fost determinate proprietățile fizice (densitatea liniară, diametrul și randamentul de extracție) și proprietățile mecanice (tenacitatea) ale WPF. Condiția optimă de extracție a fost determinată printr-un studiu statistic, care se bazează pe funcția de oportunitate. Fibrele obținute în condiții optime au fost caracterizate cu ajutorul testului morfologic (SEM), testelor chimice (spectre FT-IR, difracție de raze X) și testului termic (TGA). Fibra obținută poate fi utilizată pentru textile tehnice și, în special, la nețesutele cu fixare uscată.

Cuvinte-cheie*: proprietăți chimice, extracția fibrei, proiectare factorială, fibre de palmier, proprietăți fizice*

INTRODUCTION

Palm tree is a monocotyledonous plant belonging to the family of Arecaceae. This family varies greatly and has an incredible morphological diversity [1]. In recent years palm fibres have been the subject of numerous research studies with the main focus on environmental impact and biocompatibility of reinforced biocomposites. Especially, oil palm was attractive and usage of palm based fibres reinforcing polymers has undergone a dramatic increase [2, 3]. Sreekala et al. focused on oil palm fibre as an important lignocellulosic raw material for the preparation of environmentally friendly composite materials [4]. Aldousiri et al. used extracted oil palm in reinforcing of high density polyethylene (HDPE) [3]. Date palm and doum palm fibres were studied also [5–8]. Mohamed et al. focused on thermal characteristics and microstructure of a new insulation material extracted from date palm trees surface fibre [7]. Djoudi et al. studied the performance of date palm fibres reinforced plaster concrete [8]. Essabir et al. studied dynamic mechanical thermal behaviour of doum fibres reinforced polypropylene composites [5]. Zbidi et al. analysed the influence of alkaline and enzymatic treatment on the properties of doum palm fibres and composites [6]. Most of these papers were concentrated in the application of palm fibres on composite and plastic reinforced material but no attempt has been made to search for the use of palm fibres in technical textile applications, particularly dry nonwovens where specific properties of fibres (diameter, strength, stiffness) are required.

The process of extraction of fibres is of great importance, since the quality as well as the quantity of extracted fibres is strongly influenced by the methods of extraction employed [9]. The template vegetable fibres can be extracted by various methods ranging from mechanical, chemical and microbial action processes [10, 11]. Several studies have revealed how various methods such as silane, alkali, peroxide, and isocyanate treatments affect the properties of natural fibres [12, 13]. Out of these methods, it has been observed that one of the simplest, most economical and effective forms of treatment with least environmental impact, is alkali treatment particularly using NaOH [14].

In this paper, a combined mechanical and chemical process was elaborated for the extraction of

Washingtonia Palm Fibres (WPF). A multi-objective method based on Deming desirability function was used to optimize process yield and important fibre properties (extraction yield, fibre diameter, linear density and tenacity). This study is completed by an advanced characterization with morphological, thermal and chemical tests were made for the fibres extracted under the optimal condition. Our final objective is to evaluate the potential of using these fibres in technical textile application and in particular Drylaid Nonwoven.

MATERIAL AND METHODS

Material

Palm fibres were collected from the palm termed "Washingtonia filifer". This biomass was chosen due to their abundance in the roads and the green spaces of Tunisia as an ornament tree. The source of these fibres is the foliage of the palm tree in particular from the leaflets. The leaflet is a constituent of the leaf of the tree. Indeed, the leaf consists of several parts: the blade and the leaf axis, the latter is itself divided into a sheath encircling the stem, leafstalk and rachis bearing leaflets [1].

Fiber extraction

In this study, we first extracted the palm fibres and remove non-cellulosic materials using an alkali treatment [15] using NaOH. An experimental design scheme was followed for optimizing the extraction process (table 1). All statistical analyses have been carried out using the statistical software minitab [16]. An experimental database has been constructed summarizing the palm extraction parameters. In this database (27 tests), we used as input variables the temperature (T), the extraction time (d) and the soda concentration (C). The outputs are the extraction yield (Y), the fibre diameter (D), the fibre linear density (LD) and the fibre tenacity (T).

Table 1

FEATURES OF THE FACTORIAL DESIGN

Factors	Levels		
	1	2	3
Time d (min)	60	90	120
Temperature T (°C)	80	90	100
Soda concentration C (N)	1	2	3

The raw fibres were immersed in a digital water bath according conditions below:
- 10 g of leaflets of palm tree;
- Liquor ratio = 1/40;
- Temperature T (°C) ranges from 80°C to 100°C;
- Duration d (min) of treatment ranges from 60 to 120 min;
- Sodium hydroxide concentration C (N) ranges from 1 N to 3 N.

The factor levels were chosen based on literature first and thereafter adjusted based on our preliminary tests results. Indeed, in most of the references e.g. [17–18] 100°C temperature is the most widely adopted value for palm fibre extraction. In our study it was proved respectively that: at 80°C the extraction is no longer possible and at 120°C the fibre was hydrolysed [19]. After treating the foliages of palm leaves, they were rinsed in hot water several times, then they were mechanically brushed using a metallic brush; the brush is moved in the longitudinal direction of the edges of sheets in order to separate fibres. Finally, the obtained fibres are dried to the ambient air for 48 h. The treated fibres were physically, mechanically and chemically characterized in order to measure their properties. The tests carried out on a batch of conditioned fibres in a normal atmosphere (relative humidity: 65% ± 4%, temperature: 20°C ± 2°C).

Physical fiber tests

Yield of fibers (R %) is measured by the weight percentage of final mass of the fibres after extraction process (Mf) with respect to that of the palm folioles before extraction process (Mi). The measurement of the mass is performed using the gravimetric method in accordance with standard NF G 08-001.

$$R\,(\%) = \frac{Mf}{Mi} \times 100 \qquad (1)$$

Diameter was measured using an optic microscope Leica, in accordance with the French standard NF G 07-004 (1983). The test is carried out on 300 fibres chosen at random.

The linear density was measured by weighing fibres of known lengths using the gravimetric method and according to the standard ISO 1973(1995).

The tensile tests of the fibres were performed under standard conditions with a LLOYD dynamometer according to NF G07-002 standard. The length between clamps was taken equal to 20 mm; the crosshead speed was 20 mm/min and the load was measured using a 100 N load. The values are reported as the means of 50 measurements.

The density measurement of the WPF was carried out using a gas pycnometer which is recognized as one of the most reliable techniques for obtaining density. That was made using The AccuPyc II 1340.

Morphological fibre tests

The technical WPF obtained are morphologically characterized. The specimens were observed using a Scanning Electron Microscope (SEM) to characterize the morphology of treated and untreated fibres.

Thermal and chemical fibre tests

Crystal phase characterization was carried out using XRD and ATR -FTIR analyses. *X-Ray Diffraction* (XRD) analyses patterns were recorded using a D8 Discover diffractometer (Bruker) equipped with a LynxEye detector. Cu Kα radiation (λ = 1.541 Å) with a tube voltageand amperage set at 40 kV and 40 mA respectively was used as reference configuration.

Compressed fibre samples were placed onto a flat-frosted glass and analysed at room temperature with a step of 0.04° (2θ) and a dwell time of 0.5 s from 3 to 60° (2θ). The use of XRD counts offers an easy way to evaluate the crystalline index of fibres, which can be calculated from Equation below [20]:

$$CrI\ (\%) = \frac{I_{002} - I_{am}}{I_{002}} \times 100 \qquad (2)$$

where CrI (%) is the crystalline index, I_{002} – the maximum intensity of the 002 lattice diffraction plane at a 2θ angle between 22°and 23°, I_{am} – the intensity diffraction at an angle 2θ close to 18° representing amorphous materials in plant fibres.

ATR-FTIR spectra of the WPF were recorded using a Nicolet iS10 Thermo Scientific connected to an ATR accessory. The analysis of the samples is carried out on the surface and up to a beam penetration depth of a few micrometres.

The thermal stability of fibres was evaluated by thermo gravimetric analysis (TGA).The WPF were placed in a NETZSCH TG 209 F1 Libra thermo gravimetric, under argon and were heated up to 800°C, with a heating rate of 5°C/min.

RESULTS AND DISCUSSION

Effect of the treatment processes on the physical properties of WPF fibres

To better visualize the effect of extraction conditions on physical properties of palm fibres, the effects of the main parameters were graphically illustrated. As shown in figure 1, the fibre's linear density decreases when aggravating treatment conditions (concentration of soda, temperature, duration of treatment). In fact, the linear density of untreated fibres amounts to 41 Tex whereas that of treated fibres ranges from 40 to 13 Tex. This reduced mass per unit length could be attributed to the removal of waxy and gummy materials deposited on fibres. The lower linear density was obtained under T = 100°C, treatment duration of 120 min and soda concentration of 3 N. This confirms the result obtained of diameter.

Moreover, as shown in diameter plot (figure 2), the diameter revealed the same behaviour with linear density against hydroxide treatment. In fact, the untreated fibres present a diameter of 511 μm. However the diameter of treated fibres ranges from 384 to 109 μm. This increased fibre fineness could be attributed to the removal of gummy materials present on the surface of fibres and between the ultimate fibres [21]. The lower diameter was obtained in the combination (100°C, 120 min and 3 N) which confirms result obtained from the linear density analysis. In order to obtain a fine structure, extraction conditions need to be cruel. In fact, treatment duration, soda concentration, and temperature, favour the separation of WPF and their cleanings while removing impurities. These impurities, such as pectin, lignin, hemicelluloses, wax, and fat materials, held the fibres in bundles. This reduction in fibres fineness (diameter and linear density) could be proved by the results shown for the yield extraction.

As revealed in main effect plot for yield (figure 3), the yield decreased when engraving extraction conditions. The highest extraction yield is obtained while proceeding in the least severe conditions of treatment which confirms the important fineness of fibres resulted in this case (diameter = 384 μm; linear density = 40 Tex). Therefore, in such condition, the alkalization was not effective to remove foreign substances bundling fibres. When temperature, soda concentration and duration of treatment increased, the elimination of non-cellulosic components became faster and more important, however yield decreased and consequently fineness.

Effect of the treatment processes on the mechanical properties of WPF fibres

The mechanical properties of textile fibres are very interesting properties. They define the behaviour of fibres during different transformation processes and the properties of the finished products made from these fibres. Depending on the significance of their characteristics, the lignocellulosic fibres such as those of the palm fibre can be used in various applications [22]. The tenacity is defined by the ratio of the maximum load a specimen can support and its linear density. As shown in the main effect plot for tenacity (figure 4), the tenacity of fibres has changed after the

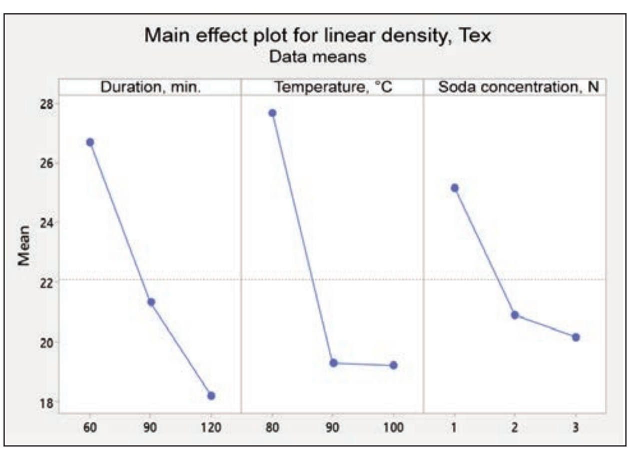

Fig. 1. Main effect plot for linear density

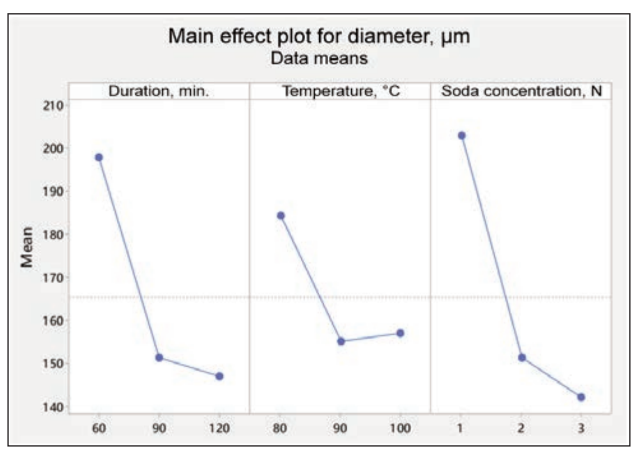

Fig. 2. Main effect plot for diameter

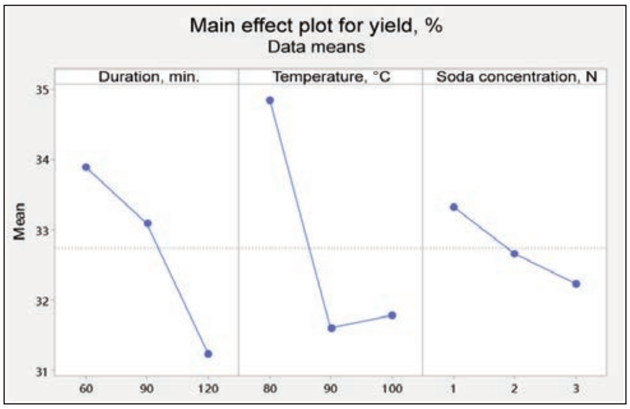

Fig. 3. Main effect plot for Yield

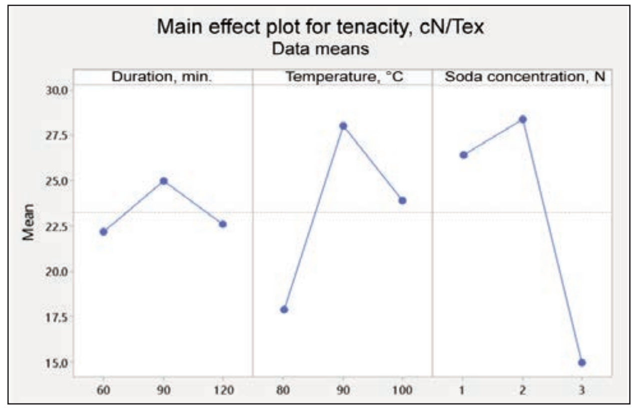

Fig. 4. Main effect plot of tenacity

alkaline treatment. The fibres obtained at the mild condition of treatment (temperature, soda concentration and duration) have a low tenacity while the removal of impurities from fibres was ineffective in this case. When aggravating treatment conditions, the tenacity was improved. This can be explained by the fact that the soda treatment in this condition, favoured arrangement of macromolecular chains of cellulose while eliminating lignin and hemicelluloses deposited on the fibre. This increases the crystallinity of the fibres and subsequently their resistance [23]. In fact, the fibres tenacity achieved a threshold (53, 55 cN/Tex) in the combination (2 N, 100°C and 90 min). When aggravated the extraction conditions, the tenacity of fibres declined (<23.5 cN/Tex) as a result of destruction of cellulosic structure and greater impurity removal.

Degree of control factors influence on the physical and mechanical properties

In order to conclude on the importance of extraction conditions, a statistical analysis of the effect of temperature, soda concentration and duration of the treatment on the various properties was developed. The p-value is used in hypothesis tests to help you decide whether to reject or accept a null hypothesis. The p-value is the probability of obtaining a statistic test that is at least as extreme as the actual calculated value, if the null hypothesis is true. A commonly used cut-off value for the p-value is 0.05. For example, if the calculated p-value of a test statistic is less than 0.05, you reject the null hypothesis. This null hypothesis in our case is the factor that has no significant influence on the fibbers' property [22, 24]. Results of the p-values are shown in table (2).
From this table, we can notice that the most influencing parameter on the measured properties was temperature and duration which was predominant.

Optimization of treatment conditions

In order to optimize the treatment conditions we have used the desirability functions in which we took into account the target "Y target", and the importance of every property "Yi" in the definition of global desirability [25]. In this study, it was used two types of desirability functions "di": desirability function to maximize and to minimize. Thus, to maximize a property "Yi", such as the yield, strength and elongation, the desirability function had to be used, where di was calculated as follows:

$$d = 0 \quad \text{if} \quad Y_i \leq Y_{min};$$
$$d_i = \left[\frac{Y_i - Y_{min}}{Y_{target} - Y_{min}}\right] \quad \text{if} \quad Y_{min} \leq Y_i \leq Y_{target}; \qquad (3)$$
$$d_i = 1 \quad \text{if} \quad Y_i \geq Y_{target}$$

To *minimize* a property "Yi", the desirability function had to be used, where d_i was calculated as follows:

$$d = 1 \quad \text{if} \quad Y_i \leq Y_{target};$$
$$d_i = \left[\frac{Y_i - Y_{max}}{Y_{target} - Y_{max}}\right] \quad \text{if} \quad Y_{target} \leq Y_i \leq Y_{max}; \qquad (4)$$
$$d_i = 0 \quad \text{if} \quad Y_i \geq Y_{max}$$

For each property affecting the global desirability, it was calculated the satisfaction degree "dg" and we

Table 2

P-VALUES MEANING				
Dependent variables	**Linear density (Tex)**	**Diameter (µm)**	**Yield (%)**	**Tenacity (cN/Tex)**
Soda concentration (N)	significant influence (p<0.05)	significant influence (p<0.05)	insignificant influence (p>0.05)	significant influence (p<0.05)
Temperature (°C)	significant influence (p<0.05)	insignificant influence (p>0.05)	significant influence (p<0.05)	insignificant influence (p>0.05)
Duration (min)	significant influence (p<0.05)	significant influence (p<0.05)	significant influence (p<0.05)	insignificant influence (p>0.05)

attributed a relative weight to indicate the property's importance. These different satisfaction degrees were grouped by using the Derringer and Suich desirability function [26] defined as follows:

$$d_g = \sqrt[w]{d_1^{w_1} \times d_1^{w_2} \times \ldots \times d_1^{w_n}} \quad (5)$$

where d_i is the individual property's desirability function Y_i $i \in [1,\ldots,n]$, w_i – the weight of the property Y_i in the "dg" desirability function, w – the sum of w_i and n – the number of properties. The compromise between the properties (minimize fibre linear density and diameter, maximize yield and tenacity) was better when "dg" increased; it became "perfect" when "dg" was equal to 1. When the satisfaction degree "di" of the property Y_i was equal to 0, the response had a value outside of the tolerance of the function "dg" was equal to 0 and so the compromise was rejected. To define the desirability function, we had to set the objective for every property. These different objectives are reported in table 3. The results of desirability for each property and the optimum values for the independent variables are presented in table 4 and table 5.

Table 3

THE OPTIMUM LEVELS OF PROPERTIES

Dependent variables	Objective	Min	Max
Linear density (Tex)	Minimize	-	30
Diameter (µm)	Minimize	-	250
Yield (%)	Maximize	28	-
Tenacity (cN/Tex)	Maximize	18	-

Table 4

DESIRABILITY VALUES FOR THE DEPENDENT VARIABLES

Dependent variables	Value	Desirability d_i (%)	Weight
Linear density (Tex)	17.34	100	1
Diameter (µm)	128.84	100	1
Yield (%)	32.07	82	1
Tenacity (cN/Tex)	30.73	100	1
Global desirability (d_g)	-	95.04	-

Note: d_i denotes individual desirability of dependent variables (linear density, diameter, yield, and strength).

Table 5

OPTIMUM VALUES FOR THE INDEPENDENT VARIABLES

Value	Normalized value	Real value
Temperature (°C)	3	100
Soda concentration (N)	2	2
Duration (min)	2	90

The statistical study determined the optimum treatment conditions which are: 100°C as temperature, 2 N as soda concentration and during 90 min.

Characterization of fibres treated with optimum conditions

Morphological properties

Figure 5, *a* and 6, *a* represent the longitudinal views of untreated and treated WPF respectively. As shown in the figure, the untreated fibres were covered by gummy and waxy material on their surfaces. After the combined treatment, SEM micro-graphics show an improvement in surface morphology. Application of soda treatment helped removing large impurities amount of from the fibre surface and causes fibrillation. It was observed that a dimensional variation of the fibre upon transverse cut (figures 5, *b* and 6, *b*). The structure of the technical WPF fibre was similar to that of natural fibres: sisal, esparto [5]. It represented a natural composite in which the ultimate microfibrils of cellulose constituted the reinforcement and the ligneous substances constituted the matrix [17]. Ray et al. [27] reported that the progressive increase in the time of treatment causes the reduction of the mass of the fibre until stabilization; that is, the treatment eliminates only the residual impurities and does not attack microfibrils of cellulose. As shown in figure 6, *b*, the treatment eliminated waxy substances present on the surface of untreated fibres. The treatment decreased the amorphous cellulose quantity to the detriment of the crystalline quantity [28]. According to the morphological survey made date palm fibre (DPF), the external layer is the lignin [28].

Figure 6 shows an increase of pore number in fibres after alkali treatment. The result agrees with previous studies conducted on the date palm fibre (DPF) [28]. By using aqueous solution, a large number of regularly distributed holes appeared on the fibre surface. These holes were caused by the reaction between the aqueous solution and the outer layer of fibres; these holes originated from the removal of the fatty deposit already existing on the surface. This large number may also tend to decrease the mechanical properties of single fibres.

Physical properties

Similar to other lignocellulosic fibres, the chemical treatments used in this study induced variation in the fibbers' physicochemical properties. *The density* of WPF treated at optimum conditions was found between 1.50 g/cm^3 and 1.53 g/cm^3, very close to that of other natural fibres: the ramie, the jute, the flax, etc. Table 6 summarizes the densities for the natural fibres. The treatment increased the density of WPF. The lower density of untreated palm fibre when compared to treated fibres could be attributed to large fibre diameter after treatment, which resulted in an increase in the diameter of the central void (lumen). Al-Khanbashi et al. and Josef et al. reported similar concerns with date palm fibre (DPF) and sisal

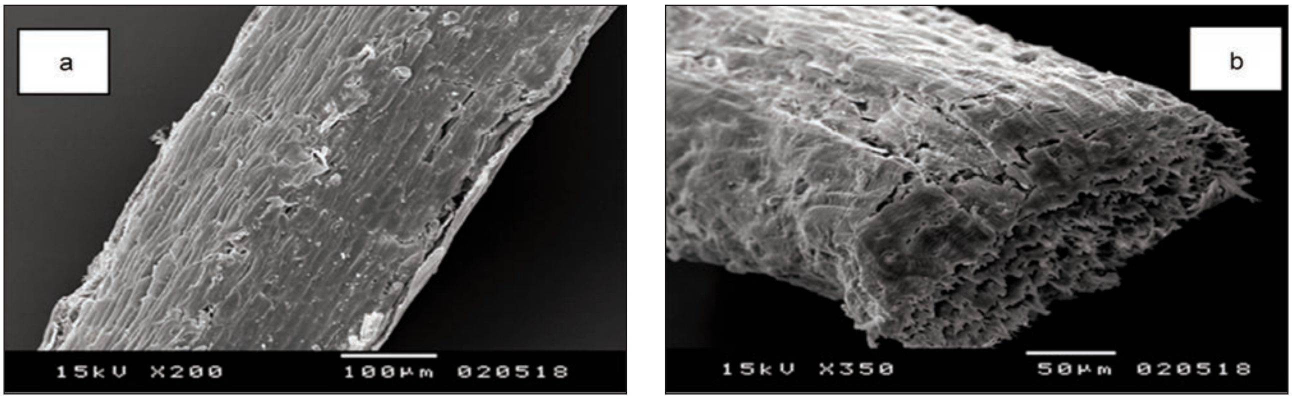

Fig. 5. SEM of untreated WPF (*a*) longitudinal and (*b*) cross-sectional views

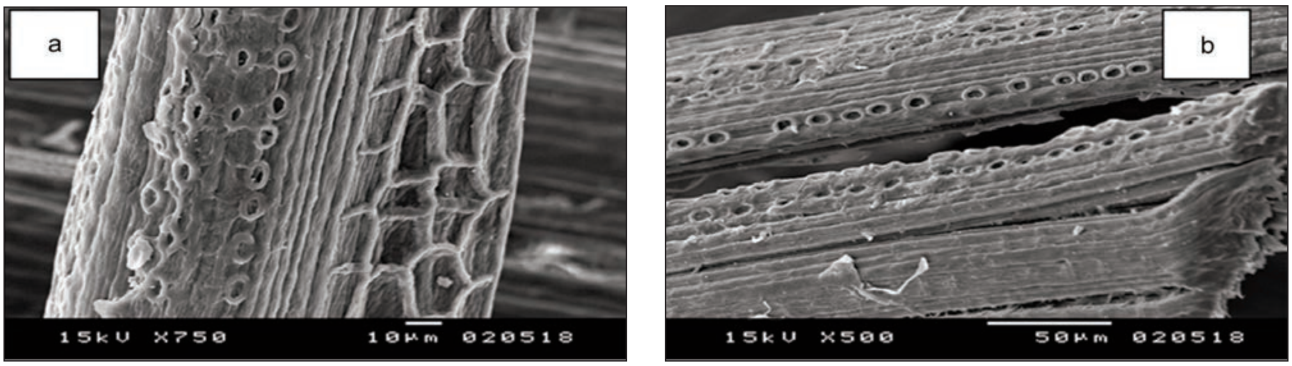

Fig. 6. SEM of treated WPF at the optimum conditions (*a*) longitudinal and (*b*) cross- sectional views

Table 6

DENSITIES FOR SOME NATURAL FIBERS [32]

Fibers	Density (g/cm^3)
Banana tree	1.4 – 1.45
Sisal	1.45
Jute	1.44
Ramie	1.56
Flax	1.54
Alfa	1.35
Agave Americana	1.36
Untreated WPF	1.15
Treated WPF	1.50 – 1.53

Table 7

LINEAR DENSITY AND DIAMETER FOR SOME NATURAL FIBERS [33–34]

Fiber	Linear density (Tex)	Apparent diameter (µm)
Doum palm leafstalk fiber	45.67	315.4
Kenaf	12	123
Typha fiber	31.3	205.1
Esparto	21.95	-
Untreated WPF	41	511
Treated WPF	19	132

fibres [28–29]. The alkali treatment affected the central voids and contributed to the gradual elimination of microvoids, which may have resulted in an increase in fibre density.

The linear density values obtained from the various palm fibre types and other natural fibres are presented in table 7. It was observed that the experimental result for linear density is in good agreement with the statistical result (table 4). It was varied from 41 Tex of raw material to 19 Tex of optimum treated WPF. Their linear densities are less than fibres extracted from leafstalk of doum palm [4] and typha fibres [30]. But they are close to fibre extracted from esparto [31].

Treated WPF had an apparent *diameter* of approximately 131 µm. The apparent diameter of untreated WPF was 511 µm. The exterior area of the fibre increased due the elimination of impurities of lignin and hemicelluloses. Equally the experimental result for diameter is in good agreement with the statistical result (table 4). The apparent diameter of technical WPF approximated that of the other natural fibres; it was always lower than 1000 µm and close to that of the kenaf fibre.

Mechanical properties

Non cellulosic material, constituting a part of natural fibres [35], could be removed by appropriate alkali treatments, which affect the tensile characteristic of the fibre [36]. To assess this hypothesis, tensile properties of the chemically extracted fibres were determined by a LLOYD LRX tensile tester. Figure 7 illustrates load elongation diagram of treated WPF at optimum condition and untreated WPF. We notice that treatment improved the mechanical properties of WPF markedly the tensile strength but not the elongation to the break. There was an increase in the breaking strength to an average of almost 50%. It could be linked to the increase in the degree of arrangement of the cellulose (crystalline regions), the reduction of the lignin rate in the fibre, the removal of the amorphous matter and the lumen reduction of fibres. This disagrees with the work of Sghaier et al. who proved an improvement in tensile strength as well as elongation to break [17].

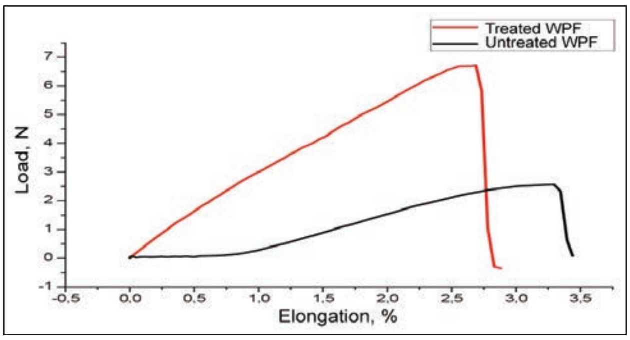

Fig. 7. Load elongation diagrams for treated WPF

The quality of any textile fibre largely depends on its two important properties, namely fineness and tenacity. The WPF have important mechanical properties. The WPF obtained have a better tenacity than the other vegetable fibres such as cotton, jute and agave Americana L (table 8). We note that the experimental result of tenacity is in good agreement with the statistical analyses (table 4).

Table 8

TENACITY AND ELONGATION OF VEGETABLE FIBER [32-33]

Fiber	Elongation (%)	Tenacity (cN/Tex)
Cotton	7 – 8	26 – 44
Jute	1.5 – 1.8	26 – 51
Alfa	1.5 – 2.4	-
Agave americana.L	49.64	28.3
Untreated WPF	4.5	13.2
Treated WPF	2.9	34

XRD analysis

The crystallographic structure and chemical composition were carried out by X-ray diffraction technique, for treated and untreated fibres. The XRD patterns of the treated and untreated WPF are shown in figure 8. It can be clearly observed that the diffraction peaks appear in the pattern corresponding to crystalline phase. The characteristic main peaks of cellulose at 2θ = 16°, 23.43° and 34.5° can be observed. These peaks are indicative of the presence of cellulose [37]. According to several authors [38–39], these two peaks can be attributed to cellulose I and IV, both having a monoclinic structure. The XRD pattern of treated WPF has similar features to that of untreated WPF but with a higher diffraction peak at 22.90° which may be attributed a crystalline cellulosic peak. The height of this peak can be due to the contribution of both the amorphous and the crystalline fractions according Sreenivasan et al. [35]. The increase in concentration of NaOH treatment increased the crystallinity index due to the removal of amorphous phase. Similar effects were observed for sisal fibre [40]. This is supported by the improvement in crystalline index (CrI) values (38 % for untreated fibre and 62% for treated fibres) which was calculated according to the method of Segal. This value is higher than that of the Wrighitia tinctoria seed fibre (49.2%) and ramie (58%); it is close to the value for cotton (60%) and smaller than that for raffia textilis (64%), sisal (71%), jute (71%), flax (80%) and hemp (88%) [39, 41–43].

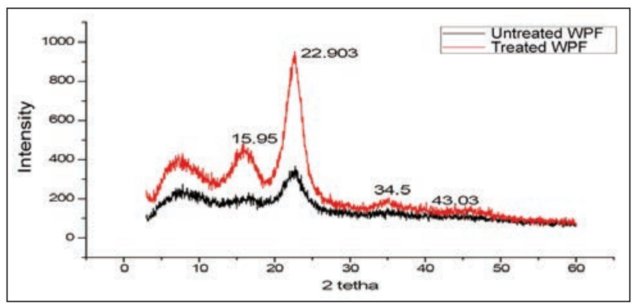

Fig. 8. X-ray diffraction spectra of raw and treated WPF

Fourier transforms infrared spectrometry

The chemical structure of WPF and the effects of NaOH treatment on the fibre's surface were also studied using FTIR. The FTIR spectra for WPF are presented in figure 9. The band positions vary between studies. When the variability of the position is taken into account, the bands at 3400 cm^{-1} and 760 cm^{-1} can be attributed to cellulose $I_β$ [44, 45]. The bands at 1740 cm^{-1} and 1510 cm^{-1} are attributed to lignin [44]. The CH stretch at 2838 cm^{-1} and

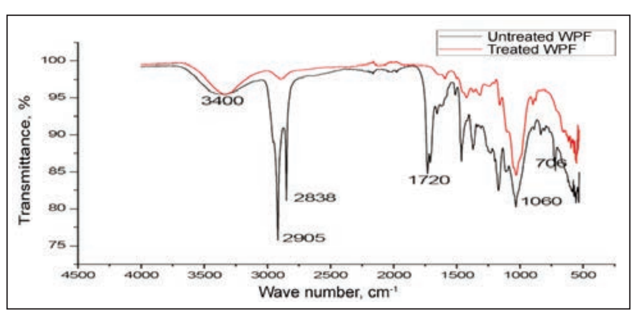

Fig. 9. FT-IR spectra's of raw and treated WPF

2905 cm^{-1} are present in the spectrum. The carbonyl band at 1720 cm^{-1} can be seen in the spectrum. The band at 1720 cm^{-1} is also attributed to the C=O stretch of the acetyl groups of hemicelluloses [35–46]. The band at 1060 cm^{-1} is a stretching vibration of C-O.

Thermal stability

The thermal properties of palm fibre were carried out by TGA under argon in the range of 25–800°C at a heating rate of 5°C/min. The TGA curve for WPF is presented in figure 10.

The fibre mass decreased from about 93% (at 100°C) to 89% (at 250°C) and to 32% (at 350°C). Different regions can be associated with the loss of retained water at 100°C, hemicellulose degradation in the 200–260°C region, cellulose degradation at 240–350°C and lignin degradation at 280–500°C [43, 45]. Between 100 and 250°C, degradation turned the ligno-cellulosic fibre into a brownish colour material, losing its strength, although this was not quantified. At higher temperatures, up to 500°C, carbonization occurred with accentuated loss of material. The degradation reactions of lignin and cellulose become exothermic at about 270 and 300°C, respectively. Pyrolysis of a cellulose occurred at about 300°C and of lignin at about 400°C, while hemicellulose decomposed at a considerably lower temperature [36]. The TGA curve profile for the untreated fibres was similar to previous work [19].

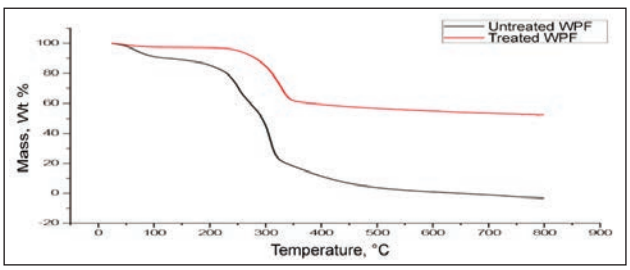

Fig. 10. Thermogram (TGA) curve of untreated and treated WPF

CONCLUSION

Vegetation associated with agriculture and forestry is a large source for extracting fibres, which has been largely under-utilized. The Washingtonia palm fiber (WPF) is vegetable fibre which derives from of the palm “Washingtonia filifera”. This plant does not need particular attention on cultivating them but their maintenance of the plantations produces a great amount of waste material. For that reason, we aimed to valorise it. The process of extraction of WPF results in an excellent quality of fibre. The optimum extraction conditions were found to be the average parameters of the extraction process with 2 N soda concentration and 100°C for 90 min. In this study we have investigated the physical, mechanical, morphological chemical and thermal properties of this fibre. The treatment eliminated the residual impurities. Therefore it decreased the diameter, the linear density and increased the density of fibres. WPF presented a natural composite in which fibrils of cellulose constituted the reinforcement and the ligneous and gummy substances constituted the matrix. The fibres had some morphological properties similar to those of other natural fibres such as the esparto. The FTIR spectra revealed the cellulosic structure of these fibres and their modification after chemical treatment. This change in structure is due to the increase of the cellulose amount exposed on the fibre surface, which increases the number of possible reaction sites (OH and CH groups). X-ray diffraction analysis performed to evaluate the variation of crystallinity index in dependence of the treatment, showed how the treatment improved the properties of the fibre. Finally, it is possible to consider the alkali treatment as a useful step in the production of WPF, since a significant improvement in quality was observed which opens the opportunity for using this kind of natural fibres in eco-friendly and low cost textile materials, in particular nonwoven materials.

REFERENCES

[1] Romain, T., *Anatomie comparée des palmiers : Identification-assistée par ordinateur, Applications en paléobotanique et en archéobotanique*, 2011, available at: https://www.researchgate.net/publication/215892059_Anatomie_comparee_des_palmiers_Identification-assistee_par_ordinateur_Applications_en_paleobotanique_et_en_archeobotanique [Accessed July 3rd 2019]

[2] Shinoj, S., Visvanathan, R., Panigrahi S., Kochubabu, M., *Oil palm fiber (OPF) and its composites: A review*, In: Ind. Crops Prod., 2011, 33, 1, 7–22

[3] Aldousiri, B., Alajmi, M., Shalwan, A., *Mechanical Properties of Palm Fibre Reinforced Recycled HDPE*, 2013, Available at: https://www.hindawi.com/journals/amse/2013/508179/ [Accessed October 21 2017]

[4] Sreekala, M.S., Kumaran, M.G., Thomas, S., *Oil palm fibers: Morphology, chemical composition, surface modification, and mechanical properties,* In: J. Appl. Polym. Sci., 1997, 66, 5, 821–835

[5] Essabir, H., Elkhaoulani, A., Benmoussa, K., Bouhfid, R., Arrakhiz, F.Z., Qaiss, A., *Dynamic mechanical thermal behavior analysis of doum fibers reinforced polypropylene composites*, In: Mater. Des., 2013, 51, Supplement C, 780–788

[6] Zbidi, F., Sghaier, S., Nejma, M.B., Zidi, M., *Influence of Alkaline and Enzymatic Treatments on the Properties of Doum Palm Fibres and Composite*, Available at: https://scialert.net/fulltext/?doi=jas.2009.366.371 [Accessed July 2nd 2019]

[7] Ali, M.E., Alabdulkarem, A., *On thermal characteristics and microstructure of a new insulation material extracted from date palm trees surface fibers*, In: Constr. Build. Mater., 2017, 138, 276–284
[8] Djoudi, A., Bali, A., Debicki, G., *Performance of date palm fibres reinforced plaster concrete*, 2012
[9] Yang, Q., et al., *Kenaf Bast Fiber Treatment for Nonwoven Fabrics*, 2001, Available at: https://www.researchgate.net/publication/239272411_Kenaf_Bast_Fiber_Treatment_for_Nonwoven_Fabrics [Accessed July 2nd 2019]
[10] Yu, H., Yu, C., *Influence of various retting methods on properties of kenaf fiber*, In: J. Text. Inst., 2010, 101, 5, 452–456
[11] Amel, B.A., Paridah, M. T., Sudin, R., Anwar, U.M.K., Hussein, A.S., *Effect of fiber extraction methods on some properties of kenaf bast fiber*, In: Ind. Crops Prod., 2013, 46, 117–123
[12] Sgriccia, N., Hawley, M.C., Misra, M., *Characterization of natural fiber surfaces and natural fiber composites*, In: Compos. Part Appl. Sci. Manuf., 2008, 39, 10, 1632–1637
[13] Joseph, K., Thomas, S., Pavithran, C., *Effect of chemical treatment on the tensile properties of short sisal fibre-reinforced polyethylene composites*, In: Polymer, 1996, 37, 23, 5139–5149
[14] Xiao, B., Sun, X.F., RunCang, S., *Chemical, structural, and thermal characterizations of alkali-soluble lignins and hemicelluloses, and cellulose from maize stems, rye straw, and rice straw*, In: Polym. Degrad. Stab., 2001, 74, 2, 307–319
[15] Alawar, A., Hamed, A.M., Al-Kaabi, K., *Characterization of treated date palm tree fiber as composite reinforcement*, In: Compos. Part B Eng., 2009, 40, 7, 601–606
[16] Evans, R., Newman, R.H., Roick, U.C., Suckling, I.D., Wallis, A.F.A., *Changes in Cellulose Crystallinity During Kraft Pulping. Comparison of Infrared, X-ray Diffraction and Solid State NMR Results*, In: Holzforsch. - Int. J. Biol. Chem. Phys. Technol. Wood, 2009, 49, 6, 498–504
[17] Sghaier, S., Zbidi, F., Zidi, M., *Characterization of Doum Palm Fibers After Chemical Treatment*, In: Text. Res. J., 2009, 79, 1108–1114
[18] Zannen, S., Ghali, L., Halimi, M.T., Hssen, M.B., *Effect of Chemical Extraction on Physicochemical and Mechanical Properties of Doum Palm Fibres*, In: Adv. Mater. Phys. Chem., 2014, 4, 10, 203
[19] Arrakhiz, F.Z., El Achaby, M., Benmoussa, K., Bouhfid, R., Essassi, E.M., Qaiss, A., *Evaluation of mechanical and thermal properties of Pine cone fibers reinforced compatibilized polypropylene,* In: Mater. Des., 2012, 40, 528–535
[20] Zannen, S., Ghali, L., Halimi, M.T., Hassen, M.B., *Effect of Combined Chemical Treatment on Physical, Mechanical and Chemical Properties of Posidonia Fiber*, In: Adv. Mater. Phys. Chem., 2016, 6, 11, 275–290
[21] Mukhopadhyay, S., Shivankar, V., Fangueiro, R., *Variability of Tensile properties in fibers extracted from pseudo-stem of banana plants,* In: Asian Text. J., 2008, 17
[22] Mâatouk, I., et al., *Numerical Simulation of Yarn Bending: Statistical Optimization*, Available at: https://www.researchgate.net/publication/316476040_NUMERICAL_SIMULATION_OF_YARN_BENDING_STATISTICAL_OPTIMIZATION [Accessed July 2nd 2019]
[23] Williams, T., et al., *Time Effects on Morphology and Bonding Ability in Mercerized Natural Fibers for Composite Reinforcement*, Available at: https://www.researchgate.net/publication/228504838_Time_Effects_on_Morphology_and_Bonding_Ability_in_Mercerized_Natural_Fibers_for_Composite_Reinforcement [Accessed July 2nd 2019]
[24] Msahli, S., Sakli, F., Drean, J.-Y., *Study of Textile Potential of Fibres Extracted From Tunisian Agave Americana L.*, In: AUTEX Res. J., 2006, 6, 1, 5
[25] Jaouadi, M., M'sahli, S., Sakli, F., *Optimization and Characterization of Pulp Extracted from the Agave Americana L. Fibers*, In: Text. Res. J., 2009, 79, 2, 110–120
[26] Deringer, G., et al., *Simultaneous optimization of several response variables*, Available at: https://www.researchgate.net/publication/312977241_Simultaneous_optimization_of_several_response_variables [Accessed July 2nd 2019]
[27] Ray, D., Sarkar, B.K., Rana, A.K., Bose, N.R., *Effect of alkali treated jute fibres on composite properties*, In: Bull. Mater. Sci., 2001, 24, 2, 129–1351
[28] Al-Khanbashi, A., Al-Kaabi, K., Hammami, A., *Date palm fibers as polymeric matrix reinforcement: Fiber characterization*, In: Polym. Compos., 2005, 26, 4, 486–497
[29] Kuruvilla, J., et al., *A Review on Sisal Fiber Reinforced Polymer Composites*, Available at: https://www.researchgate.net/publication/228956261_A_Review_on_Sisal_Fiber_Reinforced_Polymer_Composites [Accessed July 2nd 2019]
[30] Rezig, S., Jaouadi, M., Khoffi, F., Msahli, S., Durand, B., *Optimization of extraction process of Typha leaf fibres*, In: Indian J. Fibre Text. Res., 2016, 41, 3, 242–248
[31] Mounir, J., Wanassi, B., Msahli, S., Hassen, M., *Characterization of mechanical extracted Alfa fibres,* In: Int J Fiber Text. Res, 2014, 4, 1–4
[32] Slah, M., *Etude du potentiel textile des fibre d'agave americana L.*, Available at: http://www.theses.fr/06387122X [Accessed July 2nd 2019]
[33] Dallel, M., *Evaluation du potentiel textile des fibres d'Alfa (Stipa Tenacissima L.) : caractérisation physico-chimique de la fibre au fil. Mulhouse*, 2012
[34] Khalil, H.P.S.A., Alwani, M.S., Omar, A.K.M., *Chemical Composition, Anatomy, Lignin Distribution, and Cell Wall Structure of Malaysian Plant Waste Fibers*, In: BioResources, 2006, 1, 2, 220–232
[35] Sreenivasan, S., Iyer, P.B., Iyer, K.R.K., *Influence of delignification and alkali treatment on the fine structure of coir fibres (Cocos Nucifera)*, In: J. Mater. Sci., 1996, 31, 3, 721–726
[36] Zhao, H., Kwak, J., Conradzhang, Z., Brown, H., Arey, B., Holladay, J., *Studying cellulose fiber structure by SEM, XRD, NMR and acid hydrolysis*, In: Carbohydr. Polym., 2007, 68, 2, 235–241.

[37] d'Almeida, J.R.M., Aquino, R.C.M.P., Monteiro, S.N., *Tensile mechanical properties, morphological aspects and chemical characterization of piassava (Attalea funifera) fibers*, In: Compos., 2006, Part A, 9, 37, 1473–1479
[38] Helbert, W., Sugiyama, J., Ishihara, M., Yamanaka, S., *Characterization of native crystalline cellulose in the cell walls of Oomycota*, In: J. Biotechnol., 1997, 57, 1, 29–37
[39] Rajeshkumar, G., Hariharan, V., Scalici, T., *Effect of NaOH Treatment on Properties of Phoenix Sp. Fiber*, In: J. Nat. Fibers, 2016, 13, 6, 702–713
[40] Mwaikambo, L.Y., Ansell, M.P., *Chemical modification of hemp, sisal, jute, and kapok fibers by alkalization*, In: J. Appl. Polym. Sci., 2002, 84, 12, 2222–2234
[41] Elenga, R.G., Dirras, G.F., Goma Maniongui, J., Djemia, P., Biget, M.P., *On the microstructure and physical properties of untreated raffia textilis fiber*, In: Compos. Part Appl. Sci. Manuf., 2009, 40, 4, 418–422
[42] Subramanian, K., Senthil Kumar, P., Jeyapal, P., Venkatesh, N., *Characterization of ligno-cellulosic seed fibre from Wrightia Tinctoria plant for textile applications – an exploratory investigation*, In: Eur. Polym. J., 2005, 41, 4, 853–861
[43] Åkerholm, M., Hinterstoisser, B., Salmén, L., *Characterization of the crystalline structure of cellulose using static and dynamic FT-IR spectroscopy*, In: Carbohydr. Res., 2004, 339, 3, 569–578
[44] Sugiyama, J., Persson, J., Chanzy, H., *Combined infrared and electron diffraction study of the polymorphism of native celluloses*, In: Macromolecules, 1991, 24, 9, 2461–2466
[45] Liu, W., Mohanty, A.K., Drzal, L.T., Askel, P., Misra, M., *Effects of alkali treatment on the structure, morphology and thermal properties of native grass fibers as reinforcements for polymer matrix composites*, In: J. Mater. Sci., 2004, 39, 3, 1051–1054

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Garment knowledge base development based on fuzzy technology for recommendation system

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ABSTRACT – REZUMAT

Garment knowledge base development based on fuzzy technology for recommendation system

With the rapid development of garments recommendation systems, more and more garment knowledge base have been widely developed. The research in this paper aims to build a garment knowledge base in order to help general consumers to identify the most relevant products satisfying their specific requirements. We design four experiments for building this knowledge base by 8 pairs of normalized sensory evaluation criteria for describing both consumers' expectations and product profile. The theory of fuzzy composition technology is applied for setting up garment knowledge base which can be used for consumer-oriented intelligent garment recommendation system. Compared with the other knowledge base, this knowledge base is more robust and more interpretable owing to its capacity of handling vague, imprecise, uncertain, or ambiguous.

Keywords: *fuzzy technology, sensory experiment, knowledge base*

Dezvoltarea bazei de cunoștințe despre articolele de îmbrăcăminte utilizând tehnologia fuzzy pentru sistemul de recomandare

Odată cu dezvoltarea rapidă a sistemelor de recomandare a articolelor de îmbrăcăminte, au fost dezvoltate pe scară largă baze de cunoștințe din ce în ce mai extinse. Studiul din această lucrare își propune să construiască o bază de cunoștințe despre articolele de îmbrăcăminte, pentru a ajuta consumatorii să identifice cele mai relevante produse, care să îndeplinească cerințele lor specifice. Au fost proiectate patru experimente pentru construirea acestei baze de cunoștințe cu 8 perechi de criterii de evaluare senzorială, normalizate pentru a descrie atât așteptările consumatorilor, cât și profilul produsului. Teoria tehnologiei de compoziție fuzzy a fost aplicată pentru crearea bazei de cunoștințe despre articolele de îmbrăcăminte, care poate fi utilizată pentru sistemul inteligent de recomandare a articolelor de îmbrăcăminte orientate către consumator. Comparativ cu alte baze de cunoștințe, aceasta este mai robustă și mai interactivă datorită capacității sale de a gestiona informații vagi, imprecise, incerte sau ambigue.

Cuvinte-cheie: *tehnologie fuzzy, experiment senzorial, bază de cunoștințe*

INTRODUCTION

In the field of garment, knowledge can be divided into explicit knowledge and implicit knowledge based on the way of its acquisition. The explicit knowledge, referring to knowledge that can be explicitly expressed, can be acquired from oral instructions, textbooks, references, periodicals, patents, software and database and so on [1]. The explicit knowledge can be propagated through languages, books, text, database, and can be easily learned by human.

Implicit knowledge refers to tacit knowledge possessed by human experts in terms of skills and recognition, including not only skills and experiences that are informal and hard to express, but also insights, intuitions, inspirations, etc. Implicit knowledge exists in human brains, which dominate its various applications by human.

Knowledge originates from books, electronic data, expertise, and so on. The knowledge engineers can acquire knowledge from three sources:

- Indirect knowledge: experts provide their empirical and non-structured knowledge related to their past experiences by responding a well-organized questionnaire in some real scenarios.
- Direct knowledge: experts directly express their well-structured and formalized knowledge under the forms of generalized rules and relations.
- Knowledge from data: knowledge can be automatically and progressively learned from data.

This paper mainly deals with indirect knowledge and knowledge from data to set up the garment knowledge base. For an accurate and objective expression of knowledge on garments, it is important to analyse the characteristics of knowledge on garments, which can be summarized by a number of semantic statements.

Fuzziness: human's perception is fuzzy, and cannot be easily expressed. Thus, it is difficult to give quantitative results with traditional theories and methods when evaluating the perception on a garment. Also, the evaluation rules cannot be understood and stated with Boolean logic. The Kansei information expressed by a certain evaluation subject is not only uncertain but also multiple. Consequently, in practice, the Kansei information on garments can be expressed by utilizing fuzzy sets.

Complexity: garments are the most commonly-used consumer goods. However, its information is very complicated and rich. The complexity of a garment is not only embodied in its own structure and aesthetic perception, but also highlighted in the relationship between the garment and body shapes. For example, the same garment fitting with different consumer sizes, usually leads to a big difference in vision. This is so-called Kansei attraction of garments, which is difficult to understand.

Integrity: for garment products, design elements include a number of Kansei information, such as patterns, details, fabrics and so on. These elements are independent but interconnected between them, in order to show one specific identity. The perception on garments is related to the overall sensory effects on the combination of these elements. So, the evaluation on garments is performed with respect to overall perception [2].

The main computational tools used in this paper are fuzzy techniques which selected for modelling and analysis of professional knowledge and human perceptions at different levels by taking into account the previous characteristics.

FUZZY TECHNOLOGY

The entire real world is complex and the complexity arises from vagueness. If the complexity of a problem exceeds a certain threshold, the system must become vague in nature. And with the increase of complexity, our ability of making precise judgments about the behaviuor of the system diminishes [3]. There is a rapid decline in the information afforded by traditional mathematical models due to their insistence on precision.

Compared with traditional system modelling and analysis techniques, fuzzy sets have the following strengths:

- It is conceptually easy to understand. The mathematical concepts behind fuzzy reasoning are simple.
- It is tolerant with vague data. Most of things are imprecise even on careful inspection. Fuzzy reasoning permits to build this understanding into the process rather than tacking it onto the end.
- It is based on natural language. The basis for fuzzy logic is the basis for human communication.

Natural language is the carrier of efficient communication. Since fuzzy logic is built atop the structures of qualitative description used in everyday language, it is easy to use.

Some major areas of fuzzy applications in textile/garment industry include classifications, recommendations, decision-making and so on, related to materials, finished products, consumers, markets and manufacturing processes. An example is body size classification using the fuzzy c-means clustering algorithm. Also, a method of fuzzy comprehensive evaluation has been investigated for fabric stiffness handle [4]. And an intelligent system based on fuzzy logic has been developed for optimization of the textile and garment supply chain [5]. Moreover, an intelligent system based on the fuzzy techniques has been developed to evaluate fabric shape style based on motion capture [6].

In this paper, we develop a garment knowledge base by fuzzy composition technology. This knowledge base is about women's jeans, and is widely use in garment recommendation system for special consumers.

First, we design four experiments to build the knowledge base, Experiment 1, 2 and 3 are designed to find out the relation between consumer profile (body shapes, style keywords, visual images) and a set of predefined normalized evaluation criteria. Experiment 4 finds out the relations between the product profile (garment fitting and details) and the same normalized evaluation criteria.

Second, knowledge base 1 (KB1) is set up from the data get in Experiment 1, 2 and 3, while knowledge base 2 (KB2) is established from the data get in Experiment 4.

Finally, KB1 and KB2 form the knowledge base through fuzzy composition operation. The process of building the knowledge base is shown in figure 1.

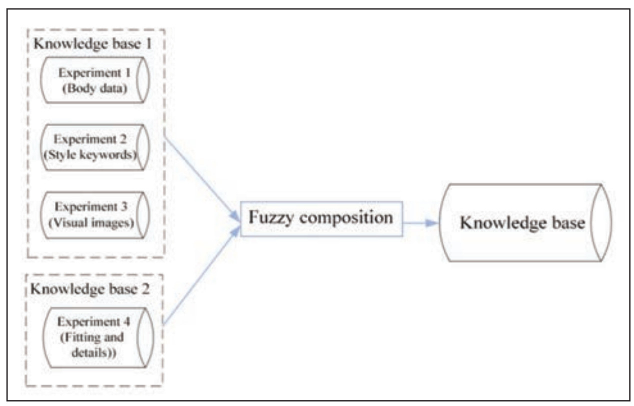


Fig. 1. The process of building the knowledge base

Fuzzy theory

Words like "young", "tall", "good", and "high" are fuzzy. There is no single quantitative value for characterizing the term "young". For some people, age 20 is young, and for others, age 30 is young. The concept young have no clear boundary.

In the real world, there exists a lot of human knowledge. By nature, knowledge is vague, imprecise, uncertain, ambiguous, or probabilistic. Human thinking and reasoning frequently involve fuzzy information, originating from vague human concepts. Humans can give satisfactory answers, which are probably true.

However, most of automatic systems are designed based upon classical set theory and two-valued logic which is unable to cope with unreliable and incomplete information and give expert opinions. In this situation, fuzzy technology has shown their special advantages of dealing with both human knowledge and uncertain information.

Fuzzy composition relation

Let R be a fuzzy relation defined on a Cartesian space $X \times Y$, S – a fuzzy relation on $Y \times Z$, and T – a fuzzy relation on $X \times Z$. The most used composition method for linking two fuzzy relations is called max-min composition:

$$T = R \circ S = \{(x,z), \max\{\min(\mu_R(x,y), \mu_S(x,y))\} / x \in X, y \in Y, z \in Z\} \quad (1)$$

EXPERIMENTS PROCEDURE

A consumer profile is a way of describing a consumer which can be defined in different ways. In this paper, we define the consumer profile as the combination of three parts, such as body shape, style keywords and visual images.

Product profile describes jeans, we define the product profiles as two parts, such as garment fitting levels and garment details.

Experiment 1

Experiment 1 aims to extract the fashion knowledge and experience from fashion designers about the relations between body shapes and evaluation criteria. The components and the procedures of experiment 1 are given below.

Body data

Since the purpose of this paper is to set up the garment knowledge base of Chinese women whose ages are from 18 to 25, we select four basic body measurements: b1: Stature, b2: Chest Circumference, b3: Waist Circumference, b4: Weight [7].

The Chinese Standard Human Body Database (female) is available in our study. It is covering the body types of the whole Chinese female population. The statures of these samples are arranged from 145 cm to 175 cm with a step length of 5 cm. According to this database, four standard body types (Y, A, B, C) are defined from the difference of chest circumference and waist circumference.

- Y means that Chest Circumference minus Waist Circumference is between 19 cm and 24 cm.
- A means that Chest Circumference minus Waist Circumference is between 14 cm and 18 cm.
- B means that Chest Circumference minus Waist Circumference is between 9 cm and 13 cm.
- C means that Chest Circumference minus Waist Circumference is between 4 cm and 8 cm.

In practice, these fours body types cover more than 99% of the whole population of Chinese women (table 1).

We use the Clo3D software to build a 3D virtual body with a standard neutral face expression shapes. In this paper, evaluation of human body shapes with 3D human models created by Clo3D for a specific consumer is more efficient than that with real body shapes [8]. In fact, some real body shapes, especially special shapes like sportsmen, are not always available in classical evaluation sessions.

Consumers should input four body data by manually taking measures on b1 (Stature), b2 (Chest Circumference), b3 (Waist Circumference) and b4 (Weight). After inputting these body data, the 3D human model of the specific consumer can be built by Clo3D.

We can describe the level of tall-low as five levels: X1: short, X2: a little short, X3: middle, X4: a little tall, X5: tall. We can name fat-thin as four levels: Y1: underweight Y2: normal, Y3: overweight, Y4: obese. Therefore, the entire body shapes can be described by 20 combinations. Which is “X1×Y1”, “X2×Y1”, “X3×Y1”, “X4×Y1”, “X5×Y1”, “X1×Y2”, “X2×Y2”, “X3×Y2”, “X4×Y2”, “X5×Y2”, “X1×Y3”, “X2×Y3”, “X3×Y3”, “X4×Y3”, “X5×Y3”, “X1×Y4”, “X2×Y4”, “X3×Y4”, “X4×Y4”, “X5×Y4”. For any specific body shape, we require each evaluator to give a predefined five levels of score for each of the eight evaluation criteria. We can use a (20×8)-dimensional matrix to express the evaluation data. The 20 body shapes correspond to the following images (table 2).

In experiment 1, 42 undergraduate and graduate students and 3 textile industry experts are invited to act sensory evaluators. Finally, for each evaluator, the evaluation scores for the 8 sensory descriptors and all 20 virtual body shapes compose a (20×8)-dimensional matrix.

Experiment 2

Experiment 2 aims to extract from human perception, fashion designer’s knowledge about the relations between style keywords and evaluation criteria. There are many words used to describe garments styles such as: Fashion, Elegant, Feminine, Young, Sexy, Classic, Romantic, and Sporty.

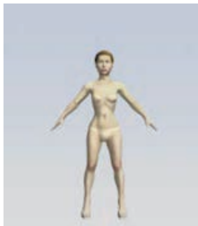
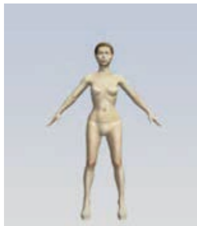
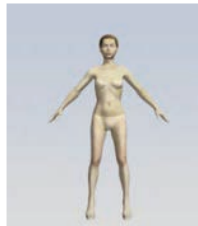
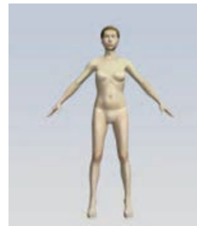
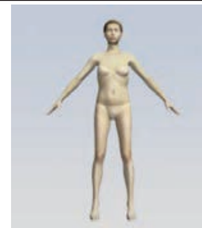
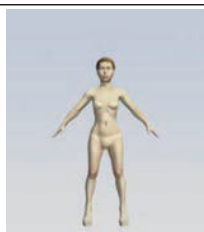
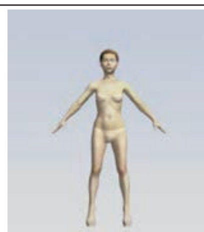
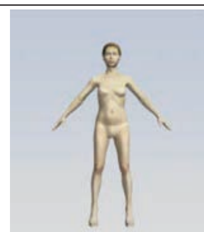
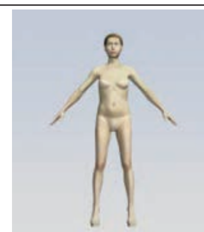
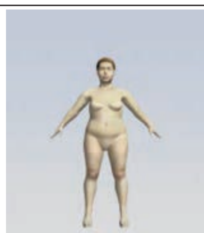
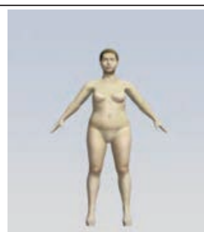
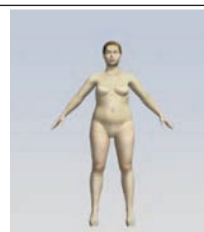
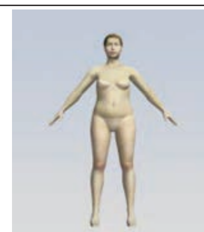
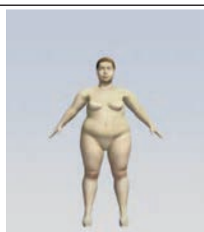
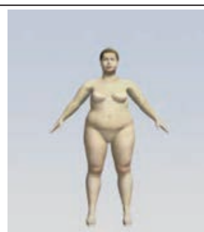
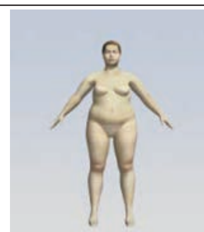
The process of selecting the style keywords is presented below. First, 20 various style keywords describing garments are summarized from the Internet and fashion trends magazine. Then each fashion expert evaluates the relevancy of each style keyword to female jeans by giving an evaluation

Table 1

FOUR BODY TYPES OF CHINESE STANDARD HUMAN BODY DATABASE				
Parameters	**Y**	**A**	**B**	**C**
b2 – b3	19 cm – 24 cm	14 cm – 18 cm	9 cm – 13 cm	4 cm – 8 cm
proportion	14.82%	44.13%	33.72%	6.45%

Table 2

THE 20 BODY SHAPES USED IN EXPERIMENT 1

X1×Y1	X2×Y1	X3×Y1	X4×Y1	X5×Y1
				
X1×Y2	X2×Y2	X3×Y2	X4×Y2	X5×Y2
				
X1×Y3	X2×Y3	X3×Y3	X4×Y3	X5×Y3
				
X1×Y4	X2×Y4	X3×Y4	X4×Y4	X5×Y4
				

score from 1 to 10 with the help of corresponding explanation and image. The final 8 style keywords are determined by choosing the keywords corresponding to the 8 highest averaged evaluation scores.

After identifying the 8 style keywords describing women's garments, we invite the same fashion experts to evaluate the relations between the 8 style keywords and the 8 normalized sensory evaluation criteria. For each expert, all the evaluation scores are collected in a (8×8)-dimensional matrix.

The experiment 2 is not only limited to these 8 style keywords. If a new style keyword is added (for example "wild"), we can update the evaluation matrix by either introducing new evaluation scores on this new keyword or expressing it using the combination of the existing keywords.

In experiment 2, 50 undergraduate and graduate students and 10 university professors are invited to play the role of sensory evaluators. The used 8 sensory descriptors are the same as in Experiment 1. The evaluation results of each evaluator compose a (8×8)-dimensional matrix.

Experiment 3

Experiment 3 can identify the relations between visual images (ambiances) and evaluation criteria. During the purchasing event, consumers do not completely know which garment is really suitable for them but they just master some vague verbal expressions that describe their expectations. In experiment 3, we perform a series of evaluations so that the selected consumers of the target population choose the most relevant images according to their requirements.

Six images have been chosen in experiment 3. For each Visual image, a number of representative photographs, are presented in order to make the evaluators understand it more easily.

Each consumer is asked to select a pair of favourite jeans from the following pictures based on her consumer preference. For each evaluator, her evaluation data are collected on a (6×8)-dimensional matrix. The updating of this evaluation matrix follows the same principle as that of style keywords.

In fact, evaluations with image are complementary to evaluation with style keywords. In this paper, the body data, the style keywords and visual images constitute together the consumer profile.

50 undergraduate and graduate students and 10 university professors are invited to participate in experiment 3. These consumer evaluators fill out the questionnaire separately. Finally, the results obtained from each consumer evaluator compose a (6×8)-dimensional linguistic matrix.

Experiment 4

Experiment 4 aims to extract from the perceptions, fashion designer's knowledge about the relations between design style and evaluation criteria.

The most important part of the garment is two parts: fitting of a garment style and details. Five values of fitting of a garment styles are assumed in experiment 4. For each fitting of a garment style, a number of representative photographs are presented to make it more easily for the evaluators to understand it.

We have three parts of details: the details of waist, the details of leg opening and the details of ornamental. For each fitting of a garment style, a number of representative photographs are presented in order to make the evaluators understand it more easily.

The recombination of the general fitting (5 evaluation levels) and the three parts of details (3+3+2 evaluation levels) can determine a product profile (13 evaluation levels covering all the cases). When evaluating the relations between design styles and evaluation criteria, each expert gives scores to the fitting effect and each detail with the 8 evaluation criteria.

For all the 13 evaluation levels describing a product, their relations with the 8 evaluation criteria constitute a (13×8)-dimensional matrix for each evaluator.

In experiment 4, 10 textile industry experts are invited to play the role of sensory evaluators. The evaluation results of each evaluator compose a (13×8)-dimensional matrix.

MATHEMATICAL FORMALIZATION

After obtaining human perceptual data from the trainees participating in the 4 experiments, we give the mathematical formalization of the related concepts. Finally, the garment knowledge base can be set up by fuzzy composition relations.

1: Let $E=\{e_1, e_2, \ldots, e_p\}$ be a set of p evaluation criteria.

2: Let $BS=\{bs_1, \ldots, bs_m\}$ be a set of m body shapes ($m=20$).

3: Let $S=\{s_1, \ldots, s_n\}$ be a set of n style keywords ($n=8$).

4: Let $C=\{c_1, \ldots, c_k\}$ be a set of k visual images ($k=6$).

Let N be the total number of consumer profile. We have $N = m+n+k$.

5: Let $G=\{g_1, \ldots, g_h\}$ be a set of h fitting levels ($h=5$).

6: Let $DW=\{dw_1, \ldots, dw_x\}$ be a set of x details of waist ($x=3$).

7: Let $DF=\{df_1, \ldots, df_y\}$ be a set of y details of leg opening ($y=3$).

8: Let $DO=\{do_1, \ldots, do_z\}$ be a set of z details of ornamentals ($z=2$).

The M variables describing product profile with $M = h+x+y+z$.

9: Let KB_{BS} be the knowledge base get from the Experiments 1, describing the relations between BS and E. It is expressed by a (m×p)-dimensional matrix.

10: Let KB_S be the knowledge base get from the Experiments 2, describing the relations between S and E. It is expressed by a (n×p)-dimensional matrix.

11: Let KB_C be the knowledge base get from the Experiments 3, describing the relations between C and E. It is expressed by a (k×p)-dimensional matrix.

12: Let KB_G be the knowledge base get from the Experiments 4, describing the relations between E and G. It is expressed by a (p×h)-dimensional matrix.

13: Let KB_{DW} be the knowledge base get from the Experiments 4, describing the relations between E and DW. It is expressed by a (p×x)-dimensional matrix.

14: Let KB_{DF} be the knowledge base get from the Experiments 4, describing the relations between E and DF. It is expressed by a (p×y)-dimensional matrix.

15: Let KB_{DO} be the knowledge base get from the Experiments 4, describing the relations between E and DO. It is expressed by a (p×z)-dimensional matrix.

16: Let KB_1 be the knowledge base get from the Experiments 1, 2, 3, describing the relations between the N consumer profiles and E.

17: Let KB_2 be the knowledge base get from the Experiments 4 describing the relations between E and the M product profiles.

Computing knowledge base

From the matrices KB_{BS}, KB_S and KB_C, we get the matrix $KB_1 = \begin{vmatrix} KB_{BS} \\ KB_S \\ KB_C \end{vmatrix}$. From the matrices of KB_G, KB_{DW}, KB_{DF} and KB_{DO}, we get the matrix KB_2 = [KB_G KB_{DW} KB_{DF} KB_{DO}]. By successive combinations the KB_1 and KB_2, we get knowledge base of the consumer profile and product profile by fuzzy composition technology, named as KB.

$KB = KB_1 \circ KB_2$.

CONCLUSION

The garment knowledge base about consumer profile and product profile of the women's jeans was built by applying the principle of fuzzy composition technology. This garment knowledge base can be used on a garment recommendation system for special consumers [8]. Fuzzy techniques are the main computational tool used in this paper because they are more relevant to modelling and analysis of the acquired data. In fact, the evaluation data on body shapes, style keywords and visual images can never be accurately expressed.

The research method of this paper can be directive for other researches on the knowledge between any kind of garments or fashion products. In addition, the method of building the garment knowledge base can be widely used for consumer-oriented recommendation system. It can guide shoppers and manufactures to recommend more competitive garments or fashion products in the consumer-oriented market. Compared with the other knowledge base, this knowledge base is more robust and more interpretable owing to its capacity of handling vague, imprecise, uncertain, or ambiguous.

Due to limited time, only the female jeans knowledge base was built in this paper. Further research could be arranged to apply fuzzy technology on other fashion fields such as suit, shoes, accessories and more.

REFERENCES

[1] Wenger, E., *Artificial intelligence and tutoring systems: computational and cognitive approaches to the communication of knowledge,* Morgan Kaufmann, 2014

[2] Zhang, J., et al., *Jeans knowledge base development based on sensory evaluation technology for customers' personalized recommendation*, In: International Journal of Clothing Science & Technology, 2018, 30, 1, 101–111

[3] Lazarus, S.A., et al., *Interpersonal functioning in borderline personality disorder: A systematic review of behavioral and laboratory-based assessments*, In: Clinical psychology review, 2014, 34, 3, 193–205

[4] Sun, F., et al., *Fuzzy comprehensive prediction of fabric stiffness handle based on quasi-three-point restraint test*, In: Fibers and Polymers, 2015, 16, 6, 1395–1402

[5] Ngai, E., et al., *Decision support and intelligent systems in the textile and apparel supply chain: An academic review of research articles*, In: Expert Systems with Applications, 2014, 41, 1, 81–91

[6] Li, Y., et al., *A new method to evaluate fabric shape style based on motion capture*, In: Fibers and Polymers, 2015, 16, 1, 201–208

[7] Zhang, J., et al., Consumer-Oriented Intelligent Garment Recommendation System, In: Uncertainty Modelling in Knowledge Engineering and Decision Making: Proceedings of the 12th International FLINS Conference, World Scientific, 2016

[8] Zhang, J., et al., *Recommending Garment Products in E-Shopping Environment by Exploiting an Evolutionary Knowledge Base*, In: International Journal of Computational Intelligence Systems, 2018, 11, 1, 340–354

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Effect of caustic treatment on cotton/modal blended fabric

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ABSTRACT – REZUMAT

Effect of caustic treatment on cotton/modal blended fabric

Attempt has been made to assess the cotton/modal (60:40) blended woven fabric properties after mercerization with caustic lye of different strengths. Cotton/Modal (60:40) fabric was subjected to bulk mercerization process and subsequently dyed with reactive dyes. The colour strength, fastness properties (washing, staining and rubbing etc.), tensile and tear strength and shrinkage were characterized. The results of this study indicate that cotton/modal blended fabric that was considered in this study can be processed under similar conditions as those that are maintained for cotton fabrics generally and that the aforementioned properties are improved generally.

Keywords: *Modal, mercerization, colour strength, fastness properties, tear & tensile strength*

Influența tratamentului cu sodă caustică asupra materialelor textile din amestec fibros de bumbac/fibre modale

S-a încercat evaluarea proprietăților țesăturii din amestec fibros de bumbac/fibre modale (60:40), după mercerizare cu soluţie alcalină de sodă caustică de diferite concentrații. Țesătura de bumbac/fibre modale (60:40) a fost supusă unui proces industrial de mercerizare și apoi de vopsire cu coloranți reactivi. Au fost determinate proprietățile de intensitate și rezistență a culorii (modificarea culorii la spălare, cedarea culorii și rezistenţa la frecare etc.), rezistența la tracțiune și la sfâșiere și contracția la spălare. Rezultatele au indicat faptul că țesătura în amestec fibros de bumbac/fibre modale luată în studiu poate fi prelucrată în condiții similare cu cele utilizate uzual pentru țesăturile din bumbac, iar proprietățile menționate anterior sunt în general îmbunătățite.

Cuvinte-cheie*: fibre modale, mercerizare, intensitatea culorii, rezistența culorii, rezistența la sfâșiere și la tracțiune*

INTRODUCTION

By the mid of the 20th century, synthetic fibers including nylon, polyester and acrylics had witnessed a growth so rapid that the production of cotton has had to be cut back by legislation in the USA, for instance. This extra-ordinary growth in the demand of synthetic fibers can be attributed to a number of factors including reduced raw material costs, series of breakthroughs in the chemical industry, developments in plant operations and arguably the most attractive option of a greater control on the fiber properties. The aforementioned and other advantages of using synthetic fibers in textiles also proved to be the driving force for continued growth in the production and utilization of regenerated fibers. In the case of regenerated fibers, the advantage of being able to use abundantly available natural raw materials for their production, has over the years, proved to be a consistent factor in maintaining the status of such fibers as a feasible option for use in textiles [1].

Despite all the excitement regarding the man-made fibers and their world wide acceptance, it is an established fact that there is role is to supplement not to supplant the natural fibers [2]. Thus, blending of synthetic fibers as well as regenerated fibers with natural fibers has been practiced for decades now and for most combinations that are worthy of making end products, the resulting benefits in terms of the characteristics of the end product are well known [3–8]. Depending upon the ratio in which a natural fiber is mixed with one or more man-made fibers, the potential benefits may include, but are not limited to, reduced overall costs, improved thermal characteristics [9], comfort properties [10], changes in abrasion and pilling performance, improved dimensional stability and shrinkage control, etc. [11].

Among the natural fibers that are used in textiles, cotton continues to be a fiber of first choice for a broad range of applications; from apparels to home textiles. Due to the advantages mentioned in the preceding text, blends of cotton with other man-made fibers are widely studied and abundant literature is available regarding the characterization of such blends [12, 13]. Arguably, the most widely studied is the cotton-polyester blend [14–17]. Among the class of regenerated fibers, viscose has gained wide spread acceptance primarily due to considerably lower production cost and the fact that it can be spun very uniform in diameter. Some of the inferior properties of viscose in comparison to cotton, for instance, low wet strength, high elongation and dimensional instability, etc. have been dealt with by different approaches ranging from new methods of spinning to resin finishing [18].

As greater control over the viscose process was achieved, several varieties of regenerated cellulosic fibers were produced to achieve specific characteristics that the earlier varieties lacked in some respects, for instance, low wet modulus [19]. “Modal” is a widely used generic term for regenerated cellulosic fibers obtained by processes giving a high tenacity and a high wet modulus. It is defined by the international bureau for standardization of manmade fibers (BISFA) as a distinct rayon fiber genre which has a higher wet modulus and satisfies a minimum value of tenacity in the wet stage at 5% elongation. Lenzing AG of austria is a leader in the development and marketing of modal fiber. Their first modal fiber was marketed under the tradename Hochmodul 333 and in the 1990s they introduced the very first micromodal®. Further developments in the manufacturing process have rendered certain varieties of modal twice as soft as cotton. More importantly, the softness lasts longer and is able to withstand repeated wash and dry cycles. In addition, superior mechanical properties, e.g., higher tenacity profile than viscose, and other advantages are resulting in an ever increasing use of modal in blended form with other fibers [20, 21]. Blends of modal and cotton fibers are generally pretreated as pure cotton i.e. Boiled off, bleached and if necessary, also mercerized. The chemicals added to the boiling and bleaching phases are reduced correspondingly depending on the proportion of modal fiber [22].

As for all other fibers, the general properties of modal are thoroughly discussed in a number of studies [23–25]. The literature regarding production-scale processing and its effects on the properties is rather limited to the dyeing behaviour of blends of modal [22, 26]. In this work, we present our findings regarding the effects production-scale processes on the properties of 60:40 cotton/modal woven fabric. In particular, the effects of caustic treatment using different strengths of caustic soda have been discussed in the context of colour strength achieved in dyeing, fastness properties, hand feel, breaking strength and shrinkage properties. Due to the high swelling propensity of modal fibers in lye of a higher concentration, lensing special guidelines have been drawn up for mercerizing cotton/modal blends particularly with respect to fabric construction and machine dynamics. These guidelines provide the basic framework for this study.

MATERIALS & METHODS

Substrate

Cotton/Modal (60:40) blended yarn was prepared and converted into woven fabric. Some of the more important fabric specifications are provided in table 1.

Table 1

SPECIFICATIONS OF THE FABRIC USED IN THE STUDY	
Blend ratio (Cotton: Modal)	60:40
Warp yarn count	60s
Weft yarn count	40s
Weave	4:1 Sateen
Ends/inch	178
Picks/inch	122
Thread count	300
GSM	140

Pre-treatment of fabric

Pretreatment of fabric was carried out on bulk, continuous processing machines. The recipes and process parameters of the various pretreatment operations are provided in tables 2–4. The primary aim of the present study was to analyse the effects of caustic treatment on the properties of modal/cotton blended fabric. Thus, caustic treatment of the substrates that were pretreated in exactly the same manner was carried out using three different strengths of caustic as mentioned in table 4.

Table 2

COMBINED SINGEING AND DESIZING PROCESS	
Singeing	
Machine name	Oshthoff Senge
Machine speed	95 m/min
Number of burners	4
Desizing	
Machine name	Singeing Oshthoff
Batch/Dwell time	6 hours
Liqour temperature	70°C
Liqour pH	7
Enzymatic sesizer	0.5 g/l
Wetting agent	3 g/l

Table 3

BLEACHING PROCESS OF FABRIC	
Bleaching Recipe	
Hydrogen peroxide	24 g/l
NaOH (50%)	20 g/l
Wetting agent	3 g/l
Sequestering agent:	1 g/l
Stabilizer	6 g/l
Bleaching Process Parameters	
Pre-washing temperature	95ºC
No. of chambers (pre-wash)	3
Machine speed	100 m/min
Steamer time	22 min
Wetting agent	3 g/l
Post washing temperature	95ºC
No. of chambers (post-wash)	4

Dyeing of fabric

Reactive dyes (Jakazol®) in powder form were used for dyeing of samples. All other chemicals used in this

Table 4

CAUSTIC TREATMENT OF FABRIC USING THREE DIFFERENT STRENGTHS OF NaOH	
Machine name	Benninger
Machine speed	55 m/min
Strong lye concentration	7 Be° 20 Be° 28 Be°
Weak lye concentration	7 Be°
Temperature of strong lye	60°C
Post washing chamber	4
Temperature	95°C
Neutralization chamber	60°C

work were of analytical grade. Dyeing was carried out on production scale machines and the pad-dry-chemical pad-steam route was followed. The process and machine parameters maintained for all samples are provided in table 5 and table 6, respectively.

Table 5

DYEING PROCESS DETAIL	
Dyeing recipe	Jakofix Yellow MERL 8.9 g/l, Jakazol Navy DSG 13.43 g/l, Jakazol Black CECL-N 47.39 g/l
Dyeing machine	Thermosol Continuous Range
Dyeing pick up	65%
Pre drying	IR dryers
Drying temp	120°C
Speed of machine	60 m/min

Table 6

CHEMICAL PAD STEAM PROCESS	
Chemical Padding	Salt, Alkali, Urea
Steaming Temp	103°C
Steaming Time	90 s
Post Washing	9 chambers
Post Washing Temp	95°C
Speed	m/min

ANALYSIS OF THE TREATED FABRICS

K/S analysis of dyed fabric samples

Colorimetric analysis of reactive dyed fabrics was carried out using a Datacolor SF 600 plus spectrophotometer. Measurement were taken regarding colour presence, brightness, dullness and colour intensity with the specular component of the light excluded and UV component included using illuminant D65 and 10° standard observer. Each fabric was folded once so as to furnish two layers in front of the aperture. The values reported here are the average of five readings that were taken.

Fastness tests

The samples were washed under condition IIIA of according to AATCC Test Method 61-2006 (2003) to determine the colour change. Light fastness tests were carried out according to AATCC Test Method 16 E-1998 (2003). The samples were exposed to 5 and 10 AFUs (AATCC Fading Unit) to determine the colour change. Standard crock meter was used to determine the rubbing fastness of dyed fabrics under wet and dry condition to assess the colour change and staining property according to the test method AATCC 08-1996 (2005).

Dimensional stability

Some superior physical properties of modal such as tenacity, elongation and wet modulus make a fabric last longer with an enduring look and feel. However, in the case of blends of Modal with other fibers, the blend ratio and the treatment conditions are of course expected to have a direct effect on the overall dimensions stability of the fabric. Thus, in the context of the present study, it was considered to be important to characterize the dimensional stability of the Cotton/Modal blended fabrics that were considered. For this purpose, dimensional stability of the test samples was tested according to ISO 6330(4N) at 40°C (Tumble Dry).

Breaking strength analysis

Owing to similar reasons as mentioned in Section 3.3, the samples were tested for tensile strength in warp and weft directions according to ISO 13934-2 (grab method). Tear strength was tested in warp and weft using ISO 13937-1 (Elmendorf tester). For each fabric average of five readings were recorded.

RESULTS & DISCUSSION

Colorimetric strength of samples

The results tabulated in table 7 clearly indicate that the K/S value increased with increasing lye concentration. This trend is expected in the case of cellulosic fibers and their blends and it is attributed to the formation of soda-cellulose and increased intra-fibrillar swelling. This phenomenon can be explained through Donnan's membrane theory. In its simplistic form, it elucidates that cellulose reacts with NaOH to form soda cellulose (Cell-O-Na+) and ionization of this

Table 7

COLORIMETRIC DATA FOR DYED SAMPLES

Sample	Caustic strength (Be°)	L	A	b	C	h	K/S
A	7	21.03	–1.61	–2.16	2.70	233.31	98.07%
B	20	21.56	–1.55	–2.39	2.85	236.91	104.52%
C	28	19.82	–1	–2.29	2.50	246.41	118.09%

compound creates a high concentration of sodium ions within the fiber. Under this concentration gradient water molecules diffuse through the cuticular semi-permeable membrane of the fiber and so cause swelling of the fiber.

Colour fastness testing

The results of washing tests are provided in table 8. It is evident from this data that there was no recordable difference between the fabric samples in terms of shade change after washing and as well as in terms of staining. Furthermore, the grey scale rating of 4 and 4–4.5 for shade change and staining, respectively, indicate that the Cotton/Modal blended fabrics treated with caustic of various strengths possessed very good colour fastness properties. Similarly, the rubbing fastness test results (table 9) also indicate that treatment of the blended fabric with caustic of various strengths did not result in a significant difference between the samples in terms of their colour fastness to rubbing.

Table 8

WASHING FASTNESS TEST RESULTS

Sample	Caustic strength (Be°)	Grey scale rating		
		Shade change	Staining on cotton	Staining on nylon
A	7	4.0	4.0	4.5
B	20	4.0	4.0	4.5
C	28	4.0	4.0	4.5

Table 9

RUBBING FASTNESS TEST RESULTS

Sample	Caustic strength (Be°)	Rubbing Fastness	
		Dry	Wet
A	7	4	2.5
B	20	4	2.5
C	28	4	2.5

Fabric strength testing

The results of tensile and tear strength in the weft and warp directions are provided in table 10. A clear trend of increasing tensile and tear strength with increasing lye concentration is observed in all cases. It is noteworthy that increasing lye concentration from 20 Be° to 28 Be° resulted in well over 10% increase in the tear strength of fabric. Furthermore, this trend is consistent with that observed in the case of mercerization of a 100% cotton fabric. It is known for this type of treatment to result in increased orientation of the molecular chains in the amorphous regions of fiber. In addition, parallelization of crystallites on stretching increases the secondary interactions between the molecular chains. Removal of inherent strains in the fiber after their relaxation on swelling also helps in improving the overall strength of fiber.

Table 10

TENSILE AND TEAR STRENGTH RESULTS

Sample	Caustic strength (Be°)	Tensile (Kg)		Tear (gf)	
		Warp	Weft	Warp	Weft
A	7	17.5	20	888.5	1100
B	20	22	21	932	1123
C	28	23	21.5	1082	1243

Dimensional stability/shrinkage

The results of shrinkage tests on the samples that were treated with caustic lye of different strengths are provided in table 11. The results clearly show that the dimensional stability is improved with increasing caustic lye strength. This can be attributed to improved dimensional stability of the cotton component in the blend. However, it also indicates that there is no considerable deterioration in the shrinkage-related properties of the modal component in the blended fabric.

Table 11

WARP-WISE AND WEFT-WISE SHRINKAGE OF SAMPLES

Sample	Caustic Strength (Be°)	Shrinkage	
		Warp	Weft
A	7	–4.0%	–4.0%
B	20	–4.0%	–3.0%
C	28	–3.0%	–3.5%

CONCLUSIONS

From the results obtained in this study, it can be concluded that mercerization of 60:40 Cotton/Modal (60:40) blend can be carried out under conditions and parameters that are normally maintained for 100% cotton fabrics. Colorimetric data for the samples treated with caustic lye of different strengths shows that treatment with 28 Be° caustic lye results in improved dyeing characteristics. Furthermore, the tensile and tear strength and the dimensional stability of the particular blend that was considered in this study were also improved after treatment with 28 Be° caustic lye. A potential extension of the reported research is to test different blend ratios and subject those samples to caustic treatment in a similar way as reported in the present study. In this way, it can be studied if caustic treatment affects different blend ratios differently or otherwise. Owing to the fact that the treatments on the cotton/modal blended fabric were carried out on production-scale machinery, it is envisaged that the present study will prove to be a helpful guideline for the concerned textile processors.

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REFERENCES

[1] Bredereck, K., Hermanutz F., *Man-made cellulosics,* 2005, 35, 1, 59–75

[2] Maria, M.T., Malgorzata, M., Jorge, B.B., *Future of Natural Fibers, Their Coexistence and Competition with Man-Made Fibers in 21st Century AU - Ryszard M., Kozlowski,* In: Molecular Crystals and Liquid Crystals, 2012, 556, 1, 200–222

[3] Atkinson, R.R., *The Blending of Jute with Man-Made Fibres. The Effect Of Various Blending Methods upon Some Yarn and Fabric Properties Au - Cumming,* In: Journal of the Textile Institute Proceedings, 1963, 54, 2, P92–P100

[4] Hunter, W.A., *Fibre Blending,* In: Journal of the Textile Institute Proceedings, 1952, 43, 8, P365–P374

[5] Leach, L.L., *Blends Containing the New Man-Made Fibers AU - Dennison, R.W.,* In: Journal of the Textile Institute Proceedings, 1952, 43, 8, P473–P495

[6] Monego, C.J., Backer, S., *Tensile Rupture of Blended Yams,* 1968, 38, 7, 762–766

[7] Owen, J.D., *51 – The Strength and Behaviour of Nylon/Cotton Blended Yarns Undergoing Strain AU - Kemp, A.,* In: Journal of the Textile Institute Transactions, 1955, 46, 11, T684–T698

[8] Ratnam, T.V., et al., *Prediction of the Quality of Blended Yarns from That of the Individual Components,* 1968, 38, 4, 360–365

[9] Majumdar, A., Mukhopadhyay, S., Yadav, R., *Thermal properties of knitted fabrics made from cotton and regenerated bamboo cellulosic fibres,* In: International Journal of Thermal Sciences, 2010, 49, 10, 2042–2048

[10] Hosseini Ravandi, S.A., Valizadeh, M., *2 – Properties of fibers and fabrics that contribute to human comfort*, in *Improving Comfort in Clothing*, Editor Song G., 2011, Woodhead Publishing, 61–78

[11] Ramaswamy, G.N., Easter, E.P., *Durability and Aesthetic Properties of Kenaf/Cotton Blend Fabrics,* 1997, 67, 11, 803–808

[12] Ibrahim, N.A., *4 – Dyeing of textile fibre blends*, in *Handbook of Textile and Industrial Dyeing*, Editor Clark M., 2011, Woodhead Publishing, 147–172

[13] Stanković, S.B., Popović, D., Poparić, G.B., *Thermal properties of textile fabrics made of natural and regenerated cellulose fibers,* In: Polymer Testing, 2008, 27, 1, 41–48

[14] Alongi, J., et al., *Thermal stability and flame retardancy of polyester, cotton, and relative blend textile fabrics subjected to sol–gel treatments,* 2011, 119, 4, 1961–1969

[15] Ruppenicker, G.F., et al., *Comparison of Cotton/Polyester Core and Staple Blend Yarns and Fabrics,* 1989, 59, 1, 12–17

[16] van Winkle, T.L., et al., *Cotton versus Polyester: Surprising facts on energy requirements for the production and maintenance of clothing made of these two kinds of fibers suggest priorities for the utilization of energy and land,* In: American Scientist, 1978, 66, 3, 280–290

[17] Yoon, H.N., Buckley, A., *Improved Comfort Polyester: Part I: Transport Properties and Thermal Comfort of Polyester/Cotton Blend Fabrics,* 1984, 54, 5, 289–298

[18] Lund, G.V., *The Blending of Viscose Rayon and Other Fibres With Particular Reference to the Cotton System of Processing, AU - Morton, W.E.,* In: Journal of the Textile Institute Proceedings, 1952, 43, 8, P375–P390

[19] Shaikh, T., Chaudhari, S., Varma, A., *Viscose Rayon: A legendary development in the manmade textile,* In: International Journal of Engineering Research & Applcation, 2012, 2, 5, 675–680

[20] Gun, A.D.J.F., Polymers, *Dimensional, physical and thermal properties of plain knitted fabrics made from 50/50 blend of modal viscose fiber in microfiber form with cotton fiber,* 2011, 12, 8, 1083–1090

[21] Latif, W., et al., *Study of mechanical and comfort properties of modal with cotton and regenerated fibers blended woven fabrics,* In: Journal of Natural Fibers, 2018, 1–10

[22] Radhika, R., Moses, J.J., *Study on dyed and finished modal, cotton and modal/cotton (50:50) blend fabrics for their color strength and fastness properties,* In: International Journal of Engineering Research and Science & Technology, 2014, 3, 2

[23] Suñol, J., et al., *Thermal degradation of lyocell, modal and viscose fibers under aggressive conditions,* 2007, 87, 1, 41–44

[24] Suńol, J., et al., *Comparison of the thermal behavior of three cellulose fibers mercerized or submitted to solar degradation,* 2003, 72, 2, 753–758

[25] Zengqiang, Z., Guiyang, L., *Relation between Modal Cotton Blended Yarn Property and Blending Ratio,* In: Clothing Textile Technology, 2005, 11

[26] Hasan-Al Mamun, et al., *Effect of Reactive Groups of Reactive Dyes on Dyeing of Modal Fabrics,* In: International Journal of Textile Science, 2017, 6, 6, 158–164

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Conductive textile structures and their contribution to electromagnetic shielding effectiveness

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ABSTRACT – REZUMAT

Conductive textile structures and their contribution to electromagnetic shielding effectiveness

Fabrics for electromagnetic shielding are especially relevant in nowadays context, contributing to human's protection and wellbeing and to proper functioning of electronic equipment, in relation to electromagnetic compatibility. Fabrics with electromagnetic shielding properties employ two main technologies, namely insertion of conductive yarns and application of conductive coatings. Magnetron sputtering is a modern technology to enable conductive coatings with thickness in the range of nanometers onto fabrics. This paper aims to analyze contribution of various conductive textile structures out of both fabrics with inserted conductive yarns and coatings to Electromagnetic shielding effectiveness (EMSE). EMSE was measured in the frequency range of 0.1–1000 MHz by using a TEM cell according to standard ASTM ES-07. Results show a gain of 10–25 dB when introducing silver yarns in warp/ weft direction, a variation of 5–35 dB between conductive yarns out of silver and stainless steel and an up to 12 dB gain out of thin copper coating by magnetron plasma onto the fabrics with inserted conductive yarns.

Keywords: *stainless steel yarns, silver yarns, thin copper coating, fabrics, electromagnetic shielding*

Contribuția la atenuarea electromagnetică a unor structuri textile cu proprietăți conductive

Materialele textile pentru ecranare electromagnetică sunt deosebit de importante în contextul actual, având în vedere aplicațiile destinate protecției sănătății umane și funcționării adecvate a echipamentelor electronice, în conformitate cu legile comptabilității electromagnetice. Materialele textile cu proprietăți de ecranare electromagnetică pot fi obținute prin două principii tehnologice: inserarea de fire conductive și aplicarea de acoperiri conductive. Plasma de tip magnetron sputtering reprezintă o tehnologie modernă, care permite acoperiri conductive de ordinul nanometrilor pe materialele textile plane. Acest articol analizează contribuția la atenuarea electromagnetică pentru diferite structuri textile, obținute atât prin inserare de fire conductive cât și prin acoperire în plasmă. Atenuarea a fost determinată în domeniul de frecvență 0,1–1000 MHz, prin utilizarea sistemului de măsuare cu celulă TEM, în conformitate cu standardul ASTM ES-07. Rezultatele arată o creștere a atenuării de 10–25 dB la inserarea firelor de argint în direcția urzelii/bătăturii, o variație de 5–35 dB între firele conductive de argint și inox și o creștere de până la 12 dB datorată acoperirii în plasmă magnetron de cupru pe materialele textile plane cu fire conductive inserate.

***Cuvinte-cheie**: fire de inox, fire de argint, acoperire de cupru, materiale textile, ecranare electromagnetică*

INTRODUCTION

Electromagnetic shielding achieved by flexible conductive fabrics represents a valuable solution in nowadays radiation polluted environment. Its application range reaches shielding of various frequencies out of various radiation sources, such as: PPE for working on broadcasting antennas, curtains for protection against GSM or WiFi signals, tents for ensuring data privacy in outdoor environment etc. The provisioned applications are related on one hand towards protection of human's health against the non-ionizing radiation, and on the other hand towards proper functioning of electronic equipment by ensuring electromagnetic compatibility principles [1, 2].

Main topic on electromagnetic shielding is the modality of achieving electrically conductive structures on fabrics, therefore most of the papers are oriented towards the description of new manufacturing methods for achieving such materials, reporting the measured values of the shielding effectiveness. The scientific literature distinguishes two main modalities: insertion of conductive yarns and coating with conductive layers [3]. Each of them involves specific technologies, such as insertion of conductive yarns by weaving or knitting for the first case and application of conductive layers on the fabric surface for the second case. The conductive yarns may be achieved by blending extremely thin metal fibers with various textile fibers like polypropylene [4] or polyester fibers [5], as well as by covering an internal metallic wire with a natural or synthetic yarn [6]. Various technologies are available for achieving the coating of fabrics, among which are: painting with metallic particles, vacuum metallization, spraying, electro less plating, conductive adhesive tapes etc. [7]. Also, the utilization of novel materials for coating the fabrics is reported, among them being those based on carbon nanotubes [8], low pressure plasma treatment followed by soaking in amine-treated multiwall carbon nanotubes [9] or coating by combinations of carbon nanotubes, conductive polymers and metal nanoparticles [10]. One modern technology to impart conductive layers to fabrics is plasma coating by magnetron sputtering, using mostly metallic targets [11].

Another topic of special interest related to electromagnetic shielding of fabrics is related to the modelling of shielding effectiveness for a certain frequency range for fabrics with electrically conductive structures, both by insertion of conductive yarns [12–15] and by coating with conductive layers [3], while other papers deal with new methods of experimental determination of shielding effectiveness for fabrics [16]. Finally, a few works discuss on the clothing comfort behaviour and influence of washing/drying cycles on values of EMSE of fabrics [17–20].

In this context, the present paper deals with the development of a new type of manufacturing method and considers a combined approach based on the production of fabrics with inserted conductive yarns which are coated by magnetron sputtering by a metal layer. The main aim of our work is to analyze how combined modalities for achieving electrically conductive structures on fabrics (insertion of conductive yarn and magnetron plasma coating) contribute to electromagnetic shielding effectiveness (EMSE) in the frequency range of 0.1–1000 MHz.

MATERIALS AND METHODS

Materials

Five samples of woven fabrics with inserted conductive yarns out of silver (Ag) and stainless steel (SS) and copper plasma coating were manufactured and analyzed regarding EMSE. Figure 1 shows the experimental concept of the five fabric samples used in this research, evidencing how the materials were consecutively increasing their complexity to allow the evaluation of the shielding in each step of the processing.

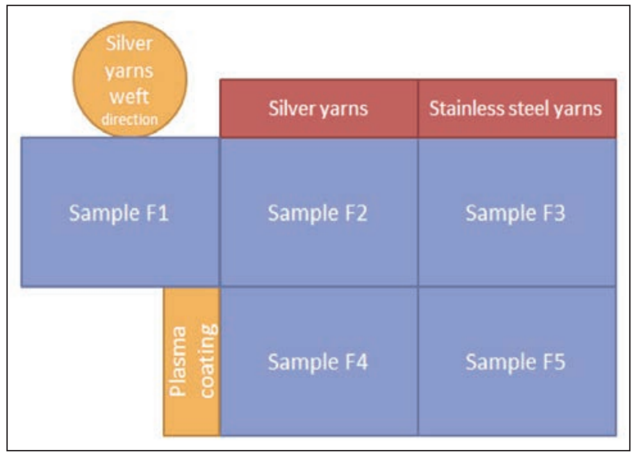

Fig. 1. Scheme of fabrics with electric conductive structures

The designed and manufactured woven fabric samples had the structures described in table 1.

The grid of the fabrics with silver and stainless steel yarns in warp and weft direction was set on 4 mm. Copper coating was achieved by magnetron plasma coating on both fabrics with inserted silver (1200 nm) and stailess steel yarns (400 nm).

Table 2 presents some of the physical-mechanical properties of the 5 fabric samples, such as mass, density and thickness.

Table 1

FABRIC STRUCTURES WITH CONDUCTIVE ELEMENTS (CONDUCTIVE YARNS AND COATINGS)

Sample code	**F1**	**F2**	**F3**	**F4**	**F5**
Main yarns	Cotton yarn (Nm 50/2)	Cotton yarn (Nm 50/2)	Cotton yarn (Nm 50/2)	Cotton yarn (Nm 50/2)	Cotton yarn (Nm 50/2)
Conductive yarns	Silver yarn (Statex 117/17 dtex 2 PLYHC+B)	Silver yarn (Statex 117/17 dtex 2 PLYHC+B)	Stainless steel yarn (Bekinox BK50/2)	Silver yarn (Statex 117/17 dtex 2 PLYHC+B)	Stainless steel yarn (Bekinox BK50/2)
Warp	NA	Ag in warp float repeat 6:2	SS in Warp, float repeat 6:2	Ag in warp float repeat 6:2	SS in Warp, float repeat 6:2
Weft	Ag in weft float repeat 6:1	Ag in weft float repeat 5:2	SS in Weft, float repeat 6:2	Ag in weft float repeat 5:2	SS in Weft, float repeat 6:2
Weaving type	plain weave	plain weave	plain weave	plain weave	plain weave
Plasma coating details	NA	NA	NA	1200 nm Cu coating on both sides	400 nm Cu coating on both sides
Sample prepared for EM shielding measurements					

Table 2

PHYSICAL-MECHANICAL PROPERTIES OF ACHIEVED TEXTILE STRUCTURES				
Fabric code	**Specific mass (g/m²)**	**Fabric density (no. yarns/10 cm)**		**Thickness (mm)**
		Warp	Weft	
F1	329	650	340	0.490
F2	118	168	150	0.495
F3	143	180	170	0.550
F4	144	170	154	0.564
F5	155	180	170	0.580

Methods

Plasma coating technique

The Cu coating of the textile fabrics was performed into a dedicated spherical stainless steel vacuum chamber (K.J. Lesker), pumped out by an assembly of a fore pump and turbomolecular pump (Pfeiffer), which allowed the obtaining of a base pressure down to 3×10^{-5} mbar. The chamber is provisioned with a magnetron sputtering gun from K.J. Lesker, accommodating a high purity Cu target (99.999%). Enhanced deposition uniformity was achieved by rotating the samples during the deposition process (200 rotations/min). A constant Ar (6.0) flow of 50 sccm was continuously introduced into the chamber by means of a Bronkhorst mass flow controller, so that the pressure established during the process was 5.3×10^{-3} mbar. The discharge was ignited with an RF generator (13.56 MHz) – model CesarR provisioned with an automatic matching box for adapting the impedance. The deposition time was set to insure a coating thickness of 400 nm and 1200 nm on both sides of the textile fabrics.

A sketch of the experimental set-up was provided elsewhere [20]. Figure 2 presents the magnetron plasma equipment of INFLPR, evidencing the copper discharge above the textile surface.

Insertion of conductive yarns

The achieved woven fabrics with inserted conductive yarns were manufactured at SC Majutex SRL, Barnova Iasi. Stainless steel yarns (Bekinox BK 50/2) and silver yarns (Statex 117/17 dtex) were inserted both in warp and weft system, after a weaving preparation process. Figures 3 and 4 present the warping machine and the weaving loom of type SOMET width 1.90 m.

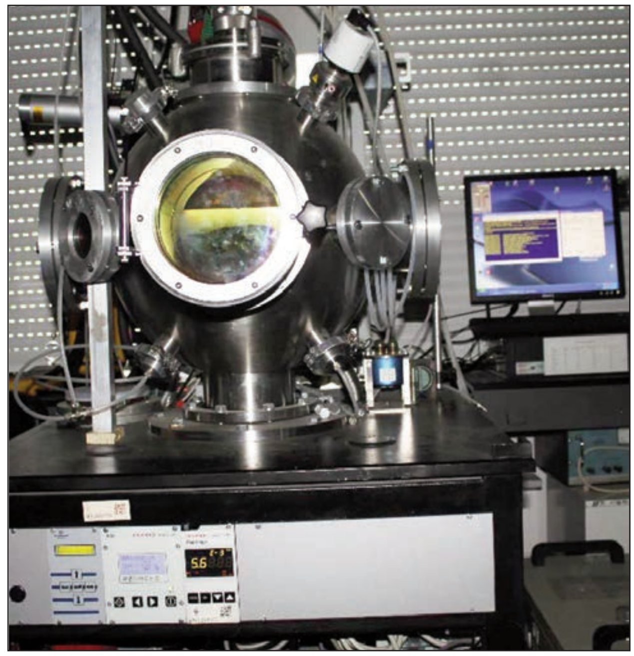

Fig. 2. Magnetron plasma equipment of INFLPR

Shielding effectiveness measurement

Electromagnetic shielding effectiveness (EMSE) is defined as:

$$EMSE = 10\log_{10}\left(\frac{\textit{power of incident signal}}{\textit{power of transmitted signal}}\right) \quad (1)$$

Shielding effectiveness of fabric samples was measured via a coaxial TEM cell, according to standard ASTM ES-07. A scheme of coaxial TEM cell and a load fabric sample is presented in figure 5.

Tested fabric samples were tailored in annular shape having an outer diameter of 100 mm and an inner diameter of 30 mm and fixed onto the cell by means of colloidal Ag paste. The measurement system included a signal generator E8257D, a Power amplifier model SMX5, the Coaxial TEM cell model 2000 and an Oscilloscope Tektronix model MDO3102.

Fig. 3. Warping machine at SC Majutex SRL

Fig. 4. SOMET Weaving loom at SC Majutex SRL

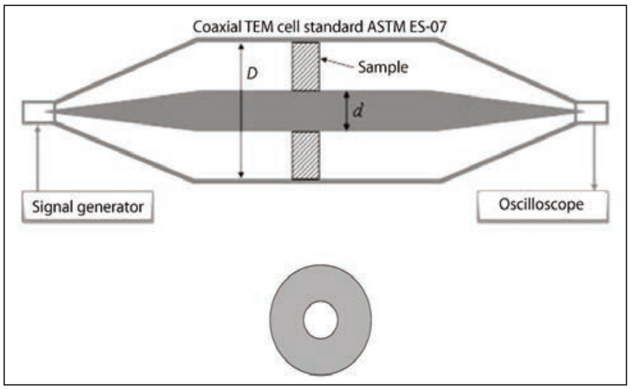

Fig. 5. Scheme of TEM cell and load sample according to standard ASTM ES-07

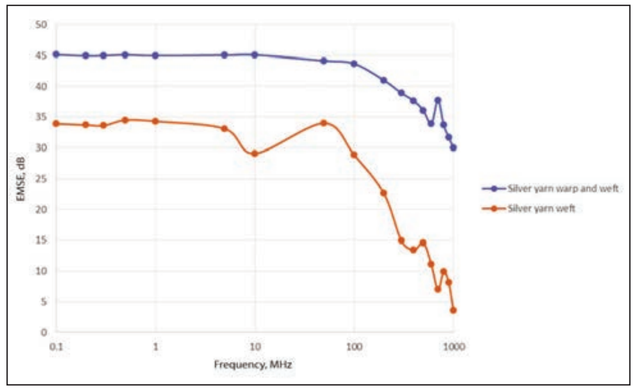

Fig. 6. Contribution to EMSE of inserting silver yarns both in warp and weft direction

EXPERIMENTAL

Woven fabrics with conductive yarns out of silver and stainless steel were manufactured by insertion in warp and weft direction, in order to obtain a conductive grid at the distance of 4 mm (Samples F2 and F3). 100% cotton was selected for the support textile material, due to its good dielectric properties and easy process ability. Sample F1 has silver yarns only in weft direction and was included in the experimental scheme, in order to underline the contribution to EMSE of the sample F2, having silver yarns both in warp and weft direction (figure 1). Samples F2 and F3 were processed by magnetron plasma deposition with a thin Copper coating of 1200 nm, respectively 400 nm, yielding samples F4 and F5. All five samples were measured by same electromagnetic shielding effectiveness (EMSE) investigation system, namely via TEM cell standard ASTM ES-07. The results of EMSE were comparatively assessed by underlining following aspects regarding fabric structures and raw materials:

– The contribution to EMSE of inserting silver yarns both in warp and weft direction when compared to inserting yarns only in weft direction (figure 6);
– The contribution to EMSE of the raw materials (silver and stainless steel), forming the grid of conductive yarns (warp and weft direction) with a distance of 4 mm (figure 7);
– The contribution to EMSE of the copper plasma coating for the fabric with inserted silver yarns (figure 8);
– The contribution to EMSE of the copper plasma coating for the fabric with inserted stainless steel yarns (figure 9).

RESULTS AND DISCUSSION

Figures 6–9 show the experimental results of electromagnetic shielding effectiveness for the five studied woven fabrics samples.

Figure 6 presents comparatively the results recorded during the test of woven fabric denoted F1 (with silver yarns only in weft direction) and F2 (with silver yarns in both warp and weft directions). The superiority of F2 is proved in the whole range of frequencies. At low frequency (0.1...100 MHz) the difference is in the range of 10...12 dB while at higher frequency (100...1000 MHz) the difference lays in the range of 12 to 25 dB. The decrease of attenuation at high frequency is justified by the fact that, generally, the reflection term is the main one for electric thin (but compact, not meshed) shields having good conductivity properties.

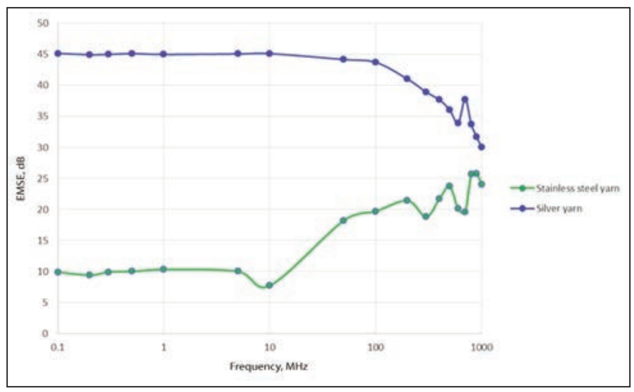

Fig. 7. Contribution to EMSE related to raw materials of inserted yarns (silver and stainless steel)

Figure 7 compares the results obtained during the tests of woven fabrics with silver and stainless yarns in warp/weft directions, the metallic meshgrid with square eyes with side of 4 mm. The graph shows the superiority, regarding the attenuation level, of the grid with good conductive wires (silver) vs. the grid with magnetic properties (steel) of about 25–35 dB in the range of 0.1–100 MHz, this one being reduced at 5–25 dB for the frequency range of 100–1000 MHz. This behaviour is explained by the properties of the two types of materials, knowing that in low frequency range the good conductive ones present better attenuation of reflection term, this one decreasing with frequency. On the other hand, at high frequencies the obtained values for both samples are in accordance with the known relation of attenuation, valid for metallic meshgrids [21]:

$$EMSE = 20 \log \frac{\lambda}{2g} \text{ [dB]} \qquad (2)$$

where λ is the plane wave electromagnetic radiation wavelength and g – the side of meshgrid.

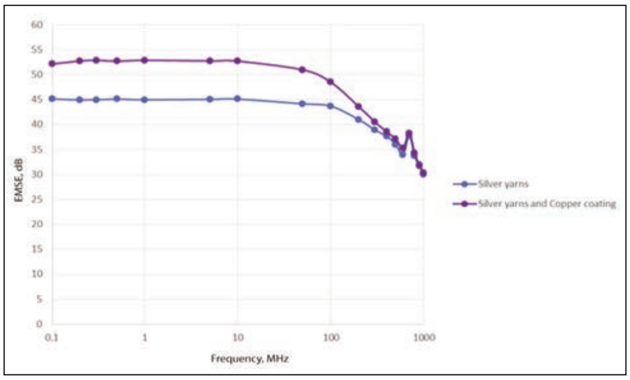

Fig. 8. Contribution to EMSE of copper plasma coating on fabrics with inserted silver yarns

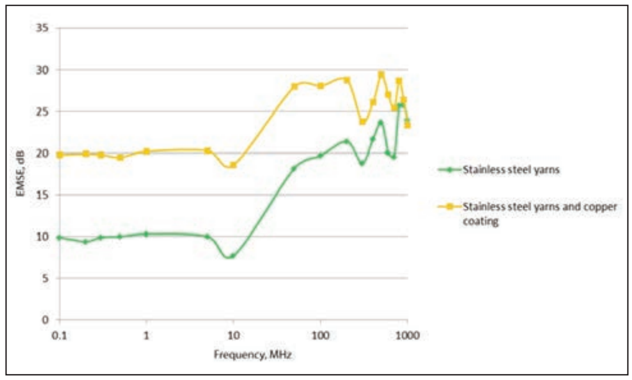

Fig. 9. Contribution to EMSE of copper plasma coating on fabrics with inserted stainless steel yarns

The values are independent of the own electric/magnetic properties of metals involved. As example, for 1000 MHz, λ = 0.3 m and because g = 0.004 m, the $EMSE$ = 31.5 dB, value close to those measured.

In order to enhance the shielding properties of woven fabrics tested up to now, these samples containing metallic meshgrids were covered with a thin layer of copper, as described in the section 2. Figure 8 shows, by comparison, the attenuation of fabric with silver yarns with and without copper coating. The copper coating ensures a higher attenuation of about 3–8 dB on the entire frequency domain explored.

Similarly, the coating with copper of woven fabrics containing stainless steel yarns improves the EMSE with about 5–12 dB on the entire explored frequency range. The results were shown in the figure 9.

CONCLUSIONS

This paper describes novel manufacturing methods to achieve flexible electromagnetic shields, out of woven fabrics. Both main technologies to impart conductivity to fabrics, namely insertion of conductive yarns in the woven structure and coating with conductive layers were applied and comparatively assessed. Electromagnetic shielding effectiveness was determined according to standard ASTM ES07, via TEM cell. Electromagnetic shielding properties of woven fabrics with metallic yarns, with conductive or magnetic properties, disposed in warp or warp/weft directions and also the effect of copper coating of these fabrics was studied. The superiority of metallic mesh grids comparing to ones having simple parallel yarns was proven. Concerning the addition of copper as coating layer, a weak enhancement of shielding effectiveness was observed for sample containing silver meshgrid and a more effect was recorded in the case of material with stainless steel yarns insertion. These results allow the proper choice of woven fabrics with metallic yarns in accordance to the imposed electromagnetic attenuation for different applications.

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REFERENCES

[1] Schwab, A., Kuerner, W., *Electromagnetic compatibility*, AGIR publishing house, 2013

[2] Paul, C.R., *Introduction to Electromagnetic compatibility*, Wiley series in microwave and optical engineering, 2006

[3] Ziaja, J., Jaroszewski, M., *EMI shielding using composite materials with plasma layers*, InTechOpen, 2011

[4] Koprowska, J., Dobruchowska, E., Reszka, K., Szwugier, A., *Morphology and Electromagnetic Shielding Effectiveness of PP Nonwovens Modified with Metallic Layers*, In: Fibres and Textiles in Eastern Europe, 2015, 5, 5, 84–91

[5] Roh J.-S., Chi, Y.-S., Kang, T.J, Nam, S.-W., *Electromagnetic Shielding Effectiveness of Multifunctional Metal Composite Fabrics*, In: Textile Res. J., 2008, 78, 9, 825–835, https://doi.org/10.1177/0040517507089748

[6] Perumalraj, R., Dasaradan, B.S., *Electromagentic shielding effectiveness of copper core yarn knitted fabrics*, In: Indian J. Fibre&textile Res., 2009, 24, 149–154

[7] Keiser, B, *Principles of Electromagnetic compatibility*, Artech House Inc, 1979

[8] Bonaldi, R., Siores, E., Shah, T., *Characterization of electromagnetic shielding fabrics obtained from carbon nanotube composite coatings*, In: Synthetic Metals, 2014, 187, 1–8

[9] Haji, A., Rahbarb, R., Shoushtaric, A., *Improved microwave shielding behavior of carbon nanotube-coated PET fabric using plasma technology*, In: Applied Surface Science, 2014, 311, 593–601

[10] Gnidakouonga, J., *Electromagnetic interference shielding of composites consisting of a polyester matrix and carbon nanotube-coated fiber reinforcement*, In: Composites Part A: Applied Science and Manufacturing, 2013, 50, 73–80

[11] Koprowska, J, Ziaja, J, Janukiewicz, J., *Plasma Metallization Textiles as Shields for Electromagnetic Fields*, International Symposium on Electromagnetic Compatibility – EMC Europe, 2008

[12] Rybicki, T., Brzenski, S., *Modelling protective properties of textile shielding grids against electromagnetic radiation*, In: Fibers and Textiles in Eastern Europe, 2013, 21, 1 (97), 78–92

[13] Neruda, M., Vojtech, L., *Electromagnetic Shielding Effectiveness of Woven Fabrics with High Electrical Conductivity: Complete Derivation and Verification of Analytical Model*, In: Materials, 2018, 11, 1657, https://doi.org/10.3390/ma11091657

[14] Caro, A.L., Vojtech, L., Modelling of textile reinforced composites barriers against electromagnetic radiation, Prague: TU Prague, 2011

[15] Safarova, V., Militky, J., *Electromagnetic shielding properties of woven fabrics made from high-performance fibers*, In: Textile Research Journal, 2014, 84, 12, 1255–1267

[16] Morari, C., Patroi, E., Balan, I., *Composite materials for electromagnetic shielding*, In: U.P.B. Sci. Bull., Series B, 2016, 78, 2

[17] Tunáková, V., Techniková, L., Militký, J., *Influence of washing/drying cycles on fundamental properties of metal fiber-containing fabrics designed for electromagnetic shielding purposes*, In: Text. Res. J., 2017, 87, 175–192

[18] Šaravanja, B., Malaric, K., Pušic, T., Ujevic, D., *Impact of dry cleaning on the electromagnetic shield characteristics of interlining fabric*, In: Fibers Text. East. Eur., 2015, 23, 104–108

[19] Tunakova, V., Militky, J., *Electromagnetic Field Shielding Fabrics with Increased Comfort Properties*, In: Advanced Materials Research, 2013, 677, 161–168

[20] Satulu, V., Mitu, B., Pandele, A.M., Voicu, S.I, Kravets, L., Dinescu, G., *Composite polyethylene terephthalate track membranes with thin teflon-like layers: Preparation and surface properties*, In: Applied Surface Science, 2019, 476, 452–459

[21] White, D., *A Handbook on Electromagnetic shielding materials and performance*,Don White Consultant, 1980

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Identification of influence factors on physical-mechanical properties, using the principal component analysis, in selecting the textile fabrics for the clothing products

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ABSTRACT – REZUMAT

Identification of influence factors on physical-mechanical properties, using the principal component analysis, in selecting the textile fabrics for the clothing products

The paper aims to highlight the correlations between the physical-mechanical properties of woven fabrics made of combed wool yarn with different fibrous compositions, using the Principal Component Analysis (PCA) method. Based on the information on each fabric/assortment group, it is found that four main factors were extracted: durability, comfort, production price and fabric design. The extracted components explain 92% of the variability of the twelve initial inter-correlated variables, so that we can considerably reduce the complexity of the data configured using these components, with only 8% loss of information. This technique that follows the controlled reduction of the number of variables can be used subsequently for modelling the physical-mechanical properties of the fabrics and for selecting the most suitable fabrics to satisfy the requirements of a particular field of use.

Keywords: *matrix of correlations, Principal Component Analysis, factorial axis, fabrics*

Identificarea factorilor de influență asupra proprietăților fizico-mecanice, utilizând analiza componentelor principale, în selecția materialelor textile pentru produsele de îmbrăcăminte

Lucrarea și-a propus să evidențieze corelațiile dintre proprietățile fizico-mecanice ale țesăturilor realizate din fire tip lână pieptănată, cu diferite compoziții fibroase, folosind metoda Analiza Componentelor Principale (PCA). Pe baza informațiilor referitoare la fiecare grup de țesături/sortiment, se constată că au fost extrași patru factori principali: durabilitatea, confortul, prețul de producție și designul țesăturilor. Componentele extrase explică 92% din variabilitatea celor douăsprezece variabile inițiale inter-corelate, astfel încât putem reduce în mod considerabil complexitatea datelor configurate folosind aceste componente, cu doar 8% pierderi de informații. Această tehnică care urmărește reducerea controlată a numărului de variabile poate fi folosită ulterior pentru modelarea proprietăților fizico-mecanice ale țesăturilor și pentru selectarea celor mai adecvate țesături privind satisfacerea cerințelor unui anumit domeniu de întrebuințare.

Cuvinte-cheie: *matricea corelațiilor, Analiza Componentelor Principale, axa factorială, țesături*

INTRODUCTION

Principal Component Analysis is a method factor – factor analysis – used to reduce data complexity by replacing massive data sets by smaller sets [1]. It is also used to highlight the way in which the variables are correlated with each other and to determining the (less) latent variables which are behind the (more) measured variables [2–3]. These latent variables are called factors, hence the name of the methodological factor analysis [4]. Principal Component Analysis (PCA) is a dimension-reduction tool, intensively used in different domains, such as: psychology, social sciences, production management, operational researches, development domain etc. [5, 6]. Some of the software packages, dedicated for this type of analysis, are: Statistics, SAS, SPSS. The objectives of the PCA method are: to synthesize the initial information contained in a large table; highlighting the similarities, respectively the differences between individuals; highlighting the correlations between variables; explaining the similarities, respectively the differences between individuals from the point of view of the considered variables [7, 8].

Principal components reflect both common and unique variance of the variables and may be seen as a variance-focused approach seeking to reproduce both the total variable variance with all components and the correlations. PCA is a tool for identifying the main axes of variance within a data set and allows for easy data exploration to understand the key variables in the initial data. The multiplicity and complexity of factors influencing the comfort phenomenon has resulted in numerous studies dealing with different comfort-related aspects [9, 10].

The state of physical comfort experienced by a wearer under a given environmental condition is greatly influenced by the tactile, thermal and moisture transport properties of the fabric. The major factors incorporating for apparel comfort are yarn structure, fabric structure and its properties, mechanical treatments, moisture and vapour permeability and finishing treatments [11]. During wear, moisture in clothing has been found to be the most significant factor contributing to discomfort. The presence of sweat will increase the friction between fabric and skin, trigger a clingy sensation and eventually increase the level of fatigue felt by the wearer [12]. Fabrics with excellent water absorption and transport properties have the potential to minimize the wetness sensation on skin, facilitate the evaporation of sweat and aid comfort [13]. Mechanical properties of fabric depend on the fabric structure and they are reflected in fabric weavability, which depends on the raw material and loom construction [14].

EXPERIMENTAL PART

Materials and methods

The study included four articles from four groups of worsted fabrics, of different compositions, representing the number of variables, according to table 1.

Table 1

CODIFICATION OF WORSTED FABRICS ARTICLES

Group	Compozition	Article code
A	100 % Wool	A1, A2, A3, A4
B	Wool/PES 45/55	B1, B2, B3, B4
C	Wool/PES/Dorlastan 45/52/3	C1, C2, C3, C4
D	PES/Viscose 60/40	D1, D2, D3, D4

The percentage of chemical fibers used in blending with the wool fibers influences not only the development of the technological process but also the physical-mechanical properties of the yarns and fabrics.
The Wool/PES 45/55 blend reflects the specific properties of polyester fibers, the most important of which is the crease stability (especially for certain products: pants, skirts). Introducing more than 55% increases the roughness of the fabric.
The destination requires the delimitation of the level of the quality characteristics, by prescribed values, whose achievement is followed both by the technical project that specifies the parameters of structure, as well as by the technological process of realization. In making fabrics of the four groups were used Sirospun yarns.
In this paper, the data obtained from the quantification of the physical-mechanical properties of the fabrics were used, by standardized methods and appreciated by a series of indices determined directly on the measure equipment or by calculation. Tests on the tensile properties of fabrics were performed on the Honsfield electronic dynamometer, according to SR EN ISO 2062.
The crease recovery angle was measured, because the creasing of the fabric is an undesirable effect of temporary or permanent deformation, determined by the fibers bending and compression demands during use, processing or maintenance, according to SR EN 22313: 2013. Fabric rigidity provides information on the ability of draping, respectively to form the desired creases, whose shape and stability depend on the physical-mechanical properties of the fibers and on the fabric structure.
Among the physical properties of the fabrics, mass of the fabric, air permeability, degree of compactness, mass variation, thickness loss and porosity of the fabrics were determined by standardized methods or by calculation. The mass of the fabrics was determined according to the standard SR EN 12127:2013, which allows the comparative evaluation, essential for the use of the fabric according to the destination. The air permeability was determined in accordance with the standard EN ISO 9237:1995, which for the fabrics with the destination of clothing, must ensure the comfort state in the conditions of the activity carried out by the wearer. The degree of compactness is a complex indicator, which describes through a unitary calculation relation the fabric structure, defined by the basic parameters and auxiliaries that characterize it. The simulation of the process of friction by wearing the fabrics intended for outerwear products is carried out by a quantitative analysis of the dynamics of the pilling phenomenon by determining the following indicators: the variation of the mass and the variation of the thickness of the test fabrics. Porosity is a feature derived from the geometrical characteristics of the fabric, being dependent on the specific mass and volume of the fibrous material. For each article, the values of the physical mechanical properties were determined by standardized and processed methods in the SPSS program. The variables included in the analysis are: breaking force, Pr (daN); the mass loss at the rubbing test, ΔM (%); thickness loss at the rubbing test, Sg (%); mechanical work of deformation at break, Ws (daN/m); tenacity, τ (cN/tex); the crease recovery angle, α (degree); elongation at break, ε (%); mass, M (g/m^2); air permeability, Pa (m^3/min·m^2); degree of compactness, Kt (%); rigidity, R (mg·cm) and porosity, Pz (%). This technique aims at controlling the number of variables (columns) of the data matrix, as far as possible two, three or four. Thus, based on the information about each cluster/fabric assortment, it is desired that instead of the nine related variables we have only two, three or four new variables called components. The purpose of the PCA is to extract the smallest number of components to recover as much of the total information contained in the initial data.

RESULTS AND DISCUSSIONS

The analysis of the behaviour of the fabrics in the wearing process shows that they are subjected to simple or repeated uniaxial or biaxial stretching.
The level of these stresses may be close to the breaking limit or may have small, insignificant values, so the designer must anticipate the behaviour to such stresses.
This can be appreciated by determining the indices deduced from the tensile strength-elongation diagram,

such as the mechanical work of deformation at break and the tenacity of the fabrics. The hierarchy of the fabrics in the aspect of the behaviour at break is realized by the evaluation of the specific mechanical energy consumed for breaking the specimen.

The value of the quality index is influenced by: the nature of the raw material, the process and the technological parameters of processing, finishing and of the geometrical structure parameters to which the fabric is produced. The value of the degree of compactness of the fabric depends on the fineness of the yarns expressed in diameter, the density of the two yarn systems, the fabric pattern and the number of yarns of the two systems – warp and weft.

After processing the data in SPSS, applying the PCA, the following statistic results are obtained: descriptive statistics indicators (Descriptive Statistics); matrix of correlations; the calculated value of the test statistic χ^2 and KMO; variance variables; values and variance explained by each factorial axis; the contributions of variables to factorial axis inertia and graphical representations.

Descriptive statistics indicators

The statistical parameters calculated for each variable are shown in table 2 (Descriptive Statistics output). Analyzing the data in table 2, which contains information about each apart analyzed variable, we can see that:

- variable breaking strength, Pr (daN), is characterized through the mean 49.838 daN and the Std. Deviation 14.2124; maximum value of the breaking strength was obtained at the article **C3** made of (Wool/PES/Dorlastan 45/52/3), Pr = 67.3 daN, and minimum value at article **A1** of 100% wool, Pr = = 23.1 daN;
- variable mass loss, ΔM (%), is characterized through the mean 1.995% and the Std. Deviation 0.7029; maximum value of the mass loss, was obtained at the article **A2** made of (100% Wool) ΔM = 3%, and minimum value at article **D3** of PES/Viscose 60/40, ΔM = 0.98%.

The other variables are analyzed analogously. As a result of this independent analysis of each variable we can see that the most homogeneous variable is the value of the mass loss.

Correlation Matrix

The Correlation Matrix presents the values of the correlation coefficients between the variables taken by two. It is a quadratic matrix symmetric with respect to the main diagonal (equal to unit, as one variable is perfectly correlated with itself). The form of the correlation matrix is presented in table 3 after having standardized the data.

The analysis of the values of correlation matrix coefficients permits to estimate the possibility of PCA

Table 2

DESCRIPTIVE STATISTICS OUTPUT					
Variable	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Pr (daN)	16	23.1	67.3	49.838	14.2124
ΔM (%)	16	1.0	3.0	1.995	0.7029
Sg (%)	16	5.60	11.21	8.1956	1.6434
Ws (daN/m)	16	17.8	66.5	30.671	16.0206
τ (cN/tex)	16	5.8	17.4	11.975	3.7412
α (°)	16	142.1	169.7	159.381	9.7319
Pa ($m^3/min \cdot m^2$)	16	14.2	23.4	19.031	3.0366
Kt (%)	16	68.87	95.67	81.4788	7.1853
Pz (%)	16	58.50	72.12	65.2394	3.6509
M (g/m^2)	16	170.3	231.8	200.931	16.3206
R (mg·cm)	16	45.33	99.10	63.7313	17.7288
ε (%)	16	16.24	57.80	34.2750	10.5725

Table 3

CORRELATION MATRIX												
Correlation	**Pr (daN)**	**ΔM (%)**	**Sg (%)**	**Ws (daN/m)**	**τ (cN/tex)**	**α (°)**	**Pa ($m^3/min \cdot m^2$)**	**Kt (%)**	**Pz (%)**	**M (g/m^2)**	**R (mg·cm)**	**ε (%)**
Pr (daN)	1.000	–0.463	–0.527	0.925	0.888	–0.341	0.187	0.798	0.403	0.153	0.017	0.776
ΔM (%)	–0.463	1.000	0.393	–0.639	–0.773	0.945	0.212	–0.419	–0.309	–0.401	–0.423	–0.002
Sg (%)	–0.527	0.393	1.000	–0.551	–0.567	0.153	–0.463	–0.316	–0.067	0.058	0.286	–0.419
Ws (daN/m)	0.925	–0.639	–0.551	1.000	0.941	–0.491	0.206	0.688	0.300	0.032	–0.075	0.699
τ (cN/tex)	0.888	–0.773	–0.567	0.941	1.000	–0.660	0.107	0.783	0.443	0.264	0.155	0.524
α (°)	–0.341	0.945	0.153	–0.491	–0.660	1.000	0.403	–0.342	–0.309	–0.498	–0.610	0.136
Pa ($m^3/min \cdot m^2$)	0.187	0.212	–0.463	0.206	0.107	0.403	1.000	0.190	0.149	–0.310	–0.792	0.341
Kt (%)	0.798	–0.419	–0.316	0.688	0.783	–0.342	0.190	1.000	0.724	0.443	0.218	0.488
Pz (%)	0.403	–0.309	–0.067	0.300	0.443	–0.309	0.149	0.724	1.000	0.629	0.292	–0.032
M (g/m^2)	0.153	–0.401	0.058	0.032	0.264	–0.498	–0.310	0.443	0.629	1.000	0.764	–0.296
R (mg·cm)	0.017	–0.423	0.286	–0.075	0.155	–0.610	–0.792	0.218	0.292	0.764	1.000	–0.353
ε (%)	0.776	–0.002	–0.419	0.699	0.524	0.136	0.341	0.488	–0.032	–0.296	–0.353	1.000

application. The high values of the coefficients (higher than +0.5 and smaller than –0.5) show that there are significant statistical correlations (direct correlation if the coefficient value is positive, and inverse correlation if the coefficient value is negative) between the considered variables.

Analyzing the data in table 3 we can see that there are:

- significant statistical links (direct correlations) between:

– Pr (daN) and Ws (daN/m); τ (cN/tex); Kt (%); Pz (%); Pa (m^3/min·m^2); M (g/m^2); R (mg·cm); ε (%);

– ΔM (%) and Sg (%); α (°); Pa (m^3/min·m^2);

- significant statistical links (reverse links) between:

– Pr (daN) and ΔM (%) and Sg (%); α (°);

– ΔM (%) and Pr (daN); Ws (daN/m); τ (cN/tex); Kt (%); Pz (%); M (g/m^2); R (mg·cm); ε (%);

– Sg (%) and Pr (daN); Ws (daN/m); τ (cN/tex); Kt (%); Pa (m^3/min·m^2); Pz (%); ε (%).

The other variables are analyzed analogously.

In this case, PCA can be applied. A characteristic of the correlation matrix consists in the fact that the number of correlation coefficients increases very much when the number of the variables (k) included in the analysis increases, irrespective of the statistic collectivity volume. The number of correlation coefficients is k(k–1)/2 . For the experimental data that present the values of 12 variables, the number of correlation coefficients is 66 (table 4). This significant increase of the number of correlation coefficients reveals the impossibility to interpret the correlation between the variables only by analyzing the values presented by the Correlation Matrix. The correlation matrix determinant can take values ranging within the interval [0, 1], showing the strength of the variables correlation. The analyzed database determinant is D = 0.000, which shows that there are strong statistic correlations between statistic variables (the values of the correlation coefficients are bigger than 0.5). In this case one can apply PCA.

The calculated value of the test statistic χ^2 and KMO (KMO and Barlett's output)

In order to test the hypothesis of the independence between the statistic variables, the SPSS program supplies the corresponding computed values of the test statistics. Test statistics (KMO and Barlett's output) is used to test if the correlation matrix is a unit matrix, therefore if there is a statistic correlation between the statistic variables. The following statistic hypotheses are stated for these:

H0: independent hypothesis (correlation matrix is a unit matrix);

H1: dependent hypothesis.

To test these hypotheses, the SPSS program supplies both the computed value of the statistics χ^2 = 216.3 and the value of the statistics associated with the computed test statistics (Sig = 0.000 < 0.05), therefore the hypothesis H0, which admitted the existence of independent variables, is rejected (table 4).

Table 4

KMO AND BARTLETT'S TEST		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.627
Bartlett's Test of Sphericity	Approx. Chi-Square	216.3
	df	66
	Sig.	0.000

Therefore, one can consider with 95% probability, that there are statistic correlations between the variables.

Variables variance

Variables standardization results in the appearance of new variables of zero-mean and variance equal to unit. The variances of statistic variables are presented in the Communalities output. Variables variance after extracting the factors is computed based on the results from the Component Matrix output (table 5). For example, for fabric tenacity it is obtained χ^2 = = 0.981. The small values of the variables variance after extracting the factors (see column Extraction) show that the corresponding variables can be eliminated from the analysis itself, since they are not correlated with the factorial axes.

Table 5

COMMUNALITIES		
Variables	**Initial**	**Extraction**
Pr (daN)	1.000	0.969
ΔM (%)	1.000	0.971
Sg (%)	1.000	0.743
Ws (daN/m)	1.000	0.960
τ (cN/tex)	1.000	0.981
α (°)	1.000	0.949
Pa (m^3/min·m^2)	1.000	0.939
Kt (%)	1.000	0.931
Pz (%)	1.000	0.906
M (g/m^2)	1.000	0.851
R (mg·cm)	1.000	0.936
ε (%)	1.000	0.950

Eigenvalues λ_k associated to each factorial axis and variance explained by each factorial axis

The eigenvalues of the correlation matrix are presented in the Total Variance Explained (TVE), column Initial Eigen Values (table 6).

From table 6, one can notice that the eigenvalues of the correlation matrix are:

$$\lambda_1 = 5.399;\ \lambda_2 = 3.330;\ \lambda_3 = 1.389;\ \lambda_4 = 0.967;$$
$$\lambda_5 = 0.480;\ \lambda_6 = 0.182;\ \lambda_7 = 0.120;\ \lambda_8 = 0.063; \quad (1)$$
$$\lambda_9 = 0.038;\ \lambda_{10} = 0.016;\ \lambda_{11} = 0.010;\ \lambda_{12} = 0.006$$

The eigenvalues correspond to the inertia explained by factorial axes. Their sum represents total inertia of

Table 6

TOTAL VARIANCE EXPLAINED						
Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	5.399	44.995	44.995	5.399	44.995	44.995
2	3.330	27.746	72.741	3.330	27.746	72.741
3	1.389	11.575	84.317	1.389	11.575	84.317
4	0.967	8.062	92.378	0.967	8.062	92.378
5	0.480	3.999	96.377	-	-	-
6	0.182	1.516	97.894	-	-	-
7	0.120	0.999	98.892	-	-	-
8	0.063	0.527	99.420	-	-	-
9	0.038	0.315	99.735	-	-	-
10	0.016	0.133	99.868	-	-	-
11	0.010	0.081	99.949	-	-	-
12	0.006	0.051	100.000	-	-	-

the points cloud, equal with the number of statistic variables from the table with initial values, respectively with the sum of the elements of the correlation matrix main diagonal:

$$\sum_{k=1}^{k} \lambda_k = 5.399 + 3.330 + 1.389 + 0.967 + 0.480 + 0.182 + 0.120 + 0.063 + 0.038 + 0.016 + 0.010 + 0.006 = 12 \quad (2)$$

The first factorial axis explains 5.399/12 = 44.99% of the total cloud variance. The extracted components explain 92.378% of the variability of the twelve initial inter-correlated variables, so that we can considerably reduce the complexity of the data configured using these components, with only 7.622% loss of information.

The number of factorial axes which are to be interpreted in PCA was chosen in terms of two criteria:

– Kaiser's criterion which supposes the selection of that number of factorial axes for which the corresponding eigenvalues are bigger than unit. According to this criterion, one chooses three factorial axes corresponding to the eigenvalues (λ_1 = 5.399; λ_2 = 3.330; λ_3 = 1.389) > 1.
– Cattel's criterion supposes eigenvalues graphical representation (Scree Plot) and pursuing the sudden inertia fall explained by these.

From the diagram shown in figure 1, three factorial axes for interpretation are chosen.

Also, the Scree Plot chart has helped to determine the optimal number of components. In general, the components on the steep slope should be removed, their contribution being superficial. It was observed that the largest decrease occurs between the penetration of the fourth and fifth components, so an easy choice is to use the first components.

These axes explain the greatest differences between statistical units in terms of the considered variables. The chosen axes are those that precede this sudden change of the slope of eigenvalues graphic (figure 1).

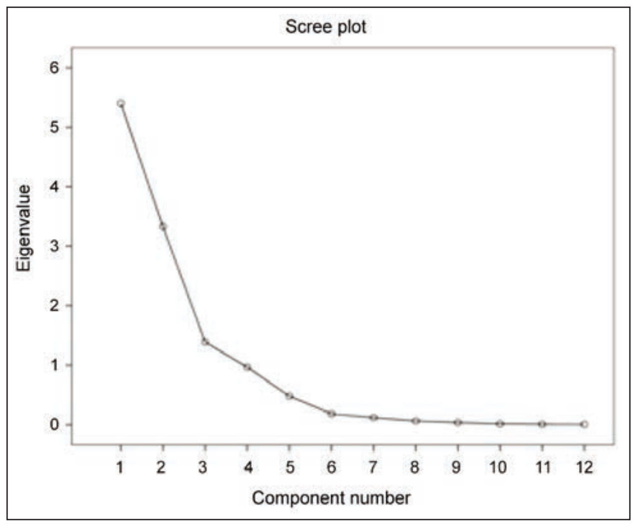

Fig. 1. Graphic representation of the correlation matrix's eigenvalues

The eigenvalues associated with the correlation matrix permit to obtain the coefficients of the variables from the linear equation of the principal axes. The eigen vectors' coordinates do not appear in the PCA results; yet they serve for the calculation of variables coordinates on the principal axes. The values from table 6 show the variables position on the factorial axes. In order to access the variables in each extracted component (table 7), the highest loading factor is selected for each variable analyzed regarding the physical-mechanical properties of combed wool fabrics, designed to make clothing products. The first component indicates that the strongest positive correlations are tenacity (r = 0.978), mechanical work of deformation at break (r = 0.903), breaking strength (r = 0.895) and degree of compactness (r = = 0.845). The mechanical properties are however better represented on this axis/component and represent about 45% of the total variant and can be called "fabric durability".

Table 7

COMPONENT MATRIX				
Variables	**Component**			
	1	**2**	**3**	**4**
Pr (daN)	0.895	0.304	0.029	0.272
ΔM (%)	–0.764	0.368	0.398	0.305
Sg (%)	–0.542	–0.463	0.188	0.446
Ws (daN/m)	0.903	0.310	–0.197	0.100
τ (cN/tex)	0.978	0.079	–0.130	–0.011
α (°)	–0.661	0.578	0.377	0.191
Pa ($m^3/min \cdot m^2$)	0.085	0.870	0.366	–0.453
Kt (%)	0.845	0.039	0.434	0.164
Pz (%)	0.563	–0.258	0.705	–0.157
M (g/m^2)	0.402	–0.713	0.717	–0.082
R (mg·cm)	0.246	–0.905	–0.003	0.238
ε (%)	0.499	0.681	–0.053	0.485

The second component indicates a strong positive correlation regarding air permeability (r = 0.870) and a strong negative correlation regarding the rigidity of the fabrics (r = –0.905). However, the physical properties are better represented on this axis and represent about 28% of the total variation, which we can call "comfort of fabrics".

The third component indicates that the highest positive correlations are given by the mass of the fabrics (r = 0.717), the porosity of the fabrics (r = 0.705) and represents about 12% of the total variation and can be called the "production price".

The fourth component indicates weaker positive correlations with thickness loss (r = 0.446), elongation at break (r = 0.485) and represents about 8% of the total variation and can be called "fabric design".

The limits of variation regarding the rigidity, the mechanical work of deformation at break, the breaking force and the degree of compactness, depend on the quality of the fibers and yarns, the density of the fabric, the type of the weave, the finishing treatments and have a special importance in appreciating the durability of a fabrics.

For the assortments of fabrics used to obtain clothing products, air permeability and flexural stiffness of the fabrics are required especially by the clothing designers who, based on common criteria, ensure the aesthetic aspect (shape, colour, design) at which some specific criteria related to ensuring the behavioural conditions from the point of view of physiological comfort is added. The mass and porosity of the fabrics are characteristics derived from the structure and blend parameters of the component yarns, which indicate the consumption of raw materials and materials, the production price, the delivery and the profit.

The qualitative and quantitative analysis of the fabrics behaviour at wear by rubbing test highlights the design of the fabrics and allows the hierarchy of the assortments of fabrics made of worsted yarns, destined for the manufacture of outerwear products.

From the results obtained can be concluded that the durability, the comfort of the fabrics, the price of production and the design of the studied fabrics are influenced by the physical-mechanical properties of the raw material and by the structural characteristics of the fabrics. By applying the PCA mathematical model we obtained the controlled reduction of the number of variables (columns) of the data matrix, to four components, containing information about each group/ assortment of fabrics.

For example, the variable Pr (daN) has a positive coordinate on the first factorial axis (r = 0.895) and a negative coordinate on the second factorial axis (r = 0.304), the variable will be graphically represented in the positive values quadrants of the first factorial axis and of the second factorial axis. The variable Pz (%) has a positive coordinate on the first factorial axis (r = 0.563) and a negative coordinate on the second factorial axis (r = –0.258), the variable will be graphically represented in the positive values quadrant of the first factorial axis and in the negative values quadrant of the second factorial axis.

The high values of the variables coordinates on the factorial axes show that they are strongly correlated with the corresponding factorial axis. The variables τ (cN/tex), Ws (daN/m) and Kt (%) are correlated with the first factorial axis, which shows that these variables significantly explain the differences between the statistic units (more precisely, there are significant differences between the statistic units from the standpoints of the values recorded for these variables). The variables coordinates on the factorial axes represents the coefficients of the linear equation of the correlations between the variables. For example, for the data presented in table 7, the first axis is a new variable defined by the linear combination of the initial variables, of the form:

$$F_1 = 0.895\,Pr - 0.764\,\Delta M - 0.542\,Sg + 0.903\,Ws + 0.978\,\tau - 0.661\,\alpha + 0.085\,Pa + 0.845\,Kt + 0.563\,Pz + 0.402\,M + 0.246\,R + 0.499\,\varepsilon \quad (3)$$

Graphic representation

The representation of the variable points on the first two factorial axes is shown in figure 2. The first factorial axis represented horizontally shows that between the variables Ws (daN/m), Kt (%), Pr (daN), τ (cN/tex) and Pz (%), there is a strong direct link and, between the variables α (°) and Pz (%), there is a reverse link (correlation).

The representative variables for the second factorial axis, represented vertically, are Pa ($m^3/min \cdot m^2$) and R (mg·cm) between which there is a reverse link. For the interpretation of the third factorial axis, it is possible to represent the variable points in a three-dimensional space (figure 3). Because it is difficult to interpret the variables in the graph from figure 3 the values of the coordinates of the variables on the third factorial axis were analysed according to the values obtained in table 7.

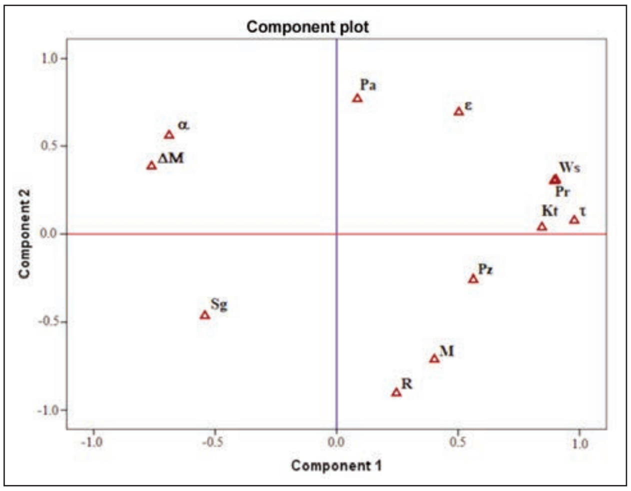

Fig. 2. Position of the variables on the first two axess

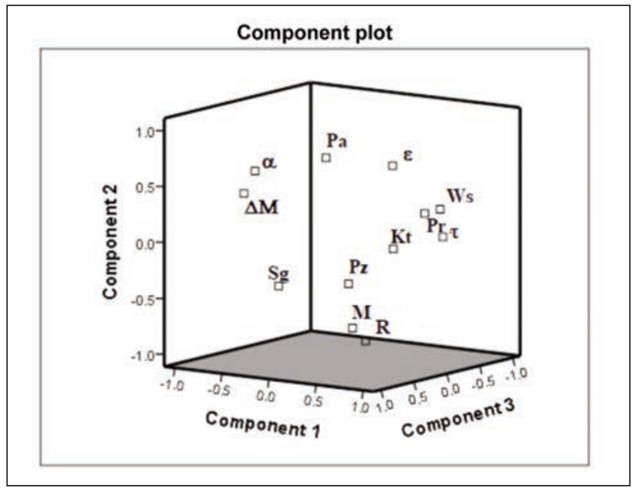

Fig. 3. Position of the variables on the three axes

CONCLUSIONS

The paper presents the applicability of Principal Component Analysis (PCA) in the area of quantitative study of the physical-mechanical properties of wool fabrics, from different fibrous compositions and aims at selecting the most suitable fabrics for outerwear products. From the analysis, four main factors were extracted: durability, comfort, production price and fabric design. The extracted components explain 92% of the variability of the twelve inter-correlated variables, so that using these components we can considerably reduce the complexity of the configured data set, with only 8% loss of information. By using an extensive database, which correlates the characteristics/properties of fabrics, the design of fabrics can be provided by analyzing a limited number of properties. In this study, based on the correlations obtained, it was found that, through an assessment of the physical-mechanical properties, it is possible to design and manufacture the fabrics, the appropriate selection of the fibrous composition and the technological parameters for the fabrication.

REFERENCES

[1] Sass, D.A., *Factor loading estimation error and stability using exploratory factor analysis*, In: Education Psychology Measurement, 2010, 70, 4, 557

[2] Carr, J., Matanawi, K., *Correspondence analysis for principal components transformation of multispectral and hyperspectral digital images*, In: Photogrammetry Engineering and Remote Sensing, 1999, 65, 8, 909–914

[3] Hristian, L., Sandu, A.V., Manea, L.M., Tulbure, E.A., Earar, K., *Analysis of the Principal Components on the Durability and Comfort Indices of the Fabrics Made of Core-coating Filament Yarns,* In: Journal of Chemistry, 2015, 66, 3, 342–347

[4] Hristian, L., Ostafe, M.M., Manea, L.R., Apostol, L.L., *Experimental Researches on the Durability Indicators and the Physiological Comfort of Fabrics using the Principal Component Analysis (PCA) Method,* In: International Conference on Innovative Research (ICIR Euroinvent), IOP Conference Series-Materials Science and Engineering, 2017, 209, 012104

[5] Dulgheriu, I., Ionescu, I., Avădanei, M., Ionesi, S.D., *The Analysis of the Interaction of Working Bodies Through Studying the Cyclorama of the Sewing Machine*, In: International Scientific Conference on eLearning and Software for Education (eLSE)-New Technologies and Redesigning Learning Spaces, 2019, III, 400–405

[6] Manea, L.R., Hristian, L., Ostafe, M.M., Apostol, L.L., Sandu, I., *Analysis of Characterization Indexes for Worsted Fabrics Type Using Correlation Method as a Statistical Tool,* In: Journal of Chemistry, 2016, 67, 9,1758–1762

[7] Tadesse, M.G., Harpa, R., Chen, R.Y., Wang, L., Nierstrasz, V., Loghin, C., *Assessing the comfort of functional fabrics for smart clothing using subjective evaluation*, In: Journal of Industrial Textiles, 2018, 48, 8, 1310–1326

[8] Senthilkumar, P., Kantharaj, M., Vigneswaran, C., *Thermal comfort characteristics of plain woven fabrics*, In: Journal of Textile Association, 2010, 71, 188–195

[9] Karaca, E., Kaharaman, N., Omeroglu, S., Becerir, B., *Effects of fiber cross sectional shape and weave pattern on thermal comfort properties of polyester woven fabrics*, In: Fibres and Textiles in Eastern Europe, 2012, 92, 3, 67–72

[10] Özdemir, H., *Thermal comfort properties of clothing fabrics woven with polyester/cotton blend yarns*, In: Textile Research Journal, 2017, 17, 2, 135–141

[11] Wang, F., Xu, G., Xu, B., *Predicting the Shearing Rigidity of Woven Fabrics*, In: Textile Research Journal, 2005, 75, 1, 30–34

[12] Kumpikaitė, E., Sviderskytė, A., *The Influence of Woven Fabric Structure on the Woven Fabric Strength,* In: Materials Science (Medžiagotyra), 2006, 12, 2, 162–166

[13] Hristian, L., Bordeianu, D.L., Iurea, P., Sandu, I., Earar, K., *Study of the Tensile Properties of Materials Destined to Manufacture Protective Clothing for Firemen,* In: Journal of Plastics, 2014, 51, 4, 405–409

[14] Nikolic, M., Michailovic, T., Simovic, Lj., *Real Value of Weave Binding Coefficient as a Factor of Woven Fabrics Strength,* In: Fibres and Textiles in Eastern Europe, 2000, 11, 74–78

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Multivariate analysis of the 3D composites based on nickel microparticles

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ABSTRACT – REZUMAT

Multivariate analysis of the 3D composites based on nickel microparticles

This paper presents multivariate analyses of the experimental parameters obtained in the scientific experiments on eight sample fabrics of 100% cotton with electrically conductive properties and electromagnetic achieved through traditional treatments such as padding with antistatic agents, and direct printing or scraping with a polymeric paste based on nickel (Ni). Textile printing was obtained using polymers such as polyethylene glycol (PEG), polyvinyl alcohol (PVA), polyacrylate, ammonium salt, carboxylic acid Copolymer polyester, and Ni microparticles. For the eight samples that have been analyzed, the morphology of the surfaces using SEM (scanning electron microscope) with magnification 2000–8000x and electronic magnification microscopy with 4x, assessed the resistance to wet rubbing and dry the resistance of the surface after treatment in the solution of alkaline and acid sweat. Also, the samples above referred have been analyzed by spectrophotometry to evaluate the transmittance, and reflectance of the electromagnetic waves. It can specify that after treatments in acid or alkaline sweat solutions, the resistance of the surface has decreased by 10^3*–*10^5*. It has been observed that for samples treated with acid or alkaline sweat, the reflectance was increased in comparison with the reflectance obtained for the original samples. The multivariate analysis provided refers to the study of some physic-chemical and optical parameters, of the samples collected, such as thickness, pH, reflectance, and transmittance.*

Keywords: *composites, electroconductive, textile, resistance, nickel, 3D*

Analiza multivariată a compozitelor 3D pe bază de microparticule de nichel

În această lucrare sunt prezentate analize multivariate pentru parametrii experimentali obţinuţi în cadrul experimentelor ştiinţifice pentru opt probe de material textil din 100% bumbac, având proprietăţi electroconductive şi electromagnetice obţinute prin tratamente clasice, cum ar fi fulardarea cu agenţi antistatici, sau imprimarea directă ori raclarea unei paste polimerice pe bază de nichel (Ni). Imprimarea textilă a fost obţinută prin utilizarea unor polimeri cum ar fi polietilen glicol (PEG), alcool polivinilic (PVA), poliacrilaţi, sare de amoniu, acid carboxilic copolimer poliester, cu conţinut de microparticule de Ni. Pentru cele 8 probe a fost analizată morfologia suprafeţelor utilizând SEM (microscopul de scanare electronică) cu gradul de magnifiere 2000–8000x şi microscopul electronic cu grad de mărire 4x, determinându-se şi rezistenţa la frecare umedă şi uscată, rezistenţa de suprafaţă după tratamente în soluţii de transpiraţie acidă şi alcalină. De asemenea, probele mai sus menţionate au fost analizate prin spectrofotometrie pentru evaluarea transmitanţei şi reflectanţei undelor electromagnetice. Se poate specifica că rezistenţa de suprafaţă în cazul probelor tratate cu soluţii de transpiraţie acidă sau alcalină a fost redusă cu 10^3*–*10^5*. S-a observat că pentru probele tratate cu soluţii de transpiraţie alcalină sau acidă reflectanţa a crescut în comparaţie cu reflectanţa obţinută pentru probele iniţiale (martor). Analiza multivariată se referă la studierea unor parametri fizico-chimici şi optici, obţinuţi pentru probele analizate, cum ar fi grosimea materialului, pH, reflectanţa şi transmitanţa.*

Cuvinte-cheie: *compozite, electroconductiv, textile, rezistenţă, nichel, 3D*

INTRODUCTION

The multivariate analysis represents the statistical study of experiments in which dependent variables from measurements and the relationship among multivariate measures [1] and their structure analyzed to understand the experiments. Moreover, the multiple responses to a test performed on the samples may offer valuable information concerning toxicity, permanent surface resistance, or temporary character. Also, this involves measuring the strength of relationships among various measurements (e.q. resistance to alkaline/acid sweat or to wet/dry rubbing).

Development of the products such as sensors, actuators, batteries, the based metal coating must be defined in some aspects concerning the toxicity of the metal used and the usability in contact or not with the skin. Concerning nickel, at the European level, it is the Nickel Directive EN 1811 [2] regulating the use of nickel (Ni) in jewelry and other products that come into contact with the skin because of nickel allergy is a common cause of contact dermatitis. However, Ni is used in many everyday items, such as coins, zippers, cell phones, and eyeglass frames, and some of these items are used in the textile industry. The European Nickel Directive EN 1811 is the internationally recognized test method to determine the rate of nickel release from jewelry, spectacle frames, and other items. In the scientific literature are presented several electrochemical tests (potential vs. time, potentiodynamic corrosion/polarization tests [3–5]) and the synthetic sweat tests.

The standard, EN 1811:2011 the amendment no. 1/2015 concerning testing to the nickel [6] release allow a level of 0.11–9.35 μg/cm^2/week for post assemblies and body piercing and 0.28–0.88 μg/cm^2/week for components in direct and prolonged contact with the skin. Several papers state that nickel migration can be identified by artificial sweat [7, 8] and, in this way, can be evaluated the exposure to trace elements through clothes [9, 10].

EXPERIMENTAL PART

In the experiments below presented, we developed eight models using 100% cotton fabric to obtain the surface with electroconductive properties. The objective was to get materials with electro-conductive properties using standard technologies (printing, scrapping, and padding) and nickel (Ni) microparticles. Preliminary treatments on the fabrics have been performed to obtain the antistatic (Avistat 3 P, Arristan AIR, and Aristan CPU), hydrophilic (Tubicoat 41, and Tubifast) and hydrophobic (NUVA) effect. The conductive paste based on water, Tubicoat binder, Tubivis DL 650, and micro/nanoparticles of nickel (< 50 μm) was dried on the fabric surface at a temperature of 120°C for two minutes and condensation at a temperature of 140°C, for 3 minutes. For comparison, the printing with a conductive paste based on nickel performed on one side of the fabric and both sides of the fabric surface. Table 1 presents the surface analyses by electronic microscope with 4x magnification and thickness of the materials analyzed. Table 2 presents the SEM (Scanning electron microscope) analysis of the samples untreated (sample no. 0) and

Table 1

SURFACE EVALUATION OF THE EXPERIMENTAL MODELS BEFORE AND AFTER THE DRY RUBBING OPERATION

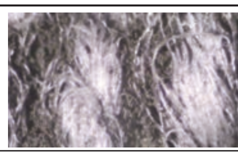
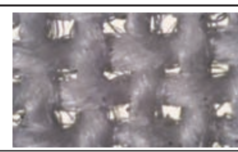
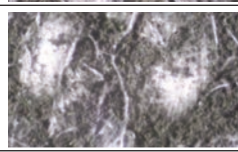
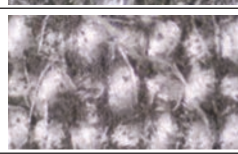
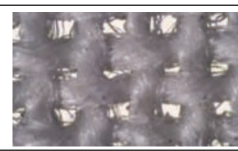
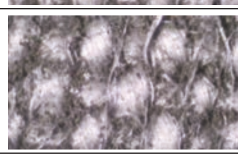
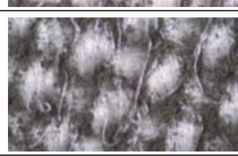
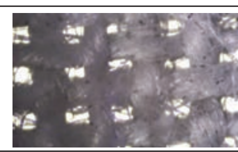
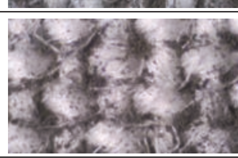
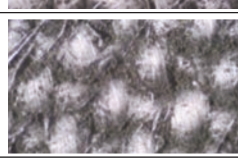
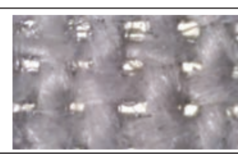
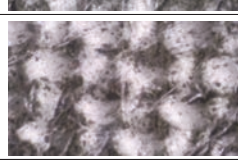
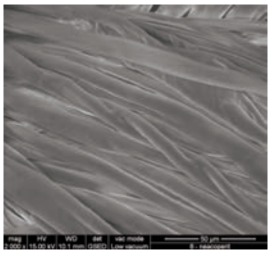
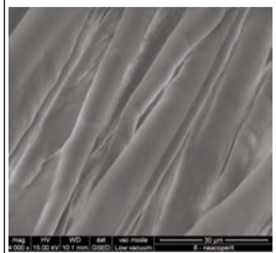
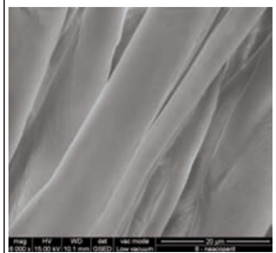
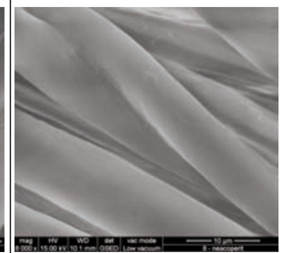
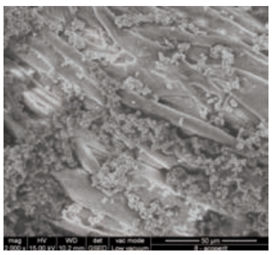
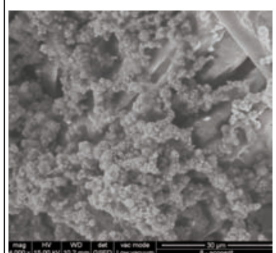
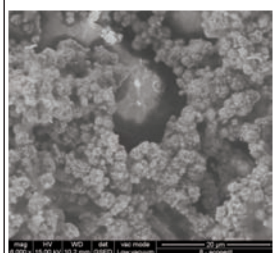
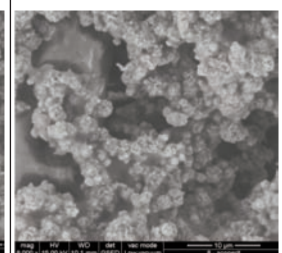
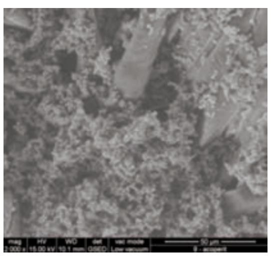
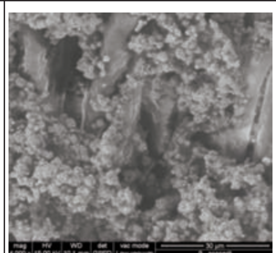
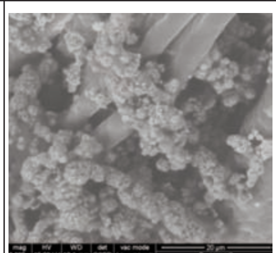
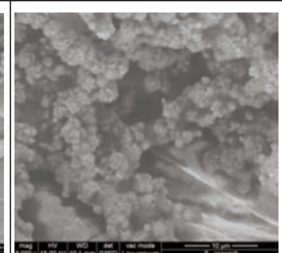
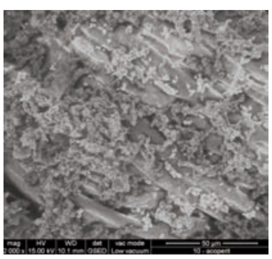
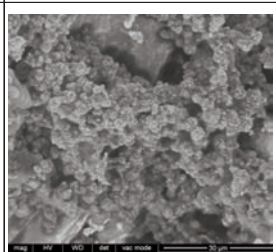
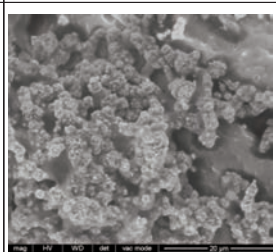
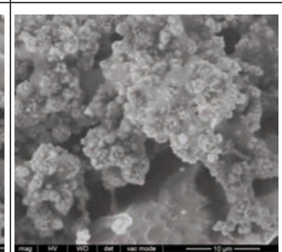
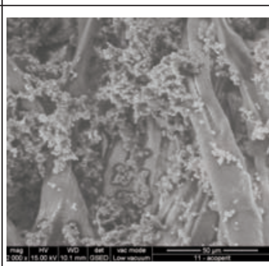
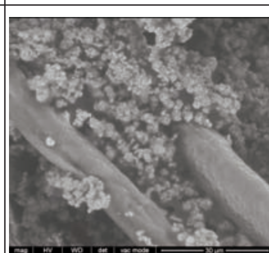
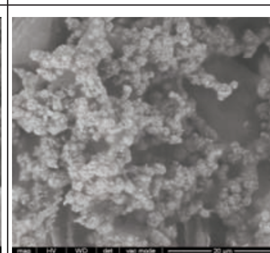
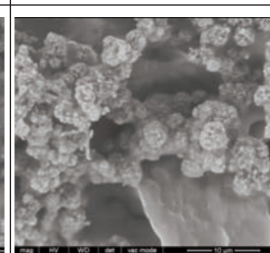
Sample no.	Image of the textile surface – Optical microscope 4×	Image of the textile surface after dry rubbing – Optical microscope 4×	Thickness (mm)
1			0.96
2			0.98
3			0.35
4			0.36
5			0.34
6			0.36
7			0.35
8			0.35

Table 2

SAMPLES TOPOGRAPHY ANALYZED BY SCANNING ELECTRON MICROSCOPY (SEM)				
No.	**Image SEM magnification 2000×**	**Image SEM magnification 4000×**	**Imagine SEM magnification 6000×**	**Image SEM magnification 8000×**
0 Initial sample untreated				
1 (Ni microparticles)				
3 (Ni microparticles)				
5 (Ni microparticles)				
7 (Ni microparticles)				

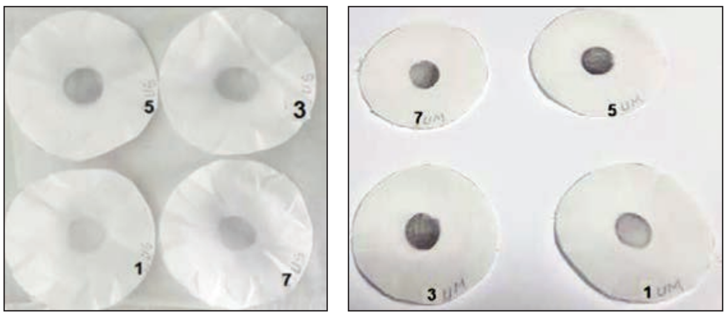
treated with conductive paste (samples no. 1, 3, 5 and 7). In table 2 the micro/nanoparticles deposited can be observed very well and also it can be seen as a clusterization tendency of the micro/nanoparticles.

Nickel is a common cause of allergic contact dermatitis and can be found in many everyday items, such as coins, zippers, cellphones, and eyeglass frames, not only in sensor components. Taking into account these aspects, we decided to provide some preliminary tests to evaluate if the nickel microparticles from polymeric paste can migrate or no on other textile layers. To assess the resistance of the conductive coating of textiles to wet and dry rubbing, we developed an experiment that consists of rubbing the coated fabric with a dry tissue and with a wet material (figure 1). The final samples (figure 1) were optically appreciated, using greyscale and notes from 1 to 5 (table 3).

For the eight experimental models there were determined in the laboratory the resistance to acid and alkaline sweat for 4 hours at a temperature of 37°C, dry (R_d – figure 1, *a*) and wet (R_w – figure 1, *b*) rubbing resistance (wetting 98%, the frictional force 9 N) parallel to the warp direction (table 3), pH following PS-C-02, SR EN ISO 3071/2006 and surface resistance before sweat treatments (R_{si}), surface resistance

Table 3

LABORATORY TESTS – RESISTANCE TO ACID AND ALKALINE SWEAT, RESISTANCE WET AND DRY RUBBING, RESPECTIVE THE REPORT [R/T]											
Sample	**Acid sweat**	**Alkaline sweat**	R_d	R_w	R_{si} (Ω)	R_{SAL} (Ω)	R_{SAC} (Ω)	$pH_{initial}$	$pH_{samples}$	**[R/T]**	δ (mm)
1	4-5	4-5	4	2-3	10^{12}	10^8	10^9	8.3	8.6	18.71	0.96
2	4-5	4-5	-	-	10^{12}	10^8	**10^7**	7.09	8.6	14.06	0.98
3	4-5	4-5	3	1-2	10^{12}	10^8	10^9	6.546	6.231	16.93	0.35
4	4-5	4-5	-	-	10^{12}	10^8	10^9	6.502	6.203	22.42	0.36
5	4-5	4-5	2	1-2	10^{12}	10^8	10^8	6.5	6.6	16.73	0.34
6	4-5	4-5	-	-	10^{12}	10^8	10^8	6.5	6.6	19.40	0.36
7	4-5	4-5	3-4	2	10^{12}	10^8	10^8	6.5	7.2	22.83	0.35
8	4-5	4-5	-	-	10^{12}	**10^7**	10^8	6.5	6.98	20.23	0.36



a *b*

Fig. 1. Resistance to dry and wet rubbing:
a – dry rubbing; *b* – wet rubbing

after alkaline sweat treatment (R_{SAL}), surface resistance after acid sweat treatment (R_{SAC}). From table 3 it can be observed a reduction to 10^4–10^5 Ω of surface resistance after alkaline sweat treatment, respective with 10^3–10^5 Ω after acid sweat treatment, and the insulator fabric becomes a material with excellent antistatic properties. This preliminary evaluation will help us in future support decisions to decide on which type of electrodes (skin contact or not) can be used in this fabric based on nickel coating.

Spectrophotometry is the method that measures the degree of absorption of light by a chemical substance by measuring the intensity of the light as a beam of light is directed through the chemical substance. The spectrophotometer Hunterlab UltraScan PRO is used for research and quality control for solid opaque, clear, transparent liquid films. The UltraScan PRO measures with precision the reflectance and transmittance, noise in the transmission, and color of the reflected and transmitted.

Samples no. 2 and no. 8, were tested using a spectrophotometer UltraScan Pro to see if occur some modification in light reflectance (equation 1)/transmission (equation 2) [R/T] and light absorption (equation 3). Figure 2 presents the spectral plot for sample no. 2 and figure 3 presents spectral plot [R/T] for sample no. 8:

$$T = e^{-\tau} = 10^{-A} \quad (1)$$

where T is the optical depth and A – the absorbance.

$$q(y) = G_r(y) / G_i(y) \quad (2)$$

where G_r is the reflected radiation and G_i – the incident radiation.

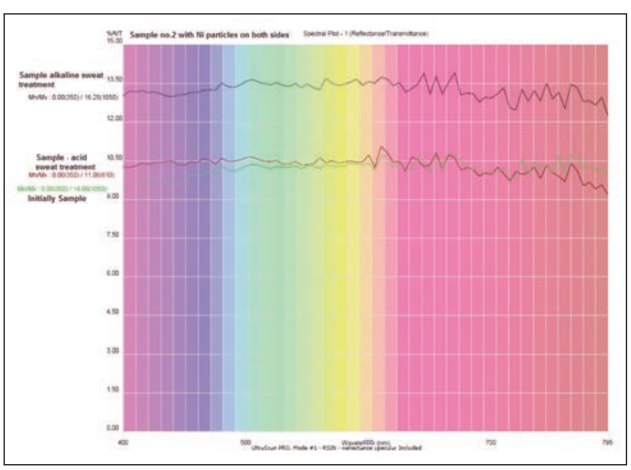


Fig. 2. Spectral plot sample no. 2 (both sides coating)

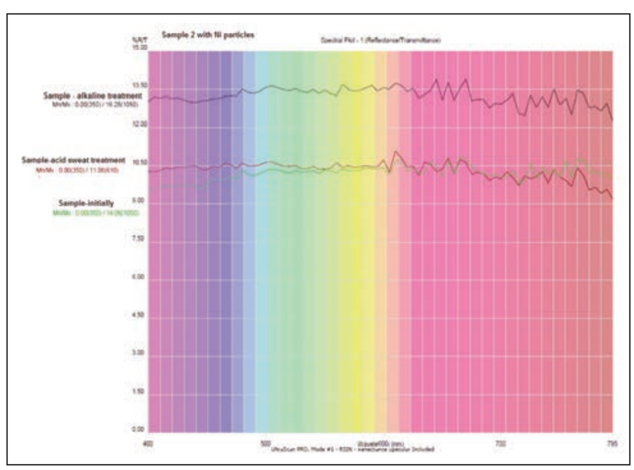


Fig. 3. Spectral plot sample no. 2 one (one side coating)

RESULTS AND DISCUSSIONS

The multivariate technique in MATLAB analyzed the experimental data, and we developed the mathematical model (equation 3) based on experimental data obtained for reflectance/transmittance ([R/T]), pH and textile material thickness (δ). Figure 4 presents the 3D representation of the reflectance/ transmittance ([R/T]) of the samples obtained by printing method in the function of the thickness (δ) and pH using MATLAB software and multivariate analysis of the reflectance/ transmittance ([R/T]) according to the thickness (δ) and pH:

$$z = f(x,y) \Leftrightarrow z = a + b*x*y + c*x^7*y + d*x^6*y^6 + + e*y^7*x^5 + f*y^6*x + g*x^2*y^5 \quad (3)$$

where z = [R/T], x = δ, y = pH, a = –573.5, b = 368.6, c = 5272, d = –0.3134, e = 0.02756, f = 0.01535 and g = –0.4938.

Also, have been analyzed how well it fits the experimental variables (pH and δ) in determining the values of the [R/T] by the R-squared R^2 (equation 4), the sum of squared errors SSE (equation 5), and root mean square error RMSE (equation 6) The coefficient of determination is R^2 = 0.99 shows that 99% of the values of the z are determined by the variables x and y:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - f_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \Leftrightarrow R^2 = 0.99 \quad (4)$$

$$SSE = \sum_{i=1}^{n} w_i (y_i - \hat{y}_i)^2 \Leftrightarrow SSE = 0.0329 \quad (5)$$

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y}_i - y_i)^2}{n}} \Leftrightarrow RMSE = 0.1814 \quad (6)$$

By analyzing the correlation between R/T and thickness (δ) and pH, we observed that R/T is an inverse proportionality relationship with the thickness (equation 7) and pH (equation 8), and this means that the reducing of the nickel layer thickness will generate a lower value for R/T:

$$Correlation\ (R/T,\ pH) = \begin{vmatrix} 1 & -0.24967 \\ -0.24967 & 1 \end{vmatrix} \quad (7)$$

$$Correlation\ (R/T,\ \delta) = \begin{vmatrix} 1 & -0.52347 \\ -0.52347 & 1 \end{vmatrix} \quad (8)$$

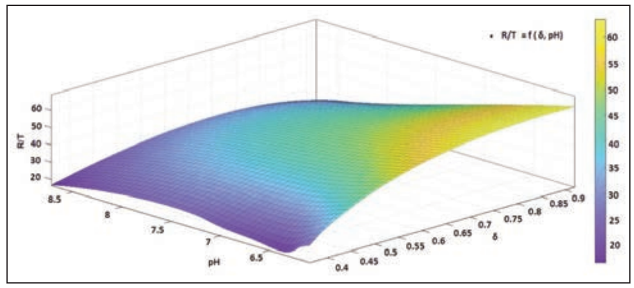


Fig. 4. 3D representation of the reflectance/transmittance ([R/T]) according to the thickness (δ) and pH

CONCLUSIONS

We can conclude that the experimental models 1–8 have specific values to insulating materials ($R_s > 10^{12}$ Ω). Still, the solutions used for acid and alkaline sweat can influence the material effectiveness in reflecting radiant energy and efficiency in transmitting radiant energy. Besides, the surface resistivity and indirectly, the surface conductivity of the textile is influenced by acid/alkaline sweat treatments. Moreover, as a result of treatment with alkaline or acid sweat solutions, the surface resistance of the samples analyzed has been reduced, proving an excellent antistatic character (10^7–10^8 Ω) and reflectance/transmittance increased. The transmittance and reflectance of the textile coated with a polymeric paste based on nickel are affected by the thickness [11–13] of the polymeric layer. Besides, the pH can influence the reflecting and transmitting radiation through the metallic layer deposited on the textile surface. A potential application of nickel printing, using both inks or paste, can be the developing of flexible composite electrodes [14–16].

Also, the correlation between R/T and δ, pH is harmful, and this means that the increase of the δ or pH values will generate the reduction of the R/T values.

ACKNOWLEDGMENTS

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REFERENCES

[1] Husson, F., Lê, S., Pagès, J., *Exploratory multivariate analysis by example using R*, , Chapman and hall/CRC, 2017

[2] Baker, M., *European Standards Developed in Support of the European Union Nickel Directive*, In: Metal Allergy, Springer Cham, 2018, 23–29

[3] Esmailzadeh, S., Aliofkhazraei, M., Sarlak, H., *Interpretation of Cyclic Potentiodynamic Polarization Test Results for Study of Corrosion Behavior of Metals: A Review*, In: Protection of Metals and Physical Chemistry of Surfaces, 2018, 54, 5, 976–989

[4] Moretti, G., Guidi, F., Tonini, R., *Alloys at low nickel-release: Pd-Ni coatings on copper*, In: Plating and surface finishing, 2001, 88, 4, 70–73

[5] Porcayo-Calderon, J., Rodríguez-Díaz, R.A., Porcayo-Palafox, E., Martinez-Gomez, L., *Corrosion performance of Cu-based coins in artificial sweat*, In: Journal of Chemistry, 2016

[6] Hostynek, J.J., Maibach, H.I., *Nickel and the skin: Absorption, immunology, epidemiology, and metallurgy*, CRC Press, 2002

[7] Rovira, J., Nadal, M., Schuhmacher, M., Domingo, J.L., *Trace elements in skin-contact clothes and migration to artificial sweat: risk assessment of human dermal exposure*, In: Textile Research Journal, 2017, 87, 6, 726–738

[8] Rovira, J., Nadal, M., Schuhmacher, M., Domingo, J.L., *Human exposure to trace elements through the skin by direct contact with clothing: risk assessment*, In: Environmental research, 2015, 140, 308–316

[9] von Goetz, N., Lorenz, C., Windler, L., Nowack, B., Heuberger, M., Hungerbuhler, K., *Migration of Ag-and* TiO_2*-(Nano) particles from textiles into artificial sweat under physical stress: experiments and exposure modeling*, In: Environmental science & technology, 2013, 47, 17, 9979–9987

[10] Barel, A.O., Paye, M., Maibach, H.I., *Handbook of cosmetic science and techno*logy, CRC Press, 2014

[11] Sultan, M., Sultana, N., *Analysis of reflectance and transmittance characteristics of optical thin film for various film materials, thicknesses and substrates*, In: J. Electr. Electron. Sys., 2015, 4, 2332–0796

[12] McKnight, S.W., Stewart, K.P., Drew, H.D., Moorjani, K., *Wavelength-independent anti-interference coating for the far-infrared,* In: Infrared physics, 1987, 27, 5, 327–333

[13] Akman, O., Kavas, H., Baykal, A., Toprak, M.S., Çoruh, A., Aktaş, B., *Magnetic metal nanoparticles coated polyacrylonitrile textiles as microwave absorber,* In: Journal of Magnetism and Magnetic Materials, 2013, 327, 151–158

[14] Zheng, Z., Casey, Y.A.N., Lau, L.C., EPRO DEVELOPMENT Ltd, *Electrically conductive textile element and method of producing same*, U.S. Patent Application 16/593,885, 2020

[15] Hayashi, A., Yamazaki, T., Kinoe, K., Riso Kagaku Corp, *Ink for inkjet textile printing, ink set, and method for producing printed item*, U.S. Patent Application 16/454,669, 2020

[16] Meng, X., Wang, Z., Di Benedetto, G., Zunino III, J.L., Mitra, S., *Development of printable, flexible nickel-iron batteries based on composite electrodes*, In: Energy Storage, 2020, 2, 1, 105

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Dynamic response of filament winding angle on complex shaped mandrels

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ABSTRACT – REZUMAT

Dynamic response of filament winding angle on complex shaped mandrels

Aerodynamic parts such as rocket nose and heat shield related composites are mainly produced with filament winding machines. Winding angle of the reinforcement filament is the main parameter to determine the thermomechanical properties of the final composite part. The angle adjustments on the machine cause the temporary response of the filaments. This study derives an analytical method to determine the real angle of the filaments on the mandrel.

Keywords: *winding angle, filament winding, composite materials, conical parts, complex shape mandrels*

Răspunsul dinamic al unghiului de înfășurare al filamentelor asupra poansoanelor cu forme complexe

Piesele aerodinamice, cum ar fi vârful rachetei și materialele compozite pentru scutul termic, sunt produse în principal cu mașini pentru înfășurarea filamentelor. Unghiul de înfășurare al filamentului de armare este principalul parametru pentru a determina proprietățile termomecanice ale piesei compozite finale. Reglajele unghiului pe mașină determină răspunsul temporar al filamentelor. Acest studiu descrie o metodă analitică pentru a determina unghiul real al filamentelor de pe poanson.

Cuvinte-cheie*: unghi de înfășurare, înfășurarea filamentelor, materiale compozite, piese conice, poansoane cu forme complexe*

INTRODUCTION

Textile reinforced composites are used for a wide range of applications. The anisotropic nature of the composite parts extends the potential of conventional materials; however, an educated design of the layers and fiber alignment are necessary to fulfill the requirements. Filament winding is the main method to produce axially symmetrical body parts from composite materials. Winding angle of the layers is the main parameter to determine the mechanical properties. Depending on the structural design and requirements of the composite part, winding angle is changed during the production. The filament angles respond with a delay to the changing machine parameters. The aim of this study is to determine the filament angle functions analytically both for constant and changing machine settings on complex shaped mandrels.

There are many studies which analyze the effects of filament angle on the mechanical properties. Spencer and Hull have shown that both the tensile and shear strength depends on the winding angles [1]. Mistry has studied the mechanical behavior in particular bending and compression stresses of filament wound composite structures under hydrostatic pressure. The effects of winding angle were shown both experimentally and via finite elements analysis. The optimum winding angle was around 80 degrees for this coupled stress condition [2]. Filament winding on conical shapes is important for the production of aerodynamical composite structures. In the literature no study is published on the temporary response of filament angle to the changing machine velocity. Kessels and Akkerman have developed a numerical method to determine the local angles on complex shaped braided structures [3]. Zhang et al. have analyzed the kinematical properties [4] and mechanical properties [5] of cylindrical braiding. Nishimoto et al. have developed an analytical method to predict the response of filaments on cylindrical braiding [6].

THEORETICAL APPROACH

Cylindrical mandrel

In this section, the equations of angle formations will be determined by starting with a simple cylindrical mandrel and the equations for complex shapes will be derived from this model. The mechanism of winding angle formation for filament winding on a cylindrical mandrel with constant speeds is depicted in figure 1. The tangential angle α of the filament is determined by the cylinder radius r, angular velocity of the mandrel w_0 and lateral velocity of the filament guide v_0.

$$u_0 = r w_0 \tag{1}$$

$$\alpha = \tan^{-1}\left(\frac{r w_0}{v_0}\right) \tag{2}$$

If the angular velocity w_0 or the tangential velocity v_0 of the system is changed as a step function, it takes time for the filaments to adapt the new production conditions. This can be called as unstationary state of the system between two stationary conditions. After the new steady state is reached, the winding of filaments continues with constant angle.

The system response for the cylindrical filament winding to velocity changes can be analyzed by dividing the cross section of the cylinder with θ small angles (figure 2). For every turning of θ, the initial winding angle α_i approaches to the final winding angle α_f.

In figure 2 on the right side, the first differential step leads the filament to go to the point X_2 instead of point X_1. In this case, the triangles Y_2X_2Z and Y_2OC are similar, therefore:

$$\frac{|OC|}{|Y_2C|} = \frac{|X_2Z|}{|ZY_2|} \tag{3}$$

If the iterations of the Y points are numbered as a_i and a_{i+1}, the equation 3 can be constructed as:

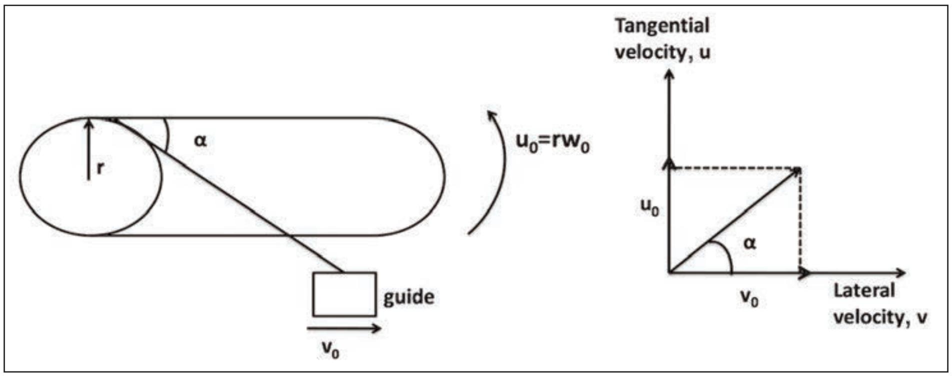

Fig. 1. Cylindrical model of filament winding with constant speeds

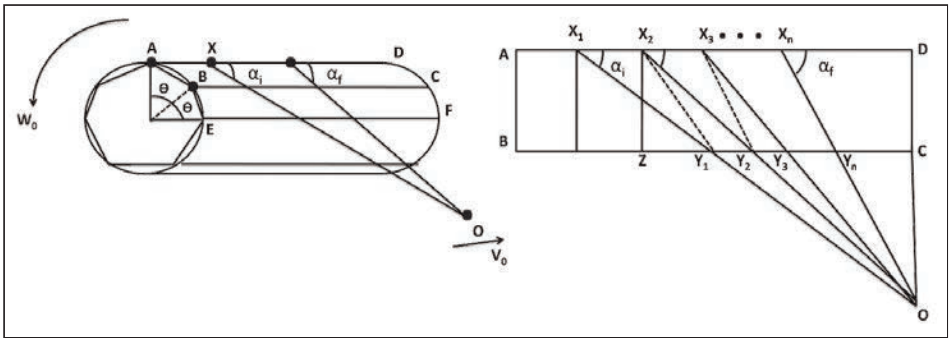

Fig. 2. Cylindrical Angle response to the velocity change

$$\frac{|OC|}{a_{i+1}} = \frac{r \cdot w_0 \cdot \Delta t}{a_i - a_{i+1} + v_f \cdot \Delta t}; \quad \Delta a = a_{i+1} - a_i \tag{4}$$

After dividing the right hand side of the equation with Δt:

$$\frac{|OC|}{r \cdot w_0}\left[-\frac{\Delta a}{\Delta t} + v_f\right] = a_{i+1}; \text{ where } \frac{\Delta a}{\Delta t} = \frac{da}{dt};$$

$$a_{i+1} = a(t); \quad \frac{r \cdot w_0}{v_f} = \tan\alpha_f \tag{5}$$

$$-\frac{|OC|}{r \cdot w_0} \cdot \frac{da}{dt} = a(t) - \frac{|OC|}{\tan\alpha_f} \rightarrow$$

$$\rightarrow \int \frac{da}{a(t) - \dfrac{|OC|}{\tan\alpha_f}} = \int \frac{-r \cdot w_0 \cdot dt}{|OC|} \tag{6}$$

The differential equation (equation 6) can be solved by separating variables and integrating afterwards.

$$a(t) = C_0 \cdot e^{-\frac{r \cdot w_0}{|OC|} \cdot t} + \frac{|OC|}{\tan\alpha_f} \tag{7}$$

The boundary values are:

$$a(0) = \frac{|OC|}{\tan\alpha_i}; \quad a(\infty) = \frac{|OC|}{\tan\alpha_f} \tag{8}$$

After inserting boundary values into equation 7:

$$a(t) = |OC| \cdot \left[(\tan\alpha_i)^{-1} - (\tan\alpha_f)^{-1}\right] \cdot e^{-\frac{r \cdot w_0}{|OC|} \cdot t} + \frac{|OC|}{\tan\alpha_f} \tag{9}$$

The time dependent function of $\alpha(t)$ according to the position change $a(t)$ can be written as:

$$\tan\alpha(t) = \frac{|OC|}{a(t)} \tag{10}$$

$$\alpha(t) = \tan^{-1}\left\{\left[\left[(\tan\alpha_i)^{-1} - (\tan\alpha_f)^{-1}\right] \cdot e^{-\frac{r \cdot w_0}{|OC|} \cdot t} + (\tan\alpha_f)^{-1}\right]^{-1}\right\} \tag{11}$$

Conical mandrel

Filament winding on conical mandrels is used in manufacturing of aerodynamic composite structures such as rocket nose. Due to the change of mandrel radius along the length of the mandrel, the circumferential velocity of the filament changes as well. Figure 3 demonstrates the main parameters of filament winding on a conical mandrel.

The radius r of cone is changing linearly along the length, which affects the circumferential velocity. Filament guide moves laterally with the velocity of v_0, however, the tangential lateral velocity of v_{tan} must be used to find the winding angle.

$$\cos\beta = \frac{L}{\sqrt{(R - r_0)^2 + L^2}} \tag{12}$$

$$\frac{\Delta r}{v_0 \cdot t} = \tan\beta = \frac{R - r_0}{L} \tag{13}$$

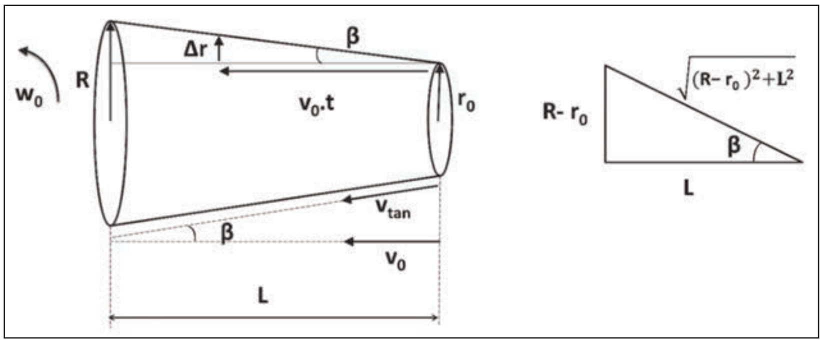

Fig. 3. Parameters on conical filament winding

$$\Delta r = v_0 \cdot t \cdot \frac{R - r_0}{L} \qquad (14)$$

$$r(t) = r_0 + \Delta r = r_0 + v_0 \cdot t \cdot \frac{R - r_0}{L} \qquad (15)$$

If the angular velocity w_0 and the lateral velocity v_{tan} are constant, the winding angle according to local axis on surface is:

$$\tan\alpha = \frac{r(t) \cdot w_0}{v_0} = \frac{\left[r_0 + v_0 \cdot t \cdot \frac{R - r_0}{L}\right] \cdot w_0}{v_0} \qquad (16)$$

If the lateral velocity v_0 is not constant and changed as a step function to v_f, then the differential equation similar to the equation 6 defines the time dependent response of the winding angle. The difference is; radius r is not constant any more as in equation 6, instead the expression in equation 15 must be used. Tangent α_f is also changing with time, but if the angle β is small, the change can be omitted and the $\tan\alpha_f$ can be taken as constant to solve the integral.

$$-\frac{|OC|}{\left[r_0 + v_{tanf} \cdot t \cdot \frac{R - r_0}{L}\right] \cdot w_0} \cdot \frac{da}{dt} = a(t) - \frac{|OC|}{\tan\alpha_f} \qquad (17)$$

$$a(t) = |OC| \cdot \left[(\tan\alpha_i)^{-1} - (\tan\alpha_f)^{-1}\right] \cdot e^{-\frac{w_0}{|OC|}\left[r_0 t + \frac{v_{tanf} \cdot (R - r_0)}{2L} \cdot t^2\right]} + \frac{|OC|}{\tan\alpha_f} \qquad (18)$$

$$\alpha(t) = \tan^{-1}\left\{\left[\left[(\tan\alpha_i)^{-1} - (\tan\alpha_f)^{-1}\right] \cdot e^{-\frac{w_0}{|OC|}\left[r_0 t + \frac{v_{tanf} \cdot (R - r_0)}{2L} \cdot t^2\right]} + (\tan\alpha_f)^{-1}\right]^{-1}\right\} \qquad (19)$$

In equation v_{tanf} is the final tangential lateral velocity after the change of lateral velocity. The initial winding angle α_i and final winding angle α_f are found according to equation 16 as followed in equation 20 and 21.

$$\alpha_i(t) = \tan^{-1}\left\{\frac{\left[r_0 + v_0 \cdot t \cdot \frac{R - r_0}{L}\right] \cdot w_0}{v_{tani}}\right\} \qquad (20)$$

$$\alpha_f(t) = \tan^{-1}\left\{\frac{\left[r_0 + v_f \cdot t \cdot \frac{R - r_0}{L}\right] \cdot w_0}{v_{tanf}}\right\} \qquad (21)$$

Paraboloid mandrel

Paraboloid mandrels can be used as heat shield or aerodynamic nose part for supersonic vehicles. Such as the approach of conical mandrels is derived from the cylindrical equations, same approach can be used to derive the paraboloid equations. The differential equation (equation 6) is taken and the radius expression of paraboloid is integrated, and then the equation is solved. Figure 4 shows the main parameters of paraboloid filament winding.

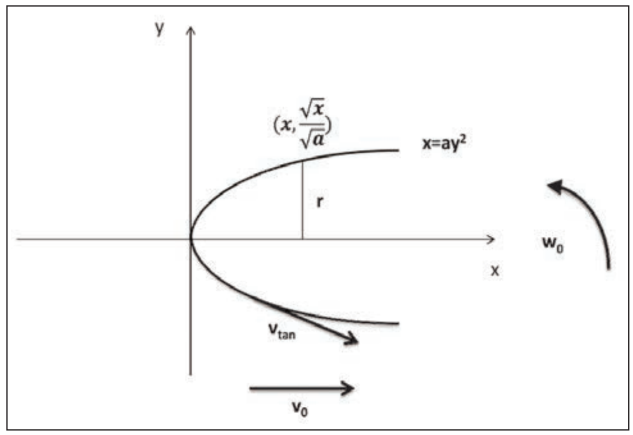

Fig. 4. Parameters on paraboloid filament winding

For the case of constant lateral guide velocity v_0 and angular velocity w_0:

$$r = y = \frac{\sqrt{x}}{\sqrt{a}};\ x = v_0 \cdot t;\ r(t) = \frac{\sqrt{v_0}}{\sqrt{a}} \cdot \sqrt{t} \qquad (22)$$

$$\tan\alpha = \frac{r \cdot w_0}{v_{tan}} = \frac{\sqrt{v_0}}{\sqrt{a}} \cdot \sqrt{t} \cdot \frac{w_0}{v_{tan}} \qquad (23)$$

The relation between the lateral filament guide velocity v_0 and the lateral velocity on the surface of the paraboloid v_{tan} is defined by the derivative of the parabola equation.

$$y = \frac{\sqrt{x}}{\sqrt{a}};\ \frac{dy}{dx} = \frac{1}{2\sqrt{ax}} = \tan\beta \qquad (24)$$

$$v_{tan} = \frac{v_0}{\cos\beta} \qquad (25)$$

Cos β in equation 25 can be found by drawing an imaginary right triangle by using the tan β expression from equation 24. The opposite edge of the right triangle is “1” and the adjacent edge is “$2\sqrt{ax}$”. The equation 25 becomes:

$$v_{tan} = \frac{v_0 \cdot 2\sqrt{ax}}{\sqrt{1 + 4ax}} \qquad (26)$$

The radius equation (eq. 22) is inserted into the differential equation (eq. 6).

$$-\frac{|OC|}{\frac{\sqrt{v_0}}{\sqrt{a}}\cdot\sqrt{t}\cdot w_0}\cdot\frac{da}{dt}=a(t)-\frac{|OC|}{\tan\alpha_f} \qquad (27)$$

$$a(t)=|OC|\cdot\left[(\tan\alpha_i)^{-1}-(\tan\alpha_f)^{-1}\right]\cdot e^{-\frac{2w_0\sqrt{v_{tanf}}\cdot t^{3/2}}{3\cdot|OC|\cdot\sqrt{a}}}+\frac{|OC|}{\tan\alpha_f} \qquad (28)$$

$$\alpha(t)=\tan^{-1}\left\{\left[\left[(\tan\alpha_i)^{-1}-(\tan\alpha_f)^{-1}\right]\cdot e^{-\frac{2w_0\sqrt{v_{tanf}}\cdot t^{3/2}}{3\cdot|OC|\cdot\sqrt{a}}}+(\tan\alpha_f)^{-1}\right]^{-1}\right\} \qquad (29)$$

The integration constants containing initial winding angle α_i and final winding angle α_f can be calculated via equations 30 and 31.

$$\alpha_i(t)=\tan^{-1}\left\{\frac{\left[\frac{\sqrt{v_0}}{\sqrt{a}}\cdot\sqrt{t}\right]\cdot w_0}{v_{tani}}\right\} \qquad (30)$$

$$\alpha_f(t)=\tan^{-1}\left\{\frac{\left[\frac{\sqrt{v_f}}{\sqrt{a}}\cdot\sqrt{t}\right]\cdot w_0}{v_{tanf}}\right\} \qquad (31)$$

RESULTS AND DISCUSSION

A cylindrical base model is assumed to see the time dependent response of filament winding angle to changing lateral filament guide velocity. The radius of the cylinder r is 10 cm, angular velocity is 10 rad/s, distance of filament guide to the mandrel |OC| is 20 cm, initial winding angle α_i is 30° and the final winding angle α_f is 60°. According to equation 11, figure 5 shows how the filament winding angle responds to a step-wise changing of velocity.

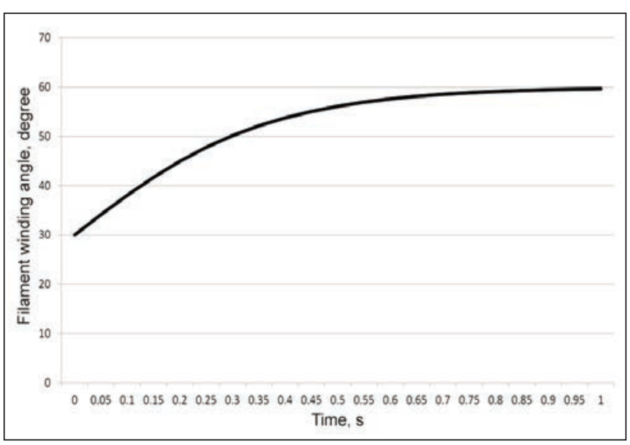

Fig. 5. Change of filament winding angle on cylindrical mandrel: 30°–60° base model

Figure 6 shows the effect of increased angular velocity from 10 rad/s of base model to 20 rad/s. As expected, the reaction of filament angle is faster and about half of the time elapses to reach the final angle compared to the base model of figure 5. Figure 7 shows similarly the effect of increasing mandrel radius from 10 cm to 30 cm. Increasing of mandrel radius has the same accelerated reaction effect as the increasing angular velocity.

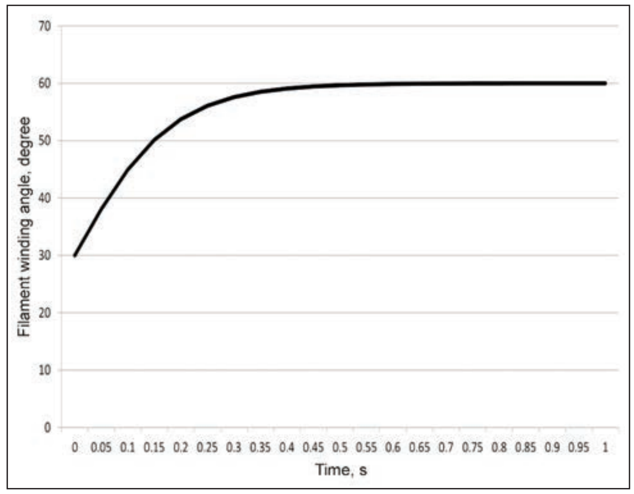

Fig. 6. Change of filament winding angle on cylindrical mandrel: 30°–60° with increased angular velocity *w*

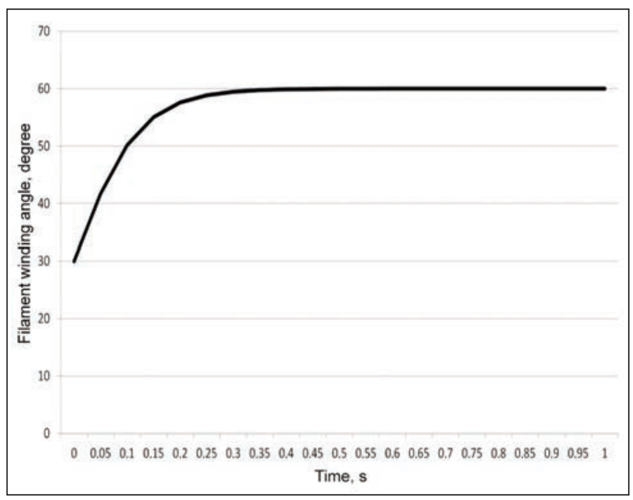

Fig. 7. Change of filament winding angle on cylindrical mandrel: 30°–60° with increased radius *r*

If the filament angle changes 30°–60° of base model is reversed to 60°–30°, the resulting curve is depicted in figure 8. The reaction time is a bit less compared to 30°–60° change. Changing from a higher winding angle to lower takes slightly less time than vice versa. A conical mandrel is assumed with parameters of narrow end radius 10 cm, large end radius R 20 cm, mandrel length 100 cm, angular velocity w 10 rad/s, final tangential velocity v_{tanf} 10 cm/s, distance of filament guide to the mandrel |OC| 20 cm, initial winding angle α_i 30° and the final winding angle α_f 60°. Figure 9 demonstrates the angle response curve, as the conicity of the mandrel is not high, the curve looks similar to base model cylindrical mandrel, however the calculated values are slightly different due to the equation 19.

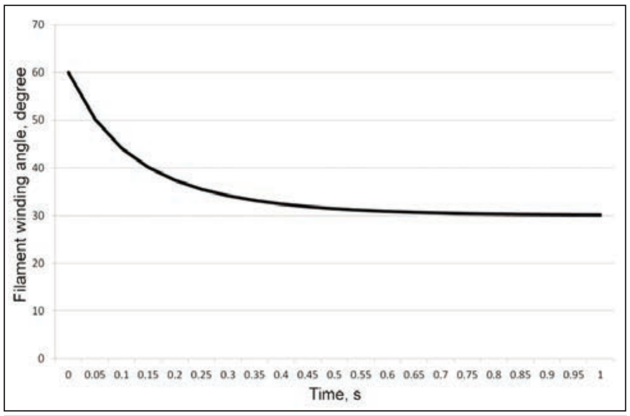

Fig. 8. Change of filament winding angle on cylindrical mandrel: 60°–30° base model

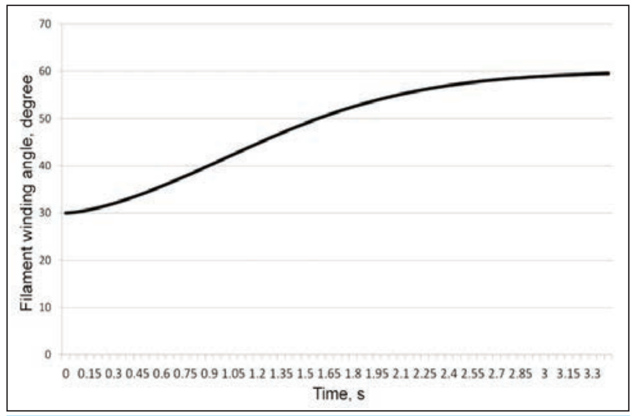

Fig. 10. Change of filament winding angle on paraboloid mandrel: 30°–60°

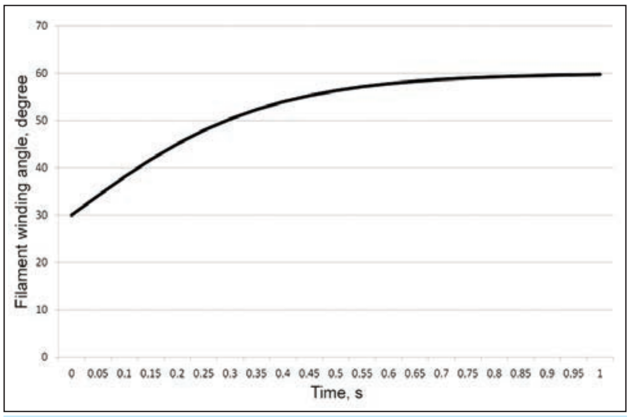

Fig. 9. Change of filament winding angle on conical mandrel: 30°–60°

Figure 10 shows the angle response curve on a paraboloid mandrel. The parameters are selected likewise to ease the comparison with previous models of figures 5–9. The angular velocity w is 10 rad/s, final tangential velocity v_{tanf} is 10 cm/s, distance of filament guide to the mandrel |OC| is 20 cm, *a* is 2 at the curve $x = 2y^2$, initial winding angle α_i is 30° and the final winding angle α_f is 60°. According to equation 29, figure 10 shows how the filament winding angle responds to a step-wise changing of velocity. The shape of the paraboloid flattens the reaction curve of winding angle.

The cylindrical, conical and paraboloid models all have the common property of circular cross-section. On the other hand, the elliptical mandrel yields a changing radius in the cross-section. The elliptic integral of type 2 (equation 36) does not have an analytical solution but it can only be approximated with a series expansion (equation 41). Due to the approximation, however, the time parameter "t" disappears from the equation and the responding character cannot be seen, instead if the angle is changing from 30°–60°, then the integral approaches to the mean value of 45°. Therefore, this method works only for mandrels with circular cross-sections, for other types of geometries a different approach is necessary to be developed.

CONCLUSIONS

An analytical approach is derived for the filament winding angle response on cylindrical, conical, paraboloid and elliptic cylindrical mandrels. Increasing of radius and angular velocity decreases the time elapsed to reach the final winding angle. Independent of the type of the mandrel, if the cross-section of the mandrel is circular, the method delivers applicable results. On the other hand, the method is not applicable to mandrels with cross-sections other than circular form because of the varying radius in the cross-section. A new method should be developed for mandrels with cross-sections of noncircular forms. This method provides an analytical calculation of winding angle for filament wound textile reinforced composites and structures.

REFERENCES

[1] Spencer, B., Hull, D., *Effect of winding angle on the failure of filament wound pipe*, In: Composites, 1978, 9, 4, 263–271

[2] Mistry, J., *Theoretical investigation into the effect of the winding angle of the fibres on the strength of filament wound GRP pipes subjected to combined external pressure and axial compression,* In: Composite Structures, 1992, 20, 2, 83–90

[3] Kessels, J.F.A., Akkerman, R., *Prediction of the yarn trajectories on complex braided preforms,* In: Composites, Part A. Applied Science and Manufacturing, 2002, 33, 8, 1073–1081

[4] Zhang, Q., Beale, D., Broughton, R.M., *Analysis of Circular Braiding Process, Part 1: Theoretical Investigation of Kinematics of the Circular Braiding Process,* In: Journal of Manufacturing Science and Engineering, 1999, 121, 3, 345–350

[5] Zhang, Q., Beale, D., Broughton, R.M., Adanur, S., *Analysis of Circular Braiding Process, Part 2: Mechanics Analysis of the Circular Braiding Process and Experiment,* In: Journal of Manufacturing Science and Engineering, 1999, 121, 3, 351–359

[6] Nishimoto, H., Ohtani, A., Nakai, A., Hamada, H., *Prediction Method for Temporal Change in Fiber Orientation on Cylindrical Braided Preforms,* In: Textile Research Journal, 2009, 80, 9, 814–821

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Further evidence on efficiency of Bahrain Bourse: A high challenge for other industries

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ABSTRACT – REZUMAT

Further evidence on efficiency of Bahrain Bourse: A high challenge for other industries

The purpose of the present study is to provide further evidence of the weak form efficiency of the Bahrain Bourse. The research methodology is based on daily closing index values of the Bahrain Bourse from 2011 to 2015 in order to test the efficiency of the stock market while runs test, Autocorrelation Function, and advance tools such as ARCH and GARCH models and Hurst Index to provide further evidence of the weak form efficiency of the Bahrain stock market. For instance, a volatile and inefficient stock market has a negative impact on textile and apparel industry in the Kingdom of Bahrain, which is one of the most prosperous and attractive industries in the country. The empirical results revealed that Bahrain stock market does not follow normal distribution and the successive price changes are not independent. Further, ARCH effect is significant and indicative of a time-varying conditional volatility. There is an arbitrage opportunity and extreme mispricing in the Bahrain stock market as indicated by the GARCH (1, 1) model. The results of the Hurst exponent also confirm the inefficiency of the market. The results of these tests are consistent indicating that the Bahrain stock market is inefficient.

Keywords: *Efficient Market Hypothesis (EMH), ARCH effect, GARCH models, Hurst Index*

Cercetări empirice extinse privind eficiența pieţelor bursiere din Bahrain: O provocare majoră pentru celelalte industrii

Scopul prezentului studiu de cercetare este de a oferi dovezi suplimentare despre eficiența slabă a Bursei din Bahrain. Metodologia de cercetare se bazează pe valorile zilnice de închidere ale indicelui bursier principal al Bursei din Bahrain din 2011 până în 2015 pentru a testa eficiența pieței bursiere. În acest sens se aplică anumite teste, funcția de autocorelare și instrumente avansate precum modelele ARCH și GARCH, dar și indicele Hurst pentru a furniza în continuare dovada eficienței slabe a pieței bursiere din Bahrain. De exemplu, o piață bursieră volatilă și ineficientă are un impact negativ asupra industriei textile și de îmbrăcăminte din Bahrain, care reprezintă una dintre cele mai prospere și atractive industrii din țară. Rezultatele empirice au arătat că piața bursieră din Bahrain nu urmează distribuția normală, iar modificările succesive ale prețurilor nu sunt independente. În plus, efectul ARCH este semnificativ și indică o volatilitate condițională care variază în timp. Există o oportunitate de arbitraj și anomalii extreme privind prețurile pe piața bursieră din Bahrain, după cum indică modelul GARCH (1, 1). Rezultatele empirice privind indicele Hurst confirmă, de asemenea, ineficiența pieței. Rezultatele acestor teste sunt consistente, indicând faptul că piața bursieră din Bahrain este ineficientă.

Cuvinte-cheie*: ipoteza piețelor eficiente (EMH), efectul ARCH, modele GARCH, indicele Hurst*

INTRODUCTION

The Efficient Market Hypothesis (EMH) is a fundamental theory in finance. The EMH relates to how quickly and accurately the market reacts to new information that enters the market through economic reports, company announcements, political statements, or public surveys. If the market is informationally efficient then security prices adjust rapidly and accurately to new information. According to this hypothesis, security prices reflect fully all the information that is available in the market. Since all the information is already incorporated in prices, a trader is not able to make any excess returns. Thus, EMH puts forth that it is not possible to outperform the market through market timing or stock selection. The efficiency of Bahrain stock market represents a high challenge for other industries. For instance, textile and apparel producers play a very important role in the Kingdom of Bahrain since this industry has significant growth potential. This complex topic will be considered for a future extensive research study.

The origins of the EMH can be traced to Bachelier's doctoral thesis "Theory of Speculation" in 1900 and seminal paper titled 'Proof That Properly Anticipated Prices Fluctuate Randomly' by Nobel Laureate Paul Samuelson in 1965 [1]. However, it was Eugene Fama who coined the term EMH in 1970. He advocated that in efficient market, securities prices fully reflect all the information. If capital markets are efficient, investors cannot expect to achieve superior profits by adopting a certain trading strategy. According to Fama [2], there are three forms of efficiency, i.e. weak form, semi-strong form and strong form. First, EMH in its weak form states that all information impounded in the past price of a stock is fully reflected in current price of the stock. Therefore, information about recent or past trend in stock prices is of no use in forecasting future price. Undoubtedly, it rules out the use of technical analysis in predicting future prices of securities. The semi-strong form takes the information set one step further and includes all publicly available information. There is plethora of information of potential interest to investors. Besides past stock prices, information such as announcement of earnings, bonus, dividends, mergers and acquisitions, change of CEO and so on are available through annual reports, economic reports, brokerage firm recommendations, and investment advisory letters.

According to the semi-strong form of the EMH, analysing annual reports or other published data with a view to make profit in excess is not possible because market prices had already adjusted to any good or bad news contained in such reports as soon as they were revealed. The EMH in its strong form states that current market price reflects all – both public and private information and even insiders would find it impossible to earn abnormal returns in the stock market. In his work, Fama, sustained the existence of the efficiency of the markets at least in weak form, affirming that the market is a martingale, since the good respect of the price of the title to the time $t+1$ is the price of the same to the time t. A martingale is a sequence of random variables for which, at a particular time in the realized sequence, the expectation of the next value in the sequence is equal to the present observed value even given knowledge of all prior observed values. If S_t (stock price) is a stochastic process, F is a is a filtration of the underlying probability space and for each t S_t is measurable in F_t: $\mathbf{E}(S_{t+1} \mid F_t) = S_t$; where $\mathbf{E}(S_{t+1} \mid F_t)$ is the conditional expectation. Although financial literature supports the theory of market efficiency, in reality the market is not perfectly efficient. Anomalies do exist and there are investors and traders who outperform the market. The EMH thus has very important implications for both investors and authorities that regulate and control the market.

LITERATURE REVIEW

In the literature, due to the huge implications of the EMH, the operations of financial markets is still constantly been examined by the academicians and practitioners. Over a period of time a number of researchers have examined the existence of the EMH theory in various developed and undeveloped markets with varying results [3, 4]. Chan et al. [5] analyzed the weak form hypothesis in Hong Kong, South Korea, Singapore, Taiwan, Japan, and the United States [4]. Their findings indicate that stock prices in these major Asian markets and the United States are efficient in the weak form. Lo and MacKinlay [6] use a variance ratio test to analyze the weekly returns of both the equally weighted and value weighted CRSP indices and find that stock prices do not follow a random walk. Iqbal and Mallikarjunappa [7, 8] studied Indian stock market and found that Indian stock market is not efficient in weak and semi-strong form. Dahel and Laabas [9] investigated the efficiency of Bahrain, Kuwait, Saudi Arabia and Oman belonging to Gulf Cooperation Council equity markets. They investigated the observations from year 1994 to 1998. They concluded that the stock market of Kuwait is strongly in support of weak form of efficiency and other markets reject the weak form of the EMH. The reason seems to be the strong market characteristics of the Kuwait in comparison to the other three markets.

The empirical findings of Abeysekera [10] and Abraham et al. [11] reject the hypothesis of weak form efficiency for stock markets in Sri Lanka, Bahrain Kuwait, and Saudi Arabia. Rao and Shankaraiah [12] investigated the stock market efficiency and endeavoured to develop strategies for Gulf Co-operation Council (GCC) stock markets. They concluded that these markets were neither developed nor informationally efficient and recommended that apart from better networking, co-operation and the creation of investor awareness, the simultaneous listing of GCC countries to reduce the thin trading problem need to be implemented. Moustafa [13] examined the weak form efficiency of United Arab Emirates (UAE) stock market by observing the behaviour of stock prices. The result of UAE stock market showed weak form efficiency. Sharma [14] in his study, tested whether daily returns series of Gulf Co-operation Council (GCC) stock markets are an approximation of normal distribution or not. Saudi, Qatar, Kuwait, and Oman stock market indices were examined by him in his study. Chi-square, Kolmogorov-Smirnov test, Autocorrelation Function and Partial Autocorrelation Functions were applied to test for randomness. The results revealed that the distribution of daily returns on these markets significantly deviated from the normal distribution during the study period.

Elango and Hussein [15] examined market efficiency across the seven stock markets in the GCC countries. Using daily indices data from October 2001 to October 2006 and Kolmogorov–Smirnov test, they reject the null hypothesis that the returns follow a normal distribution for all the seven markets. Again, based on runs test for randomness, they find that the hypothesis pertaining to random walk and weak-form efficiency of the GCC markets is rejected for all the seven markets during the study period. Smith [16] conducted research for weak form Efficient Market Hypothesis in five Middle East stock markets by applying multiple variance ratio test to the data. For Israeli, Lebanese and Jordanian markets followed the random walk, while stock markets of Kuwait, and Oman random walk hypothesis were rejected. Asiri [17] measured the performance of the Bahrain Stock

Exchange (BSE) by applying the Dickey Fuller unit root tests, the ARIMA model, and exponential smoothing techniques. The results showed evidence that stock returns followed a random walk process with no drift and trend.

Al Kharusi and Weagley [18] studied the Weak form efficiency in Muscat Securities Market from 2007 to 2011 by using the daily stock indices. The parametric test of serial correlations was used and rejected the Efficient market hypothesis by researchers in all the three periods of pre-crisis during crisis and post crisis in Muscat Securities Market. Awan and Subayyal [19] studied six Stock Exchanges in Gulf (Oman, UAE, Kuwait, Saudi Arabia, Bahrain and Qatar) for the period 2011 to 2015. The results of the Auto Correlation and Runs test provide evidence that the stock prices in all the Gulf Markets are not following the random walk model and the significant auto correlation coefficient at different lags has rejected the null hypothesis of that the market is efficient in its weak form. In order to test the efficiency at the weak-form several statistical techniques have been used such as runs test, unit root test, and autocorrelation tests. Sharma and Kennedy [20], Karemera et al. [21] and Abraham et al. [11] adopted run test, while Mookerjee and Yu [22], Groenwold et al. [23] and Seddighi and Nian [24] conducted both run test and unit root test in their studies. Volatility in the stock market of the developed markets has been studied extensively. The seminal work of Engle [25] on Autoregressive Conditional Heteroscedasticity (*ARCH*) model on UK inflation data and its Generalized form GARCH (*Generalized ARCH*) by Bollerslev [26] have led to using these models to form the characteristics of financial time series.

DATA AND METHODOLOGY

There are very few studies that have made an attempt to test the efficiency of the Bahrain stock market. Gharaibeh and Hammadi [27] tested the day of the week effect, Hawaldar [28] empirically tested the capital asset pricing on Bahrain Bourse. Hawaldar [29] studied the reaction of Bahrain Bourse to announcement of annual financial results. Hawaldar [29] examined the cross-sectional variation of portfolio returns. Hawaldar et al. [30] investigated the month of the year effect on selected commercial banks and service sector companies listed on the Bahrain Bourse. Asiri [17] applied the Dickey Fuller unit root tests, the ARIMA model and exponential smoothing techniques to measure the performance of Bahrain Stock Market. This study attempts to study the weak form of efficiency of the Bahrain stock market using statistical tools such as the runs test, autocorrelation function, ARCH effect test and GARCH (1,1) model, in the last part we add the estimation the Hurst Index through the R/S method. The present study is unique as it examines the volatility in Bahrain stock market by using the ARCH and GARCH (1,1) model. ARCH Effect and GARCH (1,1) tests are employed to examine the weak form efficiency of Bahrain stock market. In the last part we introduced the estimation of the Hurst Index. Through the index, it is possible to measure the market's efficiency. According to the financial literature, if the market is efficient, the price variations follow a Brownian Geometric motion (BGm) with $H = 0.5$, when the index is different form 0.5 the market loses the efficiency and theoretically is possible to beat it. Hurst index gives an idea of how the price increments are related (negatively or positively). Besides Runs test and Autocorrelation function, the study uses advance tools such as ARCH, GARCH models and Hurst Index to provide further evidence of the weak form efficiency of the Bahrain bourse.

Objectives of the study

- To analyse if observed price series follow normal distribution;
- To examine if share price movements are independent and random;
- To examine the autocorrelation of observed price series;
- To investigate the volatility clustering of the observed price series;
- To examine if the price variation follows a Geometric Brownian motion (GBm) (are randomly or there is a persistence/anti-persistence in the time series).

Hypotheses of the study

H_1: Successive price changes are independent and move randomly;

H_2: There is white noise effect;

H_3: There is no autocorrelation in price series;

H_4: The exogenous variable in the mean equation for GARCH model is insignificantly different from zero;

H_5: There is non-volatility clustering in the observed price series;

H_6: The estimation of the Hurst Index.

Research methodology

The data used for the study is the daily closing index of the Bahrain Bourse from 2011 to 2015. To test the weak form of market efficiency, several methodologies are available. They include Runs test, ARCH effect, GARCH (1, 1) model and the Autocorrelation Function.

Runs Test

Runs test is used to analyze the serial independence of the observed price series. The runs test is calculatedby using the following formula:

$$\mu = \frac{2n_1n_2}{n_1 + n_2} + 1 \quad (1)$$

where μ is the mean number of runs, n_1 – number of positive runs, n_2 – number of negative runs.

The variance of the expected number of runs can be calculated by using following formula:

$$\sigma^2 = \frac{2n_1n_2(2n_1n_2 - n_1 - n_2)}{(n_1 + n_2)^2(n_1 + n_2 - 1)} \quad (2)$$

The standard normal Z-statistic used to conduct a run test is given by:

$$Z = \frac{r - \mu}{\sigma^2} \quad (3)$$

where r is the number of runs (actual sequence of counts).

Autocorrelation Function

Autocorrelation is defined as a mathematical representation of the degree of similarity between a given time series and a lagged version of itself over successive time intervals. The Ljung – Box Q – statistic and their p values are used in the study to test the null hypothesis that there is no autocorrelation up to order k and is computed as:

$$\tau_k = \left[\sum_{t=k+1}^{T}((Y_t - \bar{Y})(Y_{t-k}))/(T-K)\right] \Big/ \left[\sum_{t=1}^{T}\frac{(Y_t-\bar{Y})^2}{T}\right] \quad (4)$$

$$Q_{LB} = T(T+2)\sum_{j=1}^{k}\frac{r_j^2}{T-j} \quad (5)$$

where r_j is the j^{th} autocorrelation and T – the number of observations.

ARCH model

The Arch effect has its roots in time varying conditional volatility, so:

$$\sigma_t^2 = \sum(X_t - \bar{X})^2 \quad (6)$$

where σ_t^2 is the conditional variance and $\bar{X}$ – conditional mean.

The ARCH models are based on the following formula:

$$h_t = w + \alpha_1\varepsilon_t^2 + \alpha_2\varepsilon_{t-1}^2 + \ldots + \alpha_p\varepsilon_{t-p}^2 \quad (7)$$

where h_t is the conditional variance.

The LM-ARCH test has:

$$\begin{cases} H_0\text{: coefficients} = 0 \\ H_1\text{: heteroskedasticity} \end{cases} \quad (8)$$

where $TR^2 \sim \chi^2$ is the statistic used, the test is constructed by regressing the squared residual on p past values.

GARCH (1,1) model

Under the GARCH model, the forecasts of time-varying variance depend on the lagged variance of any asset. This model is estimated on two specifications, that is, the conditional mean equation and conditional variance equation.

The basic GARCH (1, 1) is expressed as:

$$r_t = \mu + \phi r_{t-1} + \epsilon_t \quad (9)$$

$$\epsilon_t / \phi_{t-1} \sim N(0, h_t) \quad (10)$$

$$h_t = k + \alpha\epsilon_{t-1}^2 + \beta h_{t-1} \quad (11)$$

where $\alpha+\beta$ measures the volatility clustering, equation 9 is the conditional mean equation and equation 11 is the conditional variance equation. In the mean equation, the exogenous variable ϕ should be insignificantly different from zero, that is, $\phi = 0$ to accept weak-form market efficiency. If the value of $\alpha+\beta$ is close to 1 it is assumed that there is a high-persistence volatility clustering, and this indicates market inefficiency.

The following table presents the descriptive statistics for the Bahrain Index for the period 2011 to 2015. The descriptive statistics presents the distribution of observed price series. It can be observed that the frequency distribution for all the years is not normal. A distribution is normally distributed if the skewness is 0 and the kurtosis is 3. The results show that the

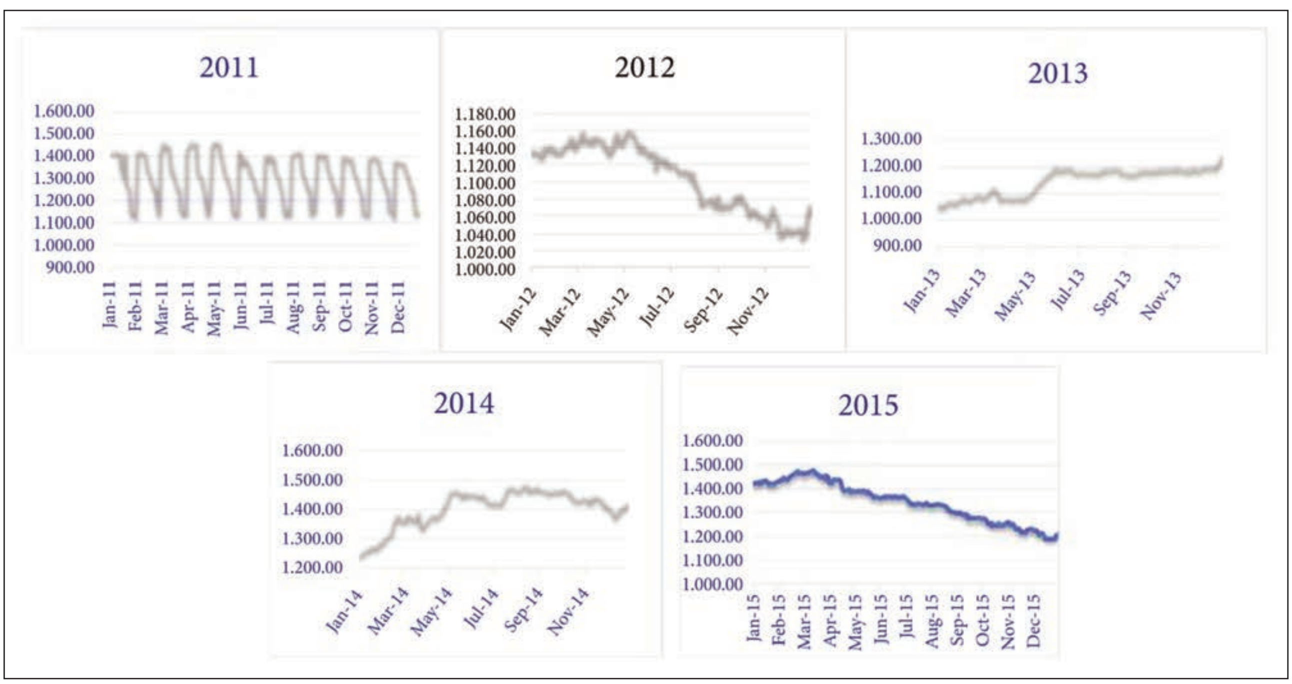

Fig. 1. The trend of Bahrain Index for the period from 2011 to 2015

values of skewness and kurtosis are not 0 and 3 for all the years. Thus, it can be inferred that the observed values are not normally distributed, and the distribution does not follow random walk. The trend in the mean values shows fluctuations in the movement of the index. The average index level was 1313.23 in 2011. The level dipped in 2012. In 2013, the index raised marginally while in 2014 it reached a peak of 1414.83. The index could not sustain this rise leading to a decline in 2015. The standard deviation of the index is the highest in 2011 at 107.65 signalling high volatility. The year 2012 records a low standard deviation of 38.44 indicating stability in the index.

Table 1

DESCRIPTIVE STATISTICS					
Parameters	**2011**	**2012**	**2013**	**2014**	**2015**
Mean	1313.23	1110.03	1156.93	1414.83	1346.97
Standard Error	6.88	2.44	3.26	3.98	5.30
Median	1330.03	1124.45	1187.47	1435.36	1362.53
Mode	1261.04	1134.61	1085.40	1425.62	1390.26
Standard Deviation	107.65	38.44	51.28	62.57	82.97
Sample Variance	11587.84	1477.28	2629.43	3914.94	6884.24
Kurtosis	–1.26	–1.36	–1.42	0.27	–1.16
Skewness	–0.32	–0.40	–0.54	–1.09	–0.19
Range	341.89	126.89	193.87	246.05	293.35
Minimum	1133.21	1035.30	1054.99	1247.98	1189.53
Maximum	1475.10	1162.19	1248.86	1494.03	1482.88
Sum	321741.04	275287.58	285760.67	349462.51	330008.04
Count	245.00	248.00	247.00	247.00	245.00

The above table depicts the output of the runs test for the years 2011 to 2015. Runs test is used to find the serial independence of the observed prices. If the succeeding price variation is independent to each other, the market is said to be efficient. The p-values of the runs test clearly show that the successive price series for all the years are statistically significant at 5% level of significance. The null hypothesis, i.e., the succeeding price changes are independent and move randomly is rejected. Hence the study concludes that the successive price changes are not independent. This indicates that the market is inefficient. Thus, the Bahrain market does not exhibit weak form efficiency. The results show that the investors can predict the market returns based on historical information Table 3 shows that p-value is less than 0.05 level of significance, hence the study rejects the null hypothesis and concludes that there is no white noise effect for the years from 2011 to 2015.

Table 4 presents the results of the ARCH test. The *p* value is less than 0.05, the level of significance for all the years. The ARCH effect is significant and indicative of a time –varying conditional volatility and, as a result, the presence of a fat-tailed distribution (i.e. excess kurtosis > 0. Autoregressive

Table 2

RUNS TEST										
Year	**Mean**	**R**	**n_0**	**n_1**	**n**	**E(R)**	**Var(R)**	**StDev(R)**	**Z**	**p-value**
2011	1313.23	24	106	139	245	121.278	58.797	7.668	–12.686	0.000*
2012	1110.03	4	104	144	248	121.774	58.565	7.653	–15.390	0.000*
2013	1156.93	2	95	152	247	117.923	55.098	7.423	–15.617	0.000*
2014	1414.83	6	93	154	247	116.968	54.197	7.362	–15.073	0.000*
2015	1346.97	2	117	128	245	123.253	60.752	7.794	–15.556	0.000*

Note: * 95% level of significance

Table 3

WHITE-NOISE TEST				
Year	**Score**	**C.V.**	**P-value**	**5%**
2011	161.03	3.84	0.000	FALSE
2012	245.82	3.84	0.000	FALSE
2013	241.12	3.84	0.000	FALSE
2014	240.15	3.84	0.000	FALSE
2015	243.54	3.84	0.000	FALSE

Note: * P-value is less than 5% we can reject the null hypothesis, there is no white-noise effect

Table 4

ARCH EFFECT TEST				
Year	**Score**	**C.V.**	**P-Value**	**5%**
2011	162.02	3.84	0.000	TRUE
2012	245.82	3.84	0.000	TRUE
2013	240.94	3.84	0.000	TRUE
2014	240.44	3.84	0.000	TRUE
2015	243.62	3.84	0.000	TRUE

Table 5

THE RESULTS OF ARMA (1,1) AND GARCH (1,1) MODELS									
Year	**ARMA (1,1)**				**GARCH (1,1)**				
	μ	φ_1	θ_1	σ	μ	α_0	α_1	β_1	$\alpha_1+\beta_1$
2011	1313.23	0.000	0.000	107.43	1313.23	318560.78	0.41	0.41	0.82
2012	1110.03	0.000	0.000	38.36	1110.03	10750.03	0.50	0.50	0.99
2013	1156.93	0.000	0.000	51.17	1156.93	5353.35	0.50	0.50	0.99
2014	1414.83	0.000	0.000	62.44	1414.83	0.00	0.50	0.50	1.00
2015	1346.97	0.000	0.000	82.80	1346.97	12268.11	0.50	0.50	0.99

Moving-Average (ARMA) models form a class of linear time series models that helps to detect time varying phenomenon in the conditional volatility.

Table 5 presents the results of ARMA (1,1) and GARCH (1,1) models. The ϕ_1 parameters in the mean equation are significant for all the years. The null hypothesis that the exogenous variable in the mean equation for GARCH model is significantly different from zero for these periods is rejected. The sum of ARCH (1,1) and GARCH (1,1) is 1 in year 2014 and very close to 1 for the other years. This indicates that the observed price series are highly volatile. Thus, null hypothesis that there is none volatility clustering in observed price series is rejected. The GARCH (1,1) model result shows that there is an arbitrage opportunity and extreme mispricing in the Bahrain stock market.

Autocorrelation test measures the relationship between the values of a random variable at time *t* and its value in the previous period. This is used to test the dependence/independence of random variables in an observed price series. The test is performed by taking 12 lags of the daily log return of the Bahrain index. The result of autocorrelation and partial autocorrelation is presented in table 6. The autocorrelation values for the year 2011 ranges from negative value of 0.045 to a high positive value of 0.806 in lag 1. This indicates that there is independence of random variables in observed price series. The years 2012 to 2015 displays high positive correlation in the lagged values. This signals that the market is inefficient in the weak form.

Efficient Market Hypothesis and Hurst Index

The basic idea of the Efficient Market Hypothesis is that the price variations follow a random walk (Bachelier).The random walk hypothesis is a financial theory stating that stock prices follow a random process and there are not predictable. From the mathematical point of view, the random walk is given by the equation: $P_t = P_{t-1} + \varepsilon$ where ε is a white noise (*WN*) ~ $(0,\sigma^t 2)$, while the value attended of the equation of which above it is equal to P_{t-1}. The Brownian motion (Bm) is the extension of the random walk in continuous time (De Moivre Laplace Central Limit Theorem*)*. From the studies of Fame and those of Sharpe, the conclusion can be drawn that the evolution of the price of a financial tool is essentially casual and therefore the movements of the same (and also of the outputs) don't follow any regularity but they would follow a trial stochastic. In fact, prices move second a Levy's process *(*Levy 1948*)*. It is

Table 6

CORRELOGRAM ANALYSIS										
Lag	**2011**		**2012**		**2013**		**2014**		**2015**	
	ACF	**PACF**	**ACF**	**PACF**	**ACF**	**PACF**	**ACF**	**PACF**	**ACF**	**PACF**
1	0.806	0.813	0.990	0.995	0.982	0.995	0.980	0.980	0.991	1.001
2	0.605	–0.123	0.981	0.060	0.967	0.062	0.958	–0.156	0.981	0.002
3	0.392	–0.162	0.972	0.014	0.952	–0.077	0.936	–0.059	0.970	–0.026
4	0.173	–0.169	0.961	0.046	0.935	–0.076	0.913	–0.049	0.959	0.008
5	–0.045	–0.185	0.949	0.051	0.920	–0.061	0.892	0.081	0.948	0.003
6	–0.223	–0.118	0.939	0.048	0.905	–0.148	0.871	–0.019	0.936	–0.005
7	–0.362	–0.110	0.928	0.063	0.891	0.096	0.849	–0.014	0.924	–0.005
8	–0.475	–0.170	0.917	0.042	0.877	0.016	0.829	0.019	0.912	0.048
9	–0.531	–0.094	0.907	–0.003	0.864	0.041	0.809	–0.022	0.900	0.108
10	–0.567	–0.193	0.899	0.105	0.850	–0.067	0.787	–0.065	0.888	0.049
11	–0.571	–0.179	0.888	–0.043	0.836	0.017	0.765	0.059	0.877	–0.128
12	–0.530	–0.163	0.877	–0.069	0.823	0.002	0.744	–0.058	0.865	–0.005

a **stochastic process** with independent, stationary increments, the most famous Levy's process is the Brownian motion (Bm).The Bm in the financial markets is compatible, because ensure the randomly of the price changes. This is in perfect tune with the Efficient Market Hypothesis (EMH). The Bm is more used in the financial literature (EHM, option pricing ...). In continuous time, the standard Brownian Motionis defined by means of the following properties:

- $W(0) = 0$;
- $W(t)$ is continuos in t, with probability 1;
- $W(t)$ has stationary and independent increments, $W(t_1) - W(t)$ is independent and form a stationary sequence;
- $W(t_2) - W(t_1) \sim N(0, t_2 - t_1)$;
- Martingale Property;
- Non differentiability of $W(t)$;
- Brownian Motion Standard and the Geometric Bm are a Markov process.

A non-negative variation of the Brownian motion has to be introduced: it is called Geometric Brownian motion (GBm), the GBm ensures no price negativity, given $S(t)$ a price of asset, we have:

$$\begin{gathered} S(t) = S_0 * \exp(\mu t + \sigma W(t)); \\ \log[S(t)] = S_0 + \log(\mu t + \sigma W(t)); \\ \log(\mu t + \sigma W(t)) = \log S(t) - \log S(0) = \log \frac{S_t}{S_0} \end{gathered} \quad (12)$$

where μ is the drift, σ – the coefficient of dispersion, $W(t)$ – the Bm.

The covariance of the Bm is:

$$\begin{gathered} \text{cov}(B(t), B(s)) \text{ for each } s, t \geq 0; \\ \text{cov}(B(t), B(s)) = E(B(t)B(s)) = \min(t,s) \end{gathered} \quad (13)$$

The Brownian geometrics' motion is used for three fundamental aspects:

- *It excludes the negativity of the prices.*
- *It is conforming to the hypothesis of the principle of arbitrage (compatible with EMH).*
- *The SDE is resolvable through the Ito's lemma*.

The fractional Brownian motion (fBm), is a generalization of Bm. Unlike classical Brownian motion, the increments of fBm do not need be independent. The covariance of this motion is:

$$E\left[B^H(t)\, B^H(s)\right] = \frac{1}{2}\left(t^{2H} + s^{2H} - |t-s|^{2H}\right) \quad (14)$$

where H is a real number in $(0, 1)$, called the **Hurst index** or Hurst parameter associated with the fractional Brownian motion. The Hurst exponent describes the raggedness of the resultant motion. The value of H determines what kind of process the fBm is:

- if $H = 1/2$ then the process is in fact a **Brownian motion (*random process compatible with EMH*)**;
- if $H > 1/2$ then the increments of the process are positively **correlated**;
- if $H < 1/2$ then the increments of the process are negatively correlated.

Also, we estimated the Hurst Index, with R/S (Rescaled Range) method, according to the Brownian motion Theory when the *markets are efficient* the Hurst Index is 0.5. R/S method was introduced by Harold Hurst, interested in determining the optimum dam sizing for the Nile river, he observed that the flow of water (random variable) exhibited some form of dependence. For a set of observations (X_i), we define Y_n and σ^2 as the partial sum and the sample variance, subsequently the Rescaled Range is:

$$R/S = \frac{1}{\sigma_n}\left[\max\left(Y_i - \frac{i}{n} Y_n\right) - \min\left(Y_i - \frac{i}{n} Y_n\right)\right] \quad (15)$$

Hurst identified the following relation: $E(R/S) \sim c_2 * n^H$; where H is the Hurst exponent and c is finite, independent of n. The graphical approach consists in: $\log(R/S) = \log c_2 + H * \log n$; note that H is the slope of the regression.

CONCLUSIONS

The current study examines the weak form efficiency of the Bahrain stock market. The study period is from 2011 to 2015. The weak form efficiency of the market is tested using runs test, autocorrelation test, ARCH and GARCH (1,1) models. The study reports that the Bahrain stock market does not follow normal distribution and the successive price changes are not independent. Further, ARCH effect is significant and indicative of a time-varying conditional volatility. There is an arbitrage opportunity and extreme mispricing in the Bahrain stock market as indicated by the GARCH (1,1) model. High positive correlation is observed in the price series. All the above results indicate that the Bahrain stock market is inefficient in its weak form. In fact, the results of the Hurst exponent confirm the inefficient of the market, the index for the period (2011–2015) is 0.61. The dependence of the events (log-returns) is called Long Range. In this case it is more likely that a positive(negative) trend is followed by another positive (negative), in other words in the Bahrain stock market time series there is a persistence (this result is consistent with the high positive correlation). Regarding the Hurst index, the estimate obtained with R/S method is very variable. The Hurst index estimator varies with the size of the sample of observations.

Many authors propose other method (Wavelet, AMBE). The dependence of the price variations and the value of the Hurst Index give us an idea of the persistence of the time series. In fact, how to show before, the market is not randomly, and there is an arbitrage opportunity through the strategies based on market trends (negatively or positively). This result is consistent with those reported in past studies [16, 18, 19]. A variety of previous empirical studies have confirmed the inefficiency of other emerging stock markets [31–34]. The inefficiency suggests that the investors have good opportunities to gain abnormal profits from analysis of the past prices through the individuation of the trends (bullish or bearish). Even if, the EMH remains one of the best famous theory in the financial topics, there are many factors that depart the market from efficiency. In particular, the individuals do not have the same set of information about the stock, and they are not fully rational how to speculate in the Neoclassical theories (CAPM, Markowitz diversificatio and so on). These aspects have led to the emergence of new the approach „behavioural finance" with Kahnmean and Tversky (Prospect Theory). Ejaz et al. [35] suggested that emerging stock markets such as Bahrain Bourse offer a much wider range of portfolio diversification opportunities compared to developed stock markets.

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REFERENCES

[1] Samuelson, P.A., *Proof that properly anticipated prices fluctuate randomly*, In: Industrial Management Review, 1965, 6, 2, 41–49

[2] Fama, E.F., Efficient Capital Markets: A Review of Theory and Empirical Work, Journal of Finance, 1970, 25(2), 383–417.

[3] Iqbal, T.H., Mallikarjunappa, T., Efficiency of Stock Market: A Study of Stock Price Responses to Earnings Announcements. LAP Lambert Academic Publishing Company, 2011, Germany.

[4] Ananzeh, I.E., *Testing the Weak Form of Efficient Market Hypothesis: Empirical Evidence from Jordan*, International Business and Management, 2014, 9, 2, 119–123

[5] Chan, K.C., Gup, B.E., Pan, M.-S., *An Empirical Analysis of Stock Prices in Major Asian Markets and the United States*, In: The Financial Review, 1992, 27, 2, 289–307

[6] Lo, A.W., MacKinlay, A.C., *Stock market prices do not follow random walks: Evidence from a simple specification test*, In: The Review of Financial Studies, 1988, 1, 1, 41–66

[7] Iqbal, T.H., Mallikarjunappa, T., *A Study of Efficiency of the Indian Stock Market*, In: Indian Journal of Finance, 2010, 4, 5, 32–38

[8] Iqbal, T.H., Mallikarjunappa, T., *An Empirical Testing of Semi-Strong Form Efficiency of Indian Stock Market*, In: The Journal of Amity Business School, 2008, 9, 1, 24–33

[9] Dahel, R., Laabas, B., *The Behaviour of Stock Prices in the GCC Markets*, In: Journal of Development & Economic Policies, 1999, 1, 89–105

[10] Abeysekera, S.P., *Efficient Markets Hypothesis and the Emerging Capital market in Sri Lanka: Evidence from the Colombo Stock Exchange – A Note*, In: Journal of Business Finance and Accounting, 2001, 28, 1, 249–261

[11] Abraham, A., Seyyed, F.j., Alsakran, S.A., *Testing the Random Walk Behavior and Efficiency of the Gulf Stock Markets*, In: The Financial Review, 2002, 37, 3, 469–480

[12] Rao, D.N., Shankaraiah, K., *Stock Market Efficiency and Strategies for Developing GCC Financial Markets: A Case Study of the Bahrain Stock Market*, In: The Arab Bank Review, 2003, 5, 2, 16–21

[13] Moustafa, M.A., *Testing the Weak-Form Efficiency of the United Arab Emirates Stock Market*, In: International Journal of Business, 2004, 9, 3, 309–325

[14] Sharma, S.N., *On the non-normality of GCC Stock Markets*, In: The ICFAI Journal of Applied Corporate Finance, 2005, 51–58

[15] Elango, R., Hussein, M. I., *An Empirical Analysis on the Weak-Form Efficiency of the GCC Markets Applying Selected Statistical Tests*, November 2007, Available at: Social Science Research Network https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1026569 [Accesed January 19, 2017]

[16] Smith, G., *Random Walks in Middle Eastern stock markets*, In: Applied Financial Economics, 2007, 17, 7, 587–596

[17] Asiri, B.K., *Testing Weak from Efficiency in the Bahrain Stock Market*, In: International Journal of Emerging Markets, 2008, 3, 1, 38–55

[18] Al Kharausi, S., Weaglay, R.O., *Weak Form Market Efficiency during the 2008 Financial Crisis: Evidence from The Muscat Securities Market*, In: The International Journal of Business and Finance Research, 2014, 8, 4, 27–42

[19] Awan, U.F., Subayyal, M., *Social Science Research Network*, 2016

[20] Sharma, J.L., Kennedy, R.E., *A comparative Analysis of Stock Price Behaviour on the Bombay, London, and New York Stock Exchanges*, In: Journal of Financial and Quantitative Analysis, 1977, 391–413

[21] Karemera, D., Ojah, K., Cole, j.A., *Random Walks and Market Efficiency Tests: Evidence from Emerging Equity Markets*, In: Review of Quantitative Finance and Accounting, 1999, 13, 171–188

[22] Mookerjee, R., Yu, Q. *An Empirical Ananlysis of the Equity Markets in China*, In: Review of Financial Economics, 1999, 8, 41–60

[23] Groenewold, N., Sam, T., Wu, Y., *The Efficiency of the Chinese Stock Market and the Role of the Banks*, In: Journal of Asian Economics, 2003, 14, 593–609

[24] Seddighi, H.R., Nian, W., *The Chinese Stock Exchange Market: Operations and Efficiency*, In: Applied Financial Economics, 2004, 14, 785–797

[25] Engle, R., *Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of UK Inflation*, In: Econometrica, 1982, 50, 4, 987–1008

[26] Bollerslev, T., *Generalised Autoregressive Conditional Heteroscedasticity*, In: Journal of Econometrics, 1986, 51, 307–327

[27] Gharaibeh, A., Hammadi, F., *The Day of the Week Anomaly in Bahrain's Stock Market*, In: International Management Review, 2013, 9, 2, 60–69

[28] Hawaldar, I.T., *The Cross-Sectional Variation in Portfolio Returns: Evidence from Bahrain Bourse,* In: British Journal of Economics, Finance and Management Sciences, 2016, 12, 2, 1–11

[29] Hawaldar, I.T., *The Reaction of Bahrain Bourse to Announcement of Annual Financial Results*, In: International Review of Business Research Papers, 2016, 12, 1, 64–75

[30] Hawaldar, I.T., Shakila, B., Pinto, P., *Empirical Testing of Month of the Year Effect on Selected Commercial Banks and Services Sector Companies Listed on Bahrain Bourse,* In: International Journal of Economics and Financial Issues, 2017, 7, 2, 426–436

[31] Spulbar, C., Birau, R., *Testing weak-form efficiency and long-term causality of the R.I.P.H emerging capital markets*, In: International Journal of Business Quantitative Economics and Applied Management Research, 2018, 5, 2, 1–19

[32] Pinto, P., Hawaldar, I.T, Guruprasad, K., Rohit, B., Spulbar, C., Birau, R., Stanciu, C.V., *The Impact of Risk Anomalies on the Pharmaceutical Sector of the Indian Stock Market – A Comparative Analysis between Pharmaceutical, FMCG and IT companies*, In: Revista de Chimie, 2020, 71, 2, 58–63

[33] Spulbar, C., Birau, R., *Emerging Research on Monetary Policy, Banking, and Financial Markets*, IGI Global USA (formerly Idea Group Inc.), 2019, 322, ISBN13: 9781522592693, ISBN10: 1522592695, EISBN13: 9781522592716, https://doi.org/10.4018/978-1-5225-9269-3

[34] Spulbar, C., Ejaz, A., Birau, R., Trivedi, J., *Sustainable Investing Based on Momentum Strategies in Emerging Stock Markets: A Case Study for Bombay Stock Exchange (BSE) of India*, In: Scientific Annals of Economics and Business, 2019, XX (X), 1–11 (tbd), https://doi.org/10.2478/saeb-2019-0029

[35] Ejaz, A., Birau, R., Spulbar, C., Buda, R., Tenea, A.C., *The impact of domestic portfolio diversification strategies in Toronto stock exchange on Canadian textile manufacturing industry*, Industria Textila, 2020, 71, 3, 215–222, http://doi.org/10.35530/IT.071.02.1696

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CAD/CAM system implementation criteria in the process generating of optimal and efficient models for clothing industry

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ABSTRACT – REZUMAT

CAD/CAM system implementation criteria in the process generating of optimal and efficient models for clothing industry

The first part of the paper is a systematic explanation of the process of defining the most important parameters for generating optimal and efficient models of small and medium sized enterprises (SMEs) of the clothing industry, with the presentation of specific and adequate methods of research, i.e. with the evaluation of data for designing new models, and including previous research data. The following is an explanation of the final phase, i.e. a systematic and objective design assessment, through the implementation of preliminary results of exploitation studies of the modal experiment and computer simulation of the new model, based on which the criteria for efficient and optimal implementation of the CAD/CAM systems are defined.

***Keywords:** criteria, CAD/CAM systems, modeling, optimization, SME*

Criteriile de implementare a sistemului CAD/CAM în procesul de generare optimă și eficientă a modelelor pentru industria de îmbrăcăminte

Prima parte a lucrării este o analiză sistematică a procesului de definire a celor mai importanți parametri pentru generarea optimă și eficientă de modele de către întreprinderile mici și mijlocii (IMM-uri) din industria de îmbrăcăminte, cu prezentarea unor metode de cercetare specifice și adecvate, adică cu evaluarea datelor pentru proiectarea de noi modele, inclusiv a datelor de cercetare anterioare. Apoi, este prezentată o analiză a fazei finale, adică o evaluare sistematică și obiectivă a proiectării, prin implementarea rezultatelor preliminare ale studiilor de exploatare ale experimentului modal și simularea pe calculator a noului model, pe baza căruia sunt definite criteriile pentru implementarea eficientă și optimă a sistemelor CAD/CAM.

***Cuvinte-cheie**: criterii, sisteme CAD/CAM, modelare, optimizare, IMM*

INTRODUCTION

The progress of every society today means a successful and quality economy with fast and efficient implementations of technological and technical innovations, which implies the interaction of science, education and economy, long-term planning of technological development, extensive investment investments and permanent education of the necessary labor force, as well as a strategic shift in innovation policy at all levels. Today, the issue is redefining the strategic economic development program for developing countries, which must include the encouragement of research and development processes of enterprises with a focus on four areas of operation: product innovation [1–3], technological processes, innovation in the organization production and marketing. It is imperative that research activities generate a productive-economic valorization of innovation and the diffusion and implementation of new technologies [4], by the rapid and efficient transformation of scientific research into new technologies, innovations and products [5, 6].

CAD/CAM SYSTEM AND OPTIMIZATION OF PRODUCTION

Implementation of ICT technologies [4] by itself leads to reengineering or generating new models of production processes and concepts of work and development, which requires the necessary study of all problems and specificities in order to eliminate or redefine them in the most efficient way, and then included in the generation of new and efficient models of clothing industry SMEs [7, 8]. The fact that ICT systems enable process optimization through time and cost parameters or through compatibility and alignment of components of efficient and quality business clearly indicates that the biggest improvements and improvements of production processes cannot be realized without their support. Research into the generation of efficient models of production processes [9] is primarily directed towards finding and defining optimal parameters, in order to obtain the best outputs with minimal use of available input resources. One of the key factors in business process optimization is business process management (BPM) [10], a discipline that combines IKT and management

[11–13], and applies either on operational business processes through the monitoring and execution of processes or management through design, simulation, and analysis processes, or through reengineering and optimization [1,2, 8, 14]. It means that the business process could be analyzed and improved, it is necessary to describe all of its relevant properties [2, 5, 15] using specific methods [6, 10, 16, 17], in order to exclude the possibility of different interpretations of the essence, and then by implementing new parameters perform simulation, monitoring and analysis of the process, along with the graphic representation.

EXPERIMENTAL PART

The organization of the research relies on and follows the basic steps of business process reengineering, so the research process consists of several stages of obtaining relevant data:

- Phase one: identifying problems, defining the objects and objectives of the research;
- Phase two: presents specific methodological techniques for collecting and analyzing data and systematization of relevant parameters by the stages of production;
- Phase three: the creation and implementation of the model, with the computer modelling method as a research process of generating a model;
- Phase four: implies simulation, i.e. transfer of data from the model to a real phenomenon, and direct and indirect experimental measurements with variable parameters, that is, analytical study of cause-effect relationships with the systematic and deliberate change of certain parameters, in order to observe and measure other parameters and phenomena, while other relevant conditions are controlled or isolated;
- Phase five: monitoring, analysis and conclusions, as well as defining the criteria for optimal and efficient CAD/CAM implementation.

Identifying problems and defining the goal of the research

Through compilation data on the automation and implementation of ICT technologies the problem of poor modernization was identified and raised as a subject of research, respectively poor or insufficient automation of production, or inadequate implementations of computer systems (CAD/CAM). The aim of the research is to define the criteria for the implementation of the CAD/CAM system [11], which, along with timely consideration and inclusion of the specifics of SMEs, clothing industry and developing countries, should be incorporated into the processes of generating new work and development strategies SME [5, 8, 14].

Compilation, SWOT analysis, brainstorming and Ishikawa research [6, 16] were used as methodological techniques for systematizing relevant factors, which are compiled, classified and systematized by similar features: participants, materials, means of work, work procedures and money, and based on this, make the Ishikawa diagram – the cause – consequence (figure 1).

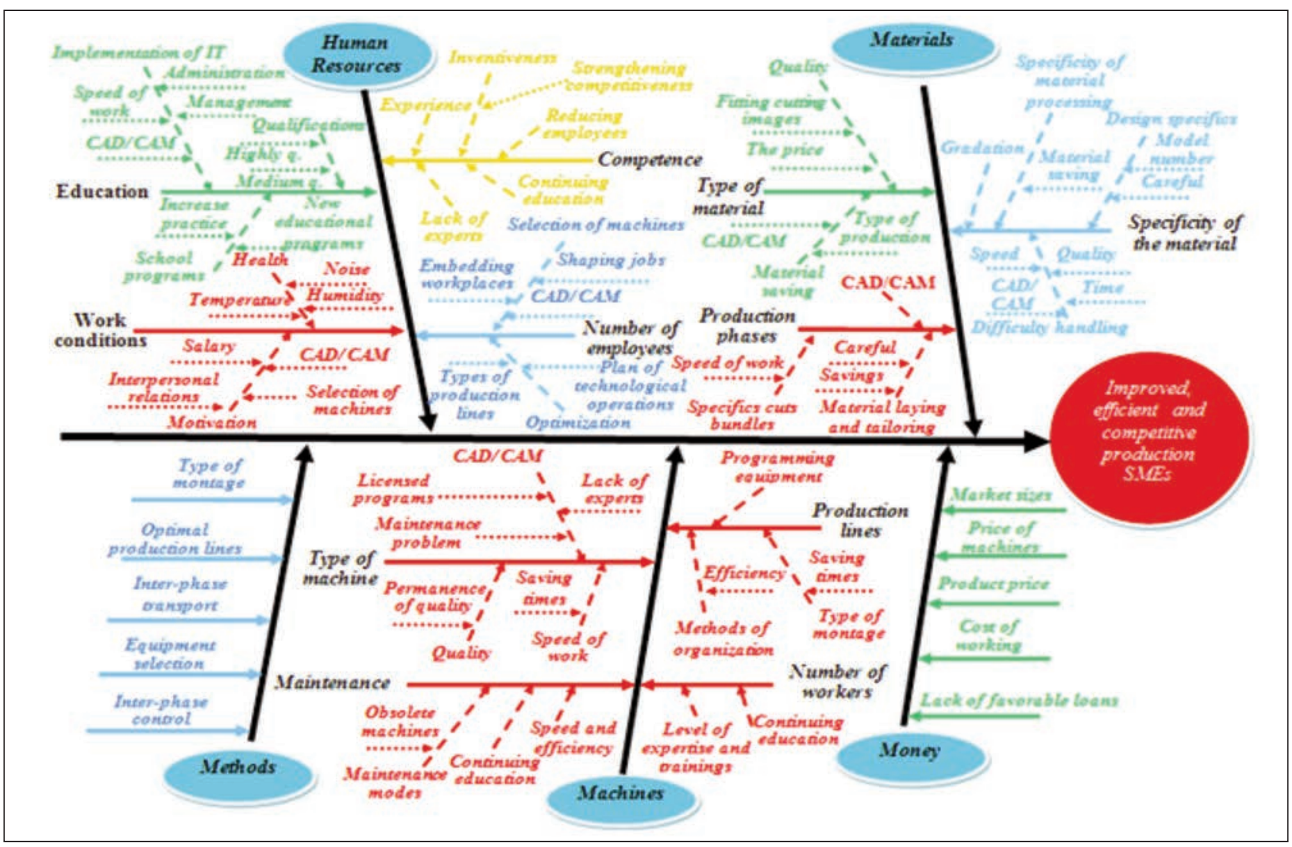

Fig. 1. Ishikawa Enumeration Diagram or the cause-effect diagram

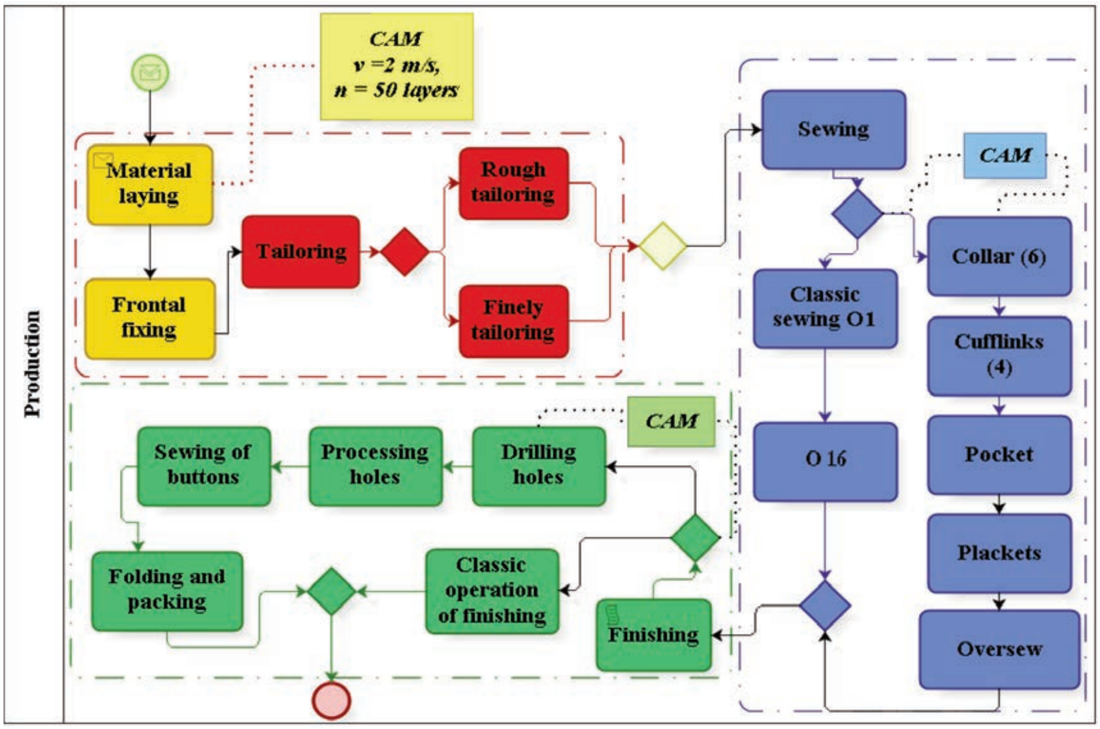

Fig. 2. Model proposal with implemented CAD/CAM systems

Model proposal and comparative parameters

Making the model of optimum and efficient production of clothes in SMEs was based on the data of the study of the impact of CAD/CAM system implementation, compilation of works and professional literature about SMEs of clothing industry, direct contacts with owners and with employees, as well as on the basis of the sublimated results of SWOT analysis, brainstorming sessions and Ishikawa research. Selected most important parameters of the clothing industry SMEs and the effects of CAD/CAM implementation must significantly influence the production process and at the same time represent a special feature of automation and efficient operation at different stages of production: 1. Time, 2. Material and 3. Number of employees. As modelling [7, 8, 15] does not need to reproduce reality completely, but to formally describe or reveal part of the structure or behaviour of the real system, then further research and measurements will only refer to the selected parameters and phases of the production process. In other words, it is necessary in the database of the selected program for business process modelling to implement new parameters for improving the efficiency of selected resources, e.g.: type of production – specialized production, number of production lines: 3, arrangement – combined composition, the width of the material: 1.12 m, final ironing – pressing machines, transport: hanging tapes/slanted tables, etc., but above all based on the implementation CAD/CAM system – proposal: in constructional preparation (constructional, modelling, grading, fti), at material laying and frontal fixing of materials, at sewing (making the collar of a shirt, cufflinks, pockets, seams, plackets), and finishing (drilling and processing of holes, sewing of buttons, folding and packing.

Most computer programs are designed to generate a model aim to create a framework for better understanding and optimization of production-business processes, as well as determining the impact of individual parameters and defining their mode of interaction with the enterprise. The aim, but also the task of the model, is to define and supply information on new business strategies, which should enable analysts to provide quality systematic analysis of the operations of an organization, focusing on tasks – functions that are regularly performed, monitoring the inputs and controlling the correct implementation of the necessary resources and carrying out tasks (figure 2). So it would identify and define bottlenecks in the production process and then propose adequate solutions or new concepts and strategies [10, 14, 17, 18].

RESULTS AND DISCUSSION

Based on the set and defined parameters that determine the ways, but also the efficiency of the business, with the recommendation of formally describing the behaviour of the real system, as a result of all research and implementation of new or redefined initial parameters, a new model of SME for clothing production is shown. Model monitoring during simulation [8, 13], as well as measurement of parameter values, is analyzed and based on this and brings conclusions about the essential properties of a new or improved model. For this type of experiment and comparative measurements, three SMEs of clothing industry with specialized production (shirt production) were selected, with no (A) and with elements of automation (B and C) – CAD/CAM systems. As modelling requires

simplified presentation of parts of the production processes that need to be changed and for which research will be carried out, table 1 shows measured values of selected parameters of the parts of the phases essential for defining new models of SMEs.
Number of employees for the production line: $N_{cl} = 43$, $N_{CAM} = 27$, is defined according to the number and type of necessary operations, as well as according to the number of perpetrators on the existing or proposed machines for the envisaged capacity: $K_{cl} = 610.25$, and $K_{CAD} = 626.88$.
Measurements by parameter Material were made for the average standardized consumption per unit of product of a men's shirt of about 0.97 m^2, a surface mass of material of 120 g/m^2, whereby the dimensions of the table of the for laying are 6×1.2 m, while material lenght is different owing to equalization of capacity and valid data comparison.
Based on the measurement of selected parameters (time, number of employees and material) and the obtained results, criteria of efficient implementation of CAD/CAM systems can be defined, in order to optimize and generate new and more efficient models the SME of clothing industry.

The best results of CAD system efficiency were obtained per parameter the Time, and as criterion taken as a value of max 6% of the time of preparation the construction in the classic way, while a criterion for the Material parameter would be: a min of 5% difference used material in the stages of grading and fitting of picture of tailoring. The results of the research indicate the obvious and large differences per parameter Number of employees so, without comparative elements, one employee in construction preparation can be defined as a criterion according to this parameter:

$$t_{CAD} \leq 6\%\ t_{kl} \quad (1)$$

$$P_{CAD} \geq 105\%\ P_{cl} \quad (2)$$

$$n_{CAD} = 1 \quad (3)$$

The best results of CAM system efficiency are by parameter Time, and then the Number of workers, while savings per parameter Material in the direct production phase are negligible. Based on the obtained results, for the implementation of CAM system, operations with time of min 4% of the total time of that production phase were proposed, while criterion by parameter Number of employees in the phase

Table 1

THE TIME PARAMETER						
Time – construction preparation		**Construction**	**Modeling**	**Grading**	**Fti and mti**	**Sum**
Classic	sec (s)	32400	21600	108000	81000	243000
CAD	sec (s)	3600	1800	1440	5400	12240
Time – producing		**Laying materials**	**Tailoring**	**Sewing**	**Finishing**	**Sum**
Classic	sec (s)	126	2988	1674	180	-
CAD	sec (s)	3.06	2988	1080	72	-

Table 2

THE NUMBER OF EMPLOYEES PARAMETER							
Number workers	**Construction**	**Modeling**	**Grading**	**Fti**	**Mti**	**Sum**	**Saving**
Classic	1	1	2	2	1	7	6
CAD	1					1	
Number workers	**Laying materials and fixing)**	**Tailoring (and marking)**	**Sewing**	**Finishing**	**Sum - workers**	**Saving**	
Classic	2	3	30	8	43	16	
CAM	1	3	18	5	27		

Table 3

THE MATERIAL PARAMETER – PREPARATION OF THE CONSTRUCTION (MEN'S SHIRT)							
Material consumption – mens shirt (m^2)	**Material length (m)**	**Materials width (m)**	**Material surface (m^2)**	**uks (%)**	**Usable material (m^2)**	**Waste**	**Saving per collections (m^2)**
Classic/0.97	12255.6	1.12	13726.3	81	11118.3	2608.0	1208.6
CAD/0.97	12494.8	1.12	13994.2	90	12594.8	1399.4	

Table 4

PERCENTAGE OF PARTICIPATION OF ALL OPERATIONS FOR THE SEWING PHASE							
Sewing							
No.	The name of the operation	*t*	%	No.	The name of the operation	*t*	%
4	Decorative of sewing of the collar	8	0.63	13	Overlap of cufflink	18	1.42
5	Sewing the base fabric of the under-collar and among lining	94	**7.42**	21	Overlap and sewing a pocket	68	5.37
6	Assembling the collar and under-collar	64	**5.06**	22	Overlap and sewing a tape	51	4.03
7	Sewing of the under-collar	14	1.11	24	Sewing collar on neckline	60	4.74
9	Sewing the between- lining on the base fabric of cufflink	32	2.53	25	Closing the collar	66	5.21
10	Before sewing cufflinks	111	**8.77**	28	Sewing the cuff	80	6.32
12	Quilting cufflink	51	**4.03**	29	Making the hem of the shirt	51	4.03

of production can be taken as: a max 65% of employees in production without automation:

$$t_{operations} \geq 4\% \quad (4)$$

$$t_{in\ total/production\ stages} \quad (5)$$

$$n_{CAM} \leq 65\%\ n_{cl} \quad (6)$$

In the specific case of manufacturing for automation, according to the above criterion, operations were proposed: 4, 5, 6, 10, 12, 21, 22, 24, 25, 28 and 29. Automation of operations 10, 24, 25, 28 and 29 are not proposed, and if it is adequate to the stated criterion, it is because comparative measurements are not possible due to the absence of such automated machines in the moment, while operations 4, 7 and 13 do not meet the condition of the selected criterion, but they are proposed for automation because they are of the same type as the operations they “rely on” (in technological and operational sense), which fulfil the condition of the defined criterion. It should be emphasized that the automation of Operation 14, by joining the automated Operations 12 and 13, is not proposed, since it requires the machine so-called two-needle, while Operations 12 and 13 are done with a single needle, so going forming a new CAM system with these requirements would be a difficult task.

CONCLUSION

The results of the research clearly and unambiguously indicate the positive effects of the implementation of the proposed CAD/CAM systems and other parameters, in new models of SMEs of the clothing industry, so it can be concluded that:

- It is possible to improve the technical-technological performance of production, and to increase the competitiveness of SMEs, by flexible implementation of CAD/CAM systems;
- By implementing CAD and CAM systems, savings in the construction preparation and production process of the SME clothing industry can be achieved, by parameters: Time, Material and Number of employees;
- Business process modelling provides added value and support to decision makers in error prevention and remediation, reengineering and production optimization;
- Generation of new models of SME requires the identification and definition and then appreciation and incorporation of the all specificities of SMEs, the clothing industry and developing countries, which correlate with ICT implementation.

REFERENCES

[1] Maia, L.C., Alves, A.C., Leão, C.P., *Design of a Lean Methodology for an Ergonomic and Sustainable Work Environment in Textile and Garment Industry,* ASME 2012 International Mechanical Engineering Congress and Exposition, 2012, 1843–1852

[2] Parsana, T.S., Desai, D.A., *Six Sigma Implementation Practices in Indian Manufacturing SMEs,* In: Journal of Engineering Research and Applications, 2014, 4, 3, 663–673

[3] Syduzzaman, M., Islam, M., Habib, A., Yeasmin, D., *Effects of Implementing TQM Principles in the Apparel Manufacturing Industry: Case Study on a Bangladeshi Clothing Factory,* In: Science and Technology, 2016, 6, 3, 68–75

[4] Sorak, M., Urošević, S., Dragić, M., Sorak, Lj., *Improvement methodology of important clothing characteristics, by applying quality tools*, In: Industria Textila, 2015, 66, 5, 283–288

[5] Cucculelli, M., Bettinelli, C., *Business models, intangibles and firm performance: evidence on corporate entrepreneurship from Italian manufacturing SMEs,* In: Small Business Economics, 2015, 45, 2, 329–350

[6] Paunović, M., Čolović, G., Borić, S., *Benčmarking proizvodnog procesa*. In: Tekstilna industrija, 2016, 64, 4, 67–71

[7] Urošević, S., Fedajev, A., Nikolić, R., *Significance and perspectives of textile industry in Republic of Serbia in transitional environment,* In: Industria tekstila, 2011, 62, 3, 134–140

[8] Zülch, G., Koruca, H.I., Börkircher, M., *Simulation-supported change process for product customization – A case study in a garment company*, In: Computers in Industry, 2011, 62, 6, 568–577

[9] Santis, S. H. da Silva., Marcicano, J. P. P., Scopinho, C. E. D., Held, M. S. B., *Evaluating the implementation of quality system in a small textile industry of knitting,* In: International Journal of Arts and Commerce, 2012, 1, 6

[10] Houy, C., Fettke, P., Loos, P., *Empirical research in business process management – analysis of an emerging field of research*, In: Business Process Management Journal, 2010, 16, 4, 619–661

[11] Garg, P., Garg, A., *An empirical study on critical failure factors for enterprise resource planning implementation in Indian retail sector*, In: Business Process Management Journal, 2013, 19, 3, 496–514

[12] Gerasymchuk, V.H., *Faktori uspešnog upravljanja organizacijom*, In: Tekstilna industrija, 2018, 66, 2, 52–60

[13] Ryan, J., Heavey, C., *Process modeling for simulation,* In: Computers in Industry, 2006, 57, 5, 437–450

[14] Dhevina, D., *Analisis Dan Pemodelan Proses Bisnis Pemenuhan Pesanan UMKM XYZ*, Undergraduate thesis, Institut Teknologi Sepuluh Nopember, 2018

[15] Kumar, A., Krishna, G., *Minimization of Rework in Denim Manufacturing Unit Through DMAIC Methodology of Six Sigma,* NIFT, 2018

[16] Dobrosavljević, A., Urošević S., *Benčmarking kao menadžerski alat za dostizanje poslovne izvrsnosti malih i srednjih preduzeća u okviru tekstilne industrije,* In: Tekstilna industrija, 2017, 65, 4, 4–10

[17] Tatsiopoulos, I.P., Panayiotou, N.A., Ponis, S.T., *A modelling and evaluation methodology for E-Commerce enabled BPR*, In: Computers in Industry, 2002, 49, 1, 107–121

[18] Venkatesh, V.G., Rathi, S., Patwa, S., *Analysis on supply chain risks in Indian apparel retail chains and proposal of risk prioritization model using Interpretive structural modeling*, In: Journal of Retailing and Consumer Services, 2015, 26, 153–167annual-report [Accesed June 2019]

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Employee's performance affected by the alignment of interest and capacity building

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ABSTRACT – REZUMAT

Employee's performance affected by the alignment of interest and capacity building

This study emphasizes the factors that may lead to increase the employee performance in the textile sector in Pakistan. The study observes an impact of capacity building, alignment of interest and manager support in employee performance through the moderating role of employee retention.
The approach consists in survey questionnaire used to collect data. Data was analysed through SPSS 23 and Smart-PLS 3. The results indicate that manager support, capacity building and the alignment of interest have a noteworthy influence on employee performance. Additionally, if employee retention is considered as a moderator then the overall impact would be more significant to employee performance.
According to these results, capacity building, manager support and alignment of interest contribute positively to employee's performance. The results encourage the managers to invest in training their employees to improve their organizational performance/productivity as well as to consider the alignment of interest as a tactical and operational strategy to retain their key employees.

Keywords: *manager support, alignment of interest, capacity building, employee retention, employee performance, Pakistan*

Performanța angajaților influențată de alinierea interesului și consolidarea capacității

Acest studiu identifică factorii care pot duce la creșterea performanței angajaților în sectorul textil din Pakistan. Studiul observă un impact al consolidării capacităților, alinierii interesului și sprijinului managerilor asupra performanței angajaților, prin rolul moderator al fidelizării angajaților.
Abordarea constă în aplicarea chestionarului pentru colectarea datelor. Datele au fost analizate prin SPSS 23 și Smart-PLS 3.
Rezultatele indică faptul că sprijinul managerilor, consolidarea capacităților și alinierea intereselor au o influență remarcabilă asupra performanței angajaților. În plus, dacă fidelizarea angajaților este considerată un moderator, atunci impactul general ar fi semnificativ pentru performanța angajaților.
Conform acestor rezultate, consolidarea capacităților, sprijinul managerilor și alinierea interesului contribuie pozitiv la performanța angajaților. Rezultatele îi încurajează pe manageri să investească în instruirea angajaților lor pentru a-și îmbunătăți performanța organizațională/productivitatea, precum și să ia în considerare alinierea intereselor ca o strategie tactică și operațională pentru a-și păstra angajații cheie.

Cuvinte-cheie: *sprijin managerial, alinierea intereselor, consolidarea capacităților, fidelizarea angajaților, performanța angajaților, Pakistan*

INTRODUCTION

Capacity development is essential to improve employee performance. Recently, the Pakistan textile industry explored the effect of capacity building, manager support and alignment of interest on employee performance and productivity. Currently, this activity has focused on key employees only but we consider that it will include the operational level soon.
The survey helps to understand the effect of capacity building, manager support and alignment of interest on retention of employees and their performance in the textile sector. The impact of capacity building shouldn't be ignored because it helps to understand the job and culture of the organization. Researchers depicted that employees from different backgrounds have their expertise so that organizations should establish training programs to introduce their own culture to employees. In this way employees can perform the job as they are required. It may lead positive impact on employees and consequently employee's retention [1]. Capacity building is the enhancement of knowledge, proficiency and behaviour of individual and group of people that contributes in design, development, management and maintenance of institutional and operational infrastructures and processes that are locally important [2].
Employee satisfaction is imagined as one of the competitive advantages. If employees would be satisfied then they would work better and devoted their full attention to the achievement of organization's goals.

Corporate success depends on the efficiency of employees [3]. Employee satisfaction and retention are considered as one of the key competitive advantage for the business. In this context, researchers postulate that through alignment of interest, an organization must introduce training programs to enhance employee's knowledge and skills to fulfil the aims of the organization [4]. Researchers conclude that manager's trust over subordinates creates a positive impact on employee performance. This study emphasizes that employee performance and retention are key factors for the reputation of the company so that the company should include these factors while elaborating the corporate strategy.

LITERATURE REVIEW

Employee performance

An organization hires individual to perform a specific job and the work results are gathered in performance [5]. According to Mathis, performance includes the punctuality of employees as well as the effectiveness and efficiency of the individual for required output in the given input [6]. Job appraisal and expertise can be seen as a positive emotion in an individual's status and it is regarded as an employee's performance [7]. Sempane et al. postulate that employee performance comprises an employee's overall assessment and appraisal of the work environment [8]. The organization's goal can be affected by an individual's efficiency [3]. Employee's performance subject to the performance management strategy adopted by the organization [9]. Performance measures such as job participation, empowerment, job satisfaction, job flexibility, employee training programs and appraisal and reward system affect the organization's performance [10]. There are many external and internal factors that impact employee's performance. According to this study manager support, capacity building and alignment of interest are key factors that effect on employee's performance.

Manager support

Employee encourages flexibility of work, rewards and suggestions on a specific assignment. Manager support improves employee's confidence over the job. Manager support develops the consistency between employee's performance and the organization's goals [11–12]. Former research concludes that participative leadership may or may not be lead to employee's satisfaction and performance [13]. In order to maintain confidence over employees, the manager should have good and direct contact with them [14]. A manager knows how to motivate employees by providing a decent work state and boost morale. In this way, they can accept more challenges and willing to maintain a positive image of learning, development and success [15]. The individual performance of employees can be achieved through unbiased appraisal against the performance levels set by their managers continuously [16]. The flexibility of work means that the manager refers to the employees in their work and supports them in all the issues that come across during the work. Many managers recognize that they lack social management skills [17]. Many organizations lack levels of non-technical training. Managers use power to ensure organizational goals through organizational dynamics. Organizations summarize the importance of power in the following way: "Energy is a central conception in physics and power is one of the central concept in the social sciences" [18].

H_1: Manager support has a positive influence on performance of employee.

Capacity building

Capacity building will enhance the productivity of employees. Consequently, they get the desired output and benefits to the organization also. Hughes explains capacity building as factors contributing to the development of the learning environment for individuals [11]. Capacity building supports teamwork and employee motivation. In this way, the resources can be utilized properly and it will help to enhance the development of resources and group efficiency. Capacity building is a vast term used in corporate strategy [19]. Capacity building refers to the enhancement of the capability of an organization to carry out operations to achieve goals. According to Al-Roubaie, skill building is not merely helps to boost up the physical infrastructure and human capital but also gives new directions for research and development [20]. For effective and efficient performance, managers must recognize every employee's strength then they would pay more attention and achieve organizational goals with loyalty.

H_2: The capacity building has a positive and significant influence on employee's performance.

Alignment of interest

Alignment of interest is considered as one of the important elements of corporate governance. According to researchers, in the presence of support schemes and policies individuals get satisfied and enable to deliver desired results to the employer. On the other hand, if there is no support employees will not be satisfied [21]. Researchers assert that alignment of interest between employee and employer may result in employee satisfaction and consequently employee retention [22–26]. Specialists postulate that we need to comprehend the relationship between employee's perception and employer's strategy so that we may conclude the employee's behaviour towards corporate strategy offering to them. According to these researcher's alignment of interest has a significant impact on individual performance so HRM should focus the alignment of interest [22, 24]. Alignment of interest is not merely used as a performance measure, but also for employee's satisfaction and reduces the turnover of the organization. In this context, Wright et al. expresses that alignment of interest is not simply a performance measure but it shows the relationship and the level of contribution of an employee to corporate strategy [27]. It also can be used to enhance the contribution of an employee in achieving organizational goals. Organization's and employee's goals should be in line to achieve employee dedication and better performance as well [28].

H_3: The alignment of interest has a positive and significant influence on performance of employee.

Employee retention

Retention of staff is a good sign for the organization and it will help companies to redesign their policies regarding employees. Employee commitment can be achieved by challenging tasks. The significant task can increase the interest of employees and employee retention [29]. There is a strong relationship between job gratification and employee's turnover, so organizations must introduce staff motivational programs fo retention of key employees [30]. Cappelli asserts the factors that have a direct relationship between organization strategy and employee's retention: organization reputation, progress opportunities, internal environment, work duration, organization's attitude and termination policy [31]. Job devotion and loyalty are related to employees' sense of value and pride [32]. The studies conclude that the key factors of employee retention are: merit orientation, training opportunity, remuneration and safety, work sovereignty, reward and promotion [33]. Level of attachment of employee with organization dictates the performance of the organization, level of absence and retaining of key employees [34]. Professional and training programs should be introduced to upsurge the abilities of employees and induce them for productive results [35]. If employers have confidence over employees and understand the feelings and ideas with the receptive bent of mind, then it will increase devotion and faithfulness [36].

Our study focused on employee performance as a dependent value indicator, considering that the best performers have more information, expertise and competence, which is essential contribution to the organization success. We used employee retention as a moderator. Therefore, the moderation variable has a large effect on the relationship between the independent variables and the dependent variables.

H_4: Employee retention plays a moderating role with the relationship between managers' support and employee performance.

H_5: Employee retention plays a moderating role with the relationship between capacity building and employee performance.

H_6: Employee retention plays a moderating role with the relationship between the alignment of interest and employee performance.

THEORETICAL FRAMEWORK

Capacity development, alignment of interest and retention of employees are key factors to improve the performance of employees in the textile sector. We have structured the theoretical framework to describe the relationship between management support, alignment of interest, skill development and employee's performance in the presence of employee retention as a moderator (figure 1). Alignments of interest, capacity building and manager support have a positive relationship on employee performance. The change in alignment of interest, capacity building, and manager support will impact employee performance.

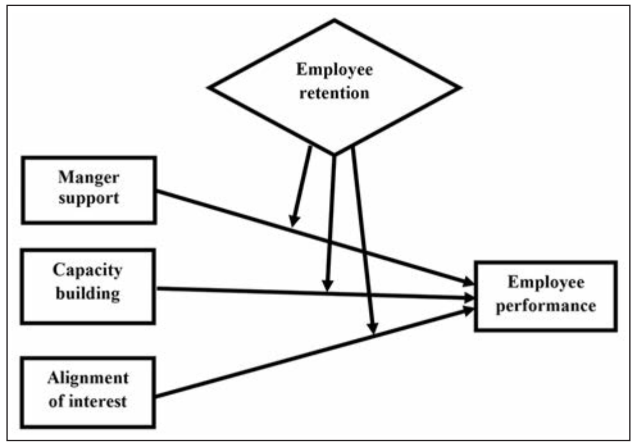

Fig. 1. Theoretical framework of this study

METHODOLOGY

The method contains data on research design, population, sampling, composition, reliability of a questionnaire and data collection along with valuation procedures. The collected data was analysed to determine the results. The effect of capacity building, manager support, alignment of interest and employee retention on employee performance is examined in the context of the textile sector. The quantitative approach that grounded on primary data has been used to study and investigate the subject matter for research. The population in this inquiry consists of lower to top-level that are performing their duties in the textile sector of Faisalabad, Pakistan. The technique that has been used for data collection is convenient sampling. 250 questionnaires were distributed, 200 questionnaires were collected from the respondents. Out of 250, fifty questionnaires were unconfined and were not suitable for interpretation of results. Statistical analysis was applied to the rest of the 200 questionnaires. The adaptive approach has been used for the questionnaires; a structured questionnaire drawn on a five-point Likert scale ranging from "5" indicating a strong agreement with the "1" statement indicates Strong disagreement with the statement. The selected questions were based on the prior good reliabilities in Pakistan and other countries. The questions reference is presented in table 1. In the study, the causal melding approach and descriptive analysis by Smart PLS (Partial Least Squares) and SPSS (Statistical Package of Social Sciences) were applied.

Table 1

THE QUESTION REFERENCE			
No.	**Construct**	**Items**	**Cronbach's alpha**
1	Manager support [37]	12	0.80
2	Capacity building [38]	12	0.86
3	Alignment of interest [39]	4	0.82
4	Employee retention [40]	5	0.88
5	Employee performance [41]	8	0.77

Table 2

EVALUATION OF THE MEASUREMENT MODEL					
Variables	**Items**	**FL**	**AVE**	**CR**	**Cronbach's alpha**
MS/ manager support	MS2	0.928	0.838	0.976	0.974
	MS4	0.946			
	MS5	0.742			
	MS6	0.941			
	MS7	0.940			
	MS8	0.954			
	MS9	0.933			
	MS10	0.920			
CB/ capacity building	CB13	0.919	0.830	0.967	0.960
	CB14	0.958			
	CB15	0.909			
	CB16	0.942			
	CB23	0.770			
	CB24	0.953			
AI/ alignment of interest	AI25	0.922	0.786	0.916	0.864
	AI26	0.924			
	AI27	0.808			
ER/ employee retention	ER29	0.949	0.980	0.995	0.993
	ER32	0.946			
	ER33	0.956			
EP/ employee performance	EP34	0.989	0.903	0.965	0.947
	EP39	0.992			
	EP40	0.983			
	EP41	0.997			

Notes: Items MS1, MS3, MS11, MS12, CB17, CB18, CB19, CB20, CB21, CB22, AI27, ER30, ER31 and EP30, EP35, EP36, EP37, EP38 were deleted to improve EP. AVE (average variance extracted); CR (composite reliability).

Table 3

DISCRIMINANT VALIDITY AT CONSTRUCT LEVEL					
Variables	**AI**	**CB**	**MS**	**EP**	**ER**
AI	**0.886**				
CB	0.072	**0.911**			
MS	0.038	–0.085	**0.915**		
EP	0.696	0.125	0.055	**0.990**	
ER	0.290	0.019	0.098	0.335	**0.950**

Note: The average variance's square root is extracted in the diagonals and the remaining entries are correlation values.

RESULTS

Descriptive analysis

For the study, 200 questionnaires represent the input in SPSS to perform the descriptive analysis and to discuss the demographic characteristics of respondents in the textile sector. In this study, demographic characteristics include gender, age, education, designation and experience.

Model assessment

PLS envisages the relationship between the dependent variable, independent variable and the explained variance [42]. The causal modelling approach by Smart PLS includes two phases, one is the evaluation of the outer model (measurement model) and the other is inner model (structural model) [43]. The measurement model explains the connection between constructive and linked items and the structural model elaborates the connection between exogenous and endogenous constructs [44].

Assessment of measurement model (reliability and validity analysis)

For reliability and validity, the assessment of the measurement model has been made [44]. Outer loading and composite reliability decided the reliability of the model [45]. In table 2, results show that the outer loading and composite reliability exceed the recommended value of 0.70, which approved the model reliability at items level as well as construct level [42]. The average variance extracted (AVE) and composite reliability were used to measure the validity of the measurement model [43]. In table 2, AVE and CR are higher than the acceptable values of 0.5 and 0.7 respectively and this will offer support to convergent validity [44–45]. Cronbach's alpha is based on internal consistency and is used to assess reliability. The Cronbach's alpha is used to calculate the average of measuring constructs and its correlation. Items with the value of Cronbach's alpha which exceeds 0.5 are reliable [46]. In table 2, the values of Cronbach's alpha are greater than 0.5.

Fornell & Larcker's criterion is used to assess the discriminant validity, i.e. the square root of the AVE of a construct (diagonal values) should be greater than the correlations between other constructs (off-diagonal values) in row and columns. Table 3 ensures the discriminant validity at the construct level as it satisfied the given condition.

Evaluation of structural model

The substantiality of path coefficients and the amount of explained variance (R square) in endogenous constructs explain the analytical

Table 4

EVALUATION OF THE STRUCTURAL MODEL						
Hypothesis	**Relationship**	**Path coefficient**	**SD**	**t-value**	**p-value**	**Observations**
H3	AI->Performance	0.627	0.058	10.857	0.000	Supported
H2	CB->Performance	0.097	0.059	2.628	0.040	Supported
H1	MS->Performance	0.023	0.078	0.298	0.766	Not Supported
H4	Retention->Performance	0.158	0.058	2.718	0.007	Supported
Moderating Effect 1->EP		0.038	0.066	0.582	0.561	Not Supported
Moderating Effect 2->EP		0.116	0.054	2.152	0.032	Supported
Moderating Effect 3->EP		0.052	0.46	2.114	0.006	Supported

inspiration of the inner model [44]. Path's significance is determined by applying the PLS algorithm and bootstrapping with 5000 samples and get path coefficients and t-values [44]. Table 4 gives a detailed picture of all path coefficients, standard errors, t-values and corresponding p-values. Moreover, the R-squared index of the variables demonstrated a satisfactory level of predictability, which exceeded the suggested starting point of 0.1 [47]. The list of R-square values is given in table 5 and shown in figure 2 that is 0.526, which is exceeding form 0.1. Figure 2 presents the relationship between variables as per the PLS-SEM model.

Table 5

THE R^2 VALUE OF ENDOGENOUS STRUCTURAL			
Predictor Construct	**Target Construct**	**R-squared**	**Predictive Accuracy**
MS, CB, AI and ER	EP	0.526	Substantial

Moreover, the R square value is listed in table 5. In the structural model, the R square's value for the construct is considered as low, medium and significant 0.25, 0.50 and 0.75 respectively [44]. The capacity buildings, managers' support, alignment of interest and employee retention as a moderator, are found to be significantly associated with employee performance respectively, explaining 52.6% of the variance.

Figures 2 and 3 display the results of the structural model through PLS output. First, we **hypothesized (H3)** that the alignment of interest has a positive and substantial effect on employee performance. In table 6 positive β value 0.627 and the p-value emphasis the significance of the exogenous variable on the endogenous variable. The t-value of the alignment of interest is 10.857, which reflect its high influence on the performance of textile sector employees. Furthermore, it has a significant p-value 0.000 level, which is less than the ordinary value of 0.5 and confirms the hypothesis (H3) is also accepted (β = 0.627, p < 0.05, t < 10.85).

H_3: The alignment of interest has a substantial influence on the employee performance of the textile sector.

Next, we **hypothesized (H1)** that manager's support positively correlates with employee performance. Figures 2 and 3 highlight the positive β value of 0.023 but the t-value shows the non-significance effect of the independent variable on the dependent variable. This independent variable has a t-value of 0.298 that reflects its non-significance on the employee's performance in the textile sector of Pakistan. On the other hand the p-value 0.766 indicates non-significance because it is slightly above than standard value 0.05 and shows that hypothesis H_1 can be ignored to some extent (β = 0.023, p = 0.086 > 0.05, t = 0.298 < 1.960).

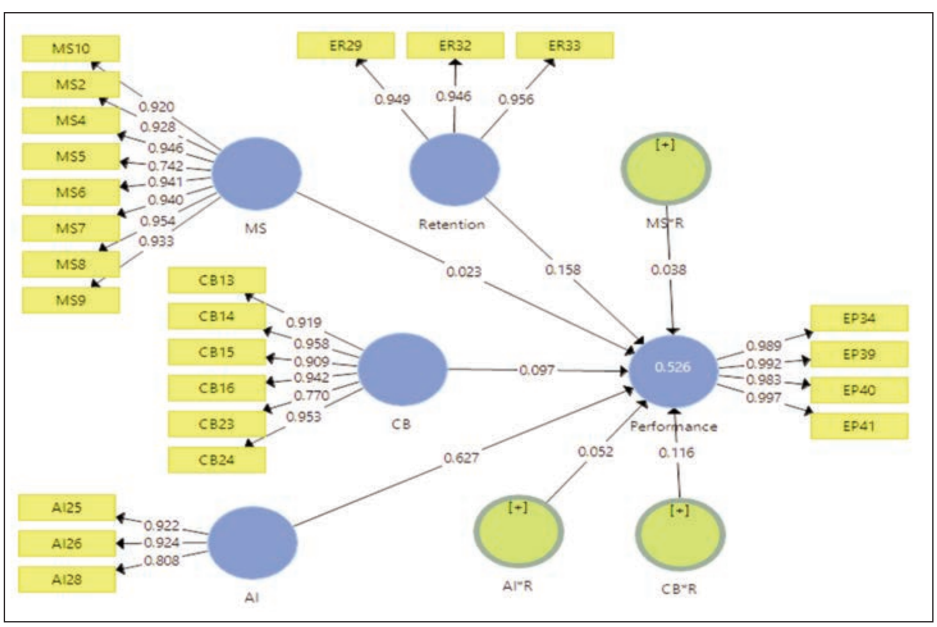

Fig. 2. PLS algorithm

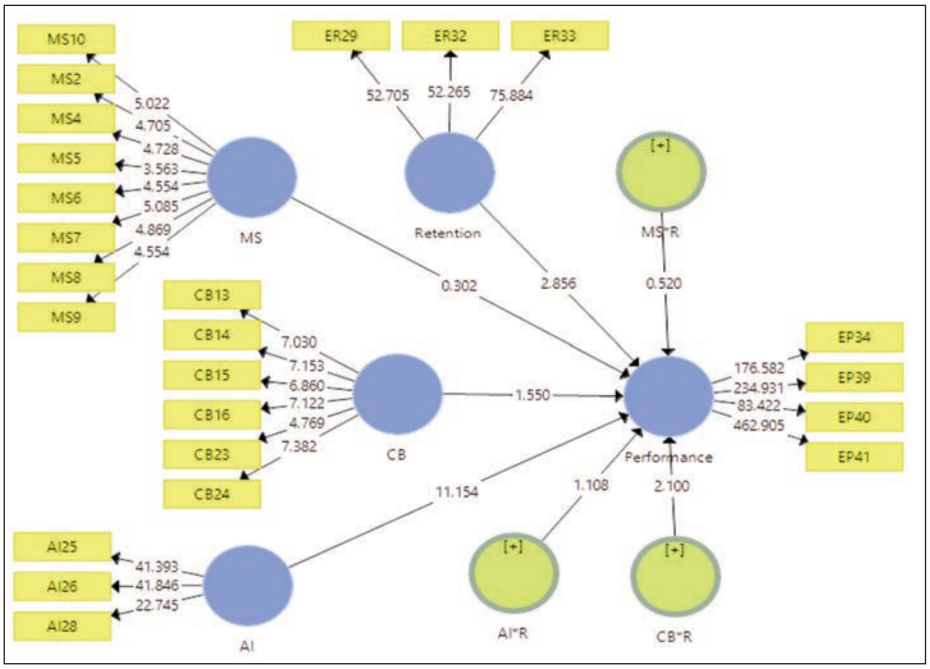

Fig. 3. Bootstrapping

Now, the capacity building has a positive influence on employee performance as per our **hypothesized (H2)**. In this context, table 4 highlights positive β value 0.097 and the p-value 0.040 < 0.5 substantiate the influence of the independent variable on the dependent variable. Furthermore, the t-value 2.628 reflects the high influence on employee performance in the textile sector. Accordingly, this hypothesis (H2) is also accepted ($\beta = 0.097$, $p < 0.05$, $t < 2.628$). Subsequently, we **hypothesized (H4)** that employee retention is a moderating variable between the manager's support, capacity building, alignment of interest and employee performance.

The positive β value 0.158, p-value 0.007 and t-value confirm that employee retention has moderated the relationship of manager's support and employee performance significantly. In the presence of the moderating effect between MS and EP, the t-value of moderation effect 0.038 reflects a positive influence between two variables and the p-value 0.561 is considered insignificant. Resultantly, **hypothesis (H_5)** is not supported ($\beta = 0.038$, $p > 0.05$, $t > 0.582$). The study hypothesis that employee retention has a moderating effect on the relationship between capacity building and employee performance. In this context, we conclude that our moderate variable has a significant influence on their relationship, as it has a t-value 2.152 and p-value 0.032. So, **hypothesis (H_6)** is also accepted by findings ($\beta = 0.116$, $p < 0.05$, $t < 2.152$). Then, the findings show that employee retention plays a moderating role between the alignment of interest and employee's performance. Figure 3 indicates that β value is 0.052, p = 0.006 and t-value = 2.114 show that employee retention has moderated the relationship of alignment of interest and employee performance significantly.

DISCUSSION

As per this study, the alignment of interest and capacity building has a positive and significant effect on employee performance in the textile sector of Pakistan and contributes 63% and 20% respectively. According to prior researches, it was concluded that the intellectual capital of employees will rise with the increase in training of employees and alignment of interest. Human resource development practices can be polished by training and capacity building programs, consequently, it will affect employees' intellectual capital positively and increase productivity and performance at work [48–49]. This relationship ultimately contributes to the organizational performance. Generally, employee retention and employee satisfaction can be achieved through training, development and capacity building [50]. The scope of capacity in individual skills includes program design, education and training to fill identified gaps in the skills and recommend a suitable number of qualified personnel to run the system.

Then, the hypothesis **H2** is accepted. Other studies conducted in connection with the hypothesis mentioned above (H2) have already studied capacity building in Pakistan's banking sector, and found that the indefinite reinforcement of 56% [40]. Wanyama et al. [51] research the relationship between employee efficiency and capacity building for commercial banks in Kenya and the conclusions signify the positive relationship between capacity building and employee productivity with ($\beta = 0.52$, $p < 0.05$).

With the comparison of empirical research, our study suggests that such claims are not convincing. Employee skills development, productivity and alignment of interest have a positive influence on organizational performance. Other studies conducted on the hypothesis **H1** discussed above, such as for Pakistan's banking sector, the support of Oversight and Organizational Support to Professional Development (OSCD) had a negligible effect on the employee performance [52]. They found a positive β value of 0.175, which means that the independent variable contributes 17.74% to the employee's performance. The indefinite t-value of the independent variable is 1.774, reflecting a lower involvement of management and OSCD in employee performance. Similarly, it indicates that the p-value is 0.1 levels, which is also less significant, above the standard value of 0.05. On the other hand, the research results of Saleem et al. [53] showed the effect of manager/supervisor support on the employee's performance. They found that ($\beta = 0.53$, $p < 0.05$, $t < 3.767$) and showed that the manager support and employee performance have a positive relationship with another. Besides, Noe [54] held this position and proved that manager support had a significant effect on an employee's developmental behaviour. The Smart PLS analysis suggests that development manager support ($\beta = 0.023$, $p < 0.766$) has an insignificant but positive effect on employee development behaviour.

Employee retention as a moderator in the relationship between managers is consistent with employee performance. The results ($\beta = 0.38$, $p < 0.007$, $t < 2.718$) show that retention of employees moderated the effect of the relationship between manager support and employee performance. So, hypothesis **H1** is not supported. The Smart PLS analysis suggests that development alignment of interest ($\beta = 0.627$, $p > 0.000$) has a significant and positive effect on employee development behaviour. Employee retention as a moderator in the relationship between the alignments of interest is consistent with employee performance. The results ($\beta = 0.052$, $p < 0.006$, $t < 2.14$) show that retention of employees moderated the effect on the relationship between the alignment of interest and employee performance and hypothesis **H3** is supported. In support of Hypothesis H3, Kwon et al. investigated the role of employee retention as a moderating relationship between the alignment of interest and employee performance, which has a significant and positive ($p < 0.02$) [55]. Alignment of interest is not merely used as a performance measure, but also for employee's satisfaction and reduces the turnover of the organization. In this context, Wright et al. [27] expresses that alignment of interest is not simply a performance measure but it shows the relationship and the level of contribution of an employee to corporate strategy.

CONCLUSIONS

This study engrossed in the alignment of interest, capacity building, manager support, employee retention and employee performance. Generally, the productivity of employees leads to progress in the textile sector. This study also includes the highlights of previous contributions to the factors that affect employee performance. Specifically, we focus on the alignment of interest and capacity building because the alignments of interest and employee skills development help to increase employee performance and productivity as approved by this research.

Additionally, this research focused on the role of manager support to employee performance and concludes that there is an insignificant impact of manager support on employee performance in the textile industry. According to our results, in the textile sector in Faisalabad, Pakistan, the relationship between the alignment of interest and employee performance in the presence of employee retention as a moderator is significant. Long-term employees have more interest in the organization such as shareholding and profit share and they are considered more loyal and concerned with the progress of the organization. So, its overall impact is positive on employee performance and provides opportunities for professional growth for their organizations.

RECOMMENDATION

Based on previous findings and conclusions, "it is recommended that alignment of interest, skill creation, and employee productivity be positively correlated with organizational performance". Therefore, companies need to plan and implement strategies that are in line with the objectives of a company and the interest of employees to improve the performance of employees. The size of the current study was small, future studies could clarify alignment of interest, capacity building and the effect of manager support in different occupational groups in a business environment is one of the major challenges facing the textile sector confronted. The main recommendation in retaining employees is that the textile sector should give the most important for the alignment of interest. Management should introduce employee benefit schemes to enhance the employee's interest. Shareholding and profit share to employees can also be considered. Moreover, capacity development and management support can create a sustainable competitive advantage over other key players. These aspects improve the efficiency of an employee. Hardworking employees ensure that companies succeed, and so they must be fully independent and allowed to take work decisions that produce better results. The importance of intellectual capital is highly recognized to improve employee performance. Currently, Pakistan's textile sector is likely to use its entire human capital. Where alignment of interest is so important for employees as well as a company but it is not in practice in the textile sector of Pakistan.

LIMITATIONS AND FUTURE RESEARCH

The interpretation of results has been done through cross-sectional data. Non-probability sampling technique is used for data collection versus probabilistic sampling which is considered more valid for generalizing the results. The small sample size also limits the generalization of results. Furthermore, the lack of collaboration among key agencies, non-leaders, training institutes and universities, it was difficult to collect accurate data from respondents. This study includes alignment of interest, capacity building and management support as key factors to improve employee performance, but there may be other factors that can affect the employee's performance.

REFERENCES

[1] Frazis, H., Gittleman, M., Joyce, M., *Correlates of Training: An Analysis Using Both Employer and Employee Characteristics*, In: ILR Rev., 2000, 53, 3, 443–462

[2] Groot, R., van den Molen, P., *Workshop on Capacity Building in Land Administration for Developing Countries,* 2000

[3] Mastrangelo, A., Eddy, E.R., Lorenzet, S.J., *The relationship between enduring leadership and organizational performance*, In: Leadersh. Organ. Dev. J., 2014, 35, 7, 590–604

[4] Hennig-Thurau, T., *Customer orientation of service employees: Its impact on customer satisfaction, commitment, and retention*, In: Int. J. Serv. Ind. Manag., 2004, 15, 5, 460–478

[5] Campbell, J.P., Gasser, M.B., Oswald, F.L., *The Substantive Nature of Job Performance Variability*, 1996, 258–299

[6] Mathis, R.L., Jackson, J.H., *Human Resource Management*, 12th ed., 2009

[7] Islam, M.Z., Siengthai, S., *Quality of work life and organizational performance: Empirical evidence from Dhaka Export Processing Zone,* 2009

[8] Roodt, G., Rieger, H.S., Sempane, M.E., *Job satisfaction in relation to organisational culture*, In: SA J. Ind. Psychol., 2002, 28, 2, 23–30

[9] Wanyama, K.W., Mutsotso, S.N., *Relationship between capacity building and employee productivity on performance of commercial banks in Kenya*, In: African J. Hist. Cult., 2010, 2, 5, 73–78

[10] Pfeffer, J., *Seven Practices of Successful Organizations*, In: Calif. Manage. Rev., 1998, 40, 2, 96–124

[11] Hughes, K.D., *Exploring Motivation and Success Among Canadian Women Entrepreneurs*, In: J. Small Bus. Entrep., 2006, 19, 2, 107–120

[12] Shabir Hyder, P., Lussier, R.N., *Why Businesses Fail*, In: J. Entrep. Manag. Sustain. Dev., 1983, 8, 1, 15–21

[13] Yukl, G.A., Becker, W.S., *Effective Empowerment in Organizations*, In: Organ. Manag. J., 2006, 3, 3, 210–231

[14] Zhang, A.Y., Tsui, A.S., Song, L.J., Li, C., Jia, L., *How do I trust thee? The employee-organization relationship, supervisory support, and middle manager trust in the organization*, In: Hum. Resour. Manage., 2008, 47, 1, 111–132

[15] Turk, W., *Manager or leader?*, In: Defense AT&L, 2007, 4

[16] Trinka, J.A., *What's a manager to do?*, In: Ind. Commer. Train., 2005, 37, 3, 154–159

[17] Scase, R., Goffee, R., *Women in management: towards a research agenda*, In: Int. J. Hum. Resour. Manag., 1990, 1, 1, 107–125

[18] Altinkurt, Y., Yilmaz, K., *Relationship between School Administrators' Organizational Power Sources and Teachers' Organizational Citizenship Behaviors*", In: Educational Sciences: Theory & Practice, 2012, 12, 3, 1843–1852

[19] Fullan, M., *The New Meaning of Educational Change*, Teachers College Press, New York, 2007

[20] Al□Roubaie, A., Building indigenous knowledge capacity for development, In: World J. Sci. Technol. Sustain. Dev., 2010, 7, 2, 113–129

[21] Crotts, J.C., Ford, R.C., Heung, V.C.S., Ngai, E.W.T., *Organizational alignment and hospitality firm performance*, In: Int. J. Cult. Tour. Hosp. Res., 2009, 3, 1, 3–12

[22] Becker, B., Gerhart, B., *The Impact of Human Resource Management on Organizational Performance: Progress and Prospects*, In: Acad. Manag. J., 1996, 39, 4, 779–801

[23] Boswell, W., Aligning employees with the organization's strategic objectives: out of 'line of sight', out of mind, In: Int. J. Hum. Resour. Manag., 2006, 17, 9, 1489–1511

[24] Delery, J.E., Shaw, J.D., *The strategic management of people in work organizations: Review, synthesis, and extension*, 165–197

[25] Truss, C., *Complexities and Controversies in Linking HRM with Organizational Outcomes*, In: J. Manag. Stud., 2001, 38, 8, 1121–1149

[26] Wright, P.M., Boswell, W.R., *Desegregating HRM: A Review and Synthesis of Micro and Macro Human Resource Management Research*, In: J. Manage., 2002, 28, 3, 247–276

[27] Wright, P.M., McMahan, G.C., *Theoretical Perspectives for Strategic Human Resource Management*, In: J. Manage., 1992, 18, 2, 295–320

[28] Truckenbrodt, Y.B., *The Relationship Between Leader-Member Exchange and Commitment and Organizational Citizenship Behavior*, In: Acquis. Rev. Q., 2000, 233–244

[29] Steers, R.M., *Antecedents and Outcomes of Organizational Commitment*, In: Adm. Sci. Q., 1977, 22, 1, 46

[30] Gul, A., Sciences, H.-M., Zeb, J., Apcoms, D., *Role of Capacity Development, Employee empowerment and Promotion on Employee Retention in the banking sector of Pakistan Sajjad Akbar*, 2012

[31] Cappelli, P., *A Market-Driven Approach to Retaining Talent*, In: Harv. Bus. Rev., 2000, 78, 1, 103

[32] Cole, C.L., *"Building Loyalty", Workforce*, 2000, 44–48

[33] Östör, Á., *Critical Events: An Anthropological Perspective on Contemporary India*, In: Am. Ethnol., 1997, 24, 4, 951–953

[34] Barrett, A., O'Connell, P.J., *Does Training Generally Work? The Returns to in-Company Training*, In: ILR Rev., 2001, 54, 3, 647–662

[35] Thite, M., *All that Glitters is not Gold: Employee Retention in Offshored Indian Information Technology Enabled Services*, In: J. Organ. Comput. Electron. Commer., 2010, 20, 1, 7–22

[36] Tan, H.H., Lim, A.K.H., *Trust in Coworkers and Trust in Organizations*, In: J. Psychol., 2009, 143, 1, 45–66
[37] Palomo, M., Beinart, H., Cooper, M.J., *Development and validation of the Supervisory Relationship Questionnaire (SRQ) in UK trainee clinical psychologists*, In: Br. J. Clin. Psychol., 2010, 49, 2, 131–149
[38] Frerk, C., et al., *Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults*, In: Br. J. Anaesth., 2015, 115, 6, 827–848
[39] Gligor, D.M., Holcomb, M.C., *Antecedents and Consequences of Supply Chain Agility: Establishing the Link to Firm Performance*, In: J. Bus. Logist., 2012, 33, 4, 295–308
[40] Asiya, G., Akbar, S., Jan, Z., *Role of Capacity Development, Employee empowerment and Promotion on Employee Retention in the banking sector of Pakistan*, In: Int. J. Acad. Res. Bus. Soc. Sci., 2012, 2, 9, 284–300
[41] Quresh, T.M., Akbar, A., Khan, M.A., Sheikh, R.A., Hijazi, S.T., *Do human resource management practices have an impact on financial performance of banks?*, In: African journal of business management., 2010, 4, 7
[42] Henseler, J., Ringle, C.M., Sinkovics, R.R., *The use of partial least squares path modeling in international marketing*, 2009, 277–319
[43] Hair, J.F., Ringle, C.M., Sarstedt, M., *PLS-SEM: Indeed a Silver Bullet*, In: J. Mark. Theory Pract., 2011, 19, 2, 139–152
[44] Hair, J.F., Sarstedt, M., Hopkins, L., Kuppelwieser, V.G., *Partial least squares structural equation modeling (PLS-SEM)*, In: Eur. Bus. Rev., 2014, 26, 2, 106–121
[45] Chin, W.W., *How to Write Up and Report PLS Analyses*, In: Handbook of Partial Least Squares, Berlin, Heidelberg: Springer Berlin Heidelberg, 2010, 655–690
[46] Kim, M.-K, Park, M.-C., Jeong, D.-H., *The effects of customer satisfaction and switching barrier on customer loyalty in Korean mobile telecommunication services*, In: Telecommunications Policy, 2004, 28, 2, 145–159
[47] Falk, R., Miller, N., *A primer for soft modeling*, 1992
[48] Guest, D.E., *Human resource management and performance: a review and research agenda*, In: Int. J. Hum. Resour. Manag., 1997, 8, 3, 263–276
[49] Asfaw, A.M., Argaw, M.D., Bayissa, G.L., *The Impact of Training and Development on Employee Performance and Effectiveness: A Case Study of District Five Administration Office, Bole Sub-City, Addis Ababa, Ethiopia*, In: Journal of Human Resource and Sustainability Studies, 2015, 3, 4, 188-202
[50] Fletcher, L., Alfes, K., Robinson, D., *The relationship between perceived training and development and employee retention: the mediating role of work attitudes*, In: Int. J. Hum. Resour. Manag., 2018, 29, 18, 2701–2728
[51] Wanyama, K.W., Mutsotso, S.N., *Relationship between capacity building and employee productivity on performance of commercial banks in Kenya*, In: African Journal of History and Culture, 2010, 2, 73–78
[52] Ahmad, T., Farrukh, F., Nazir, S., *Capacity building boost employees performance*, In: Ind. Commer. Train., 2015, 47, 2, 61–66
[53] Saleem, S., Sama, S., *The impact of organizational support for career development and supervisory support on employee performance: An empirical study from Pakistani academic*, European Journal of Business and Management, 2013, 5, 5
[54] Noe, R.A., *Is career management related to employee development and performance?*, In: J. Organ. Behav., 1996, 17, 2, 119–133
[55] Kwon, K., Chung, K., Roh, H., Chadwick, C., Lawler, J.J., *The moderating effects of organizational context on the relationship between voluntary turnover and organizational performance: Evidence from Korea*, In: Hum. Resour. Manage., 2012, 51, 1, 47–70

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Clothing fashion brands

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BRUNO ZAVRŠNIK VOJKO POTOČAN

ABSTRACT – REZUMAT

Clothing fashion brands

In the fashion, industry brands are especially important, because the competition is high, and companies need to attract new customers and keep them. Successful branding requires a good knowledge of consumers and their purchasing processes. Brands have an important function in the fashion world, both for businesses and consumers. The brand is assured to the consumers by the quality and by acquiring some image and status in the company. A strong brand makes a profit for the company. In addition, a strong brand enables setting high prices and expansion of product range and introducing new products.

In the survey, we wanted to examine the behaviour of customers in the clothing brands in the Slovenian market. We used a survey questionnaire to get the appropriate answers.

The survey found that most respondents want to buy clothes in larger shopping centres and in the Internet, most often during the sale after the season.

Keywords: *brand, fashion, consumer's behaviour, fashion clothes*

Branduri de modă pentru îmbrăcăminte

În modă, brandurile din industrie sunt deosebit de importante, deoarece concurența este mare, iar companiile trebuie să atragă noi clienți și să-i păstreze. Brandingul de succes necesită o bună cunoaștere a consumatorilor și a proceselor de cumpărare ale acestora. Brandurile au o funcție importantă în lumea modei, atât pentru companii, cât și pentru consumatori. Brandul asigură consumatorilor o înaltă calitate și dobândirea unei anumite imagini și statut în companie. Un brand puternic face profit pentru companie. În plus, un brand puternic permite stabilirea unor prețuri ridicate și extinderea gamei de produse, precum și introducerea de produse noi pe piață.

În cadrul sondajului, am dorit să analizăm comportamentul clienților în ceea ce privește brandurile de modă pentru îmbrăcăminte de pe piața slovenă. Am folosit un chestionar de sondaj pentru a obține răspunsurile adecvate.

Sondajul a constatat că majoritatea respondenților doresc să cumpere produse de îmbrăcăminte din centre comerciale mai mari și de pe internet, cel mai adesea în timpul reducerilor de la finalul sezonului.

Cuvinte-cheie*: brand, modă, comportamentul consumatorilor, îmbrăcăminte la modă*

INTRODUCTION

Fashion marketing uses a number of techniques and business philosophy that focus on actual and potential buyers of clothing and fashion accessories in order to achieve long-term goals of the organization [1].

In the fashion industry, the brand is a means of identification with certain fashion trends, styles and ways of life. A good brand has a clear identity.

Developing and building a brand is a strategically oriented activity. Understanding relationships between users and their fashion brands is essential for the marketing, as these links significantly affect the profitability of the company [2].

In the clothing industry fashion is dominant, which is why this industry is so specific and constantly under the influence of fashion culture. In the world, fashion and design are the leading European clothing industries. From the industry's point of view, a limited timeframe implies the increased need for flexibility in production, permitting continuous introduction of new lines and collections to the market, to satisfy the continuously evolving interests and expectations of consumers [3].

The trend of fashion development focuses on emphasizing comfort, focusing on light, breathable and warm materials adapted for the season. The advantage of today's fashion is the possibility of a comprehensive combination of clothing [4].

Retailers establish indirect contact between manufacturers and end-users. Their task is to ensure the appropriate volume and structure of supplies at affordable locations, at the same time and at prices that are acceptable to the end consumers [5, 6].

FASHION CLOTHING

Fashion is a unique, exciting and very dynamic market that undoubtedly shows an ability to generate changes of a social or cultural nature [7].

Fashion clothing has been described as possessing something approximating a code it is ever shifting and changing. Fashion clothing is considered a highly expressive product and one that is often used to communicate one's image and social position [8, 9]. The consumption of fashion clothing is in fact a sign of a society that focuses on status and is evidence of movement toward a heightened consciousness of the role of consumption and the value clothes play in communication status. Fashion carries status and is symbolic in expressing one's identity and importance [10].

Global mass-market fashion and beauty companies use standardized advertising to sell products to customers around the world to a greater extent than companies in other industries. For fashion companies, a crucial component of success is the presentation of a coherent brand to customers around the world [11].

Consumers are an important part of the fashion system because they can create a valuable influence in the pursuit of sustainability in the fashion industry [12, 13].

The brand gives the users psychological satisfaction and represents a greater guarantee of quality than the high price. The user associates the brand with quality, credibility and value. Customers evaluate brand performance differently and are prepared to pay more or less. The brand is therefore nothing more than a group of loyal users, so the activities of the manufacturer are aimed at extending the loyalty period of the selected brand.

THE RELATIONSHIP OF USERS TO THE PURCHASE OF CLOTHING BRANDS

Today's customer in the developed world does not always have more needs, but has more and more wishes, which are different, special and more demanding. Products, services and processes are becoming much more complex than they used to be. Buyers are becoming increasingly demanding and living in the time of the economy of desire and imagination, and not in the economy of needs. The desire of each designer is to form, the producer (both in the field of yarn, textiles and clothing) produce and the trader will only purchase such products that will be interesting for users. Experience, a comprehensive overview of events and changes in society and a good knowledge of the target group of users are needed for them to understand, anticipate and predict the wishes and needs of users.

In order to find out what is the attitude of consumers to purchasing clothes and the role of brands in the purchase process, we conducted a primary survey in 2018.

The questionnaire was completed by 235 adult individuals. It was submitted via online survey. The majority of respondents are female, with 143 responses, representing 61%. The males represent 39% of the sample, making 92 responses. Regarding their age, the majority focuses on the age group of 18 to 25 (31%), followed by the age group of 34 to 41 (29%), then 26 to 33 (17%) age and 42 to 49 years (14%). Only 9% respondents represent the group with more than 50 years.

First, we wanted to find out the gender, age and amount of monthly income. Then we were interested when and where consumers buy their clothes and what factors are most influencing their purchase of clothing. With the next question, we wanted to find out where shoppers get information about fashion clothing brands. Finally, we were interested in how consumers are loyal to the selected fashion clothes brands and their opinion about trademark counterfeiting.

Table 1

PERSONAL MONTHLY INCOME	
Monthly income (euros)	**Number of answers (%)**
Less than 1000	39
From 1000 to 1500	45
From 1501 to 2100	11
From 2101 to 3000	4
More than 3000	1

Table 1 shows that for the most respondents the monthly income is between 1,000 and 1,500 euro, and the next most common answer is less than 1,000 euro.

The next question was about the time of buying clothes.

Table 2

TIME TO BUY CLOTHES	
Time to buy clothes	**Number of answers (%)**
Only during the post-season sales	27
Equally throughout the year	26
Only when I really need something	21
Where discounts are offered, but not in the post-season sales	18
As soon as when the new collection come to the market	8

The results in table 2 show that shoppers mostly buy during the post-season sales and equally throughout the year. The least they buy when new collections come to the market.

With the next question, the respondents identified where they most often buy clothes. We got the following answers.

Most of them buy clothes in bigger shopping centres, because all stores are in one place and the shopping is quicker. In particular, the younger ones also buy online, while the elderly still have a high level of mistrust when buying online. The smallest group of them buy through catalogue sales and boutiques of

Table 3

PLACE OF BUYING CLOTHES	
Place of buying clothes	**Number of answers (%)**
Bigger shopping centres and department stores	34
In smaller stores in the city centre	20
On the Internet	19
Abroad	16
In boutiques of Slovenian designers	6
On catalogue sales	5

Slovenian designers, as they are accessible only to a handful of users.
We also wanted to know how fashion-clothing brands are important in shopping.

Table 4

IMPORTANCE OF FASHION CLOTHING BRANDS	
Importance of fashion clothing brands	**Number of answers (%)**
Very important	38
Important but not decisive	35
Not important	27

When asked how important fashion clothing brands are to users, 38 % of respondents said that brands were very important, 35% said they were important but not decisive, and 27% of respondents said that brands are not important.
The following question was related to the purchase of domestic and foreign brands

Table 5

DOMESTIC AND FOREIGN BRANDS	
Buying domestic and foreign brands	**Number of answers (%)**
Buying domestic and foreign	45
Buying mostly foreign	33
Buying mostly domestic	12
It does not matter	10

The results showed that almost half of the shoppers buy domestic and foreign brands. Compared to whether or not they are buying more domestic or foreign brands, we see that foreign brands are in advantage because shoppers more often buy them than the domestic ones. This is because there are more foreign brands in Slovenia, few are home-made, but they are not well known to shoppers, because companies invest too little money in marketing communications in order to gain greater recognition.

Table 6

THE FACTORS OF INFLUENCING THE PURCHASE	
Factors	**Number of answers (%)**
Price	28
Brand Name	25
It is important that the clothes are suitable	25
Quality	15
Other	7
On catalogue sales	5

We were also interested in what factors most influence shoppers when buying clothes.
The results showed that shoppers first look at the price, which is expected data in today's time and match the structure of the personal monthly income of the respondents, since most of them belong to the lower income group. The quality is only on the fourth place. As other, respondents indicated the lists of the packaging, the look of the product, the image of product, the colour of clothing and the clothing material.
When we asked respondents what attracts consumers when buying clothes, the respondents said differently. The results are shown in the table 7 below.

Table 7

THE FACTORS OF ATTRACTION WHEN PURCHASING PARTICULAR CLOTHES	
Factors	**Number of answers (%)**
Design	33
Brand Name	18
Quality	16
Need for a product	16
Price	11
Other	6

Most respondents said that they are first attracted by the design of the product, which is understandable, as even before the customer sees the price and quality of the product, the clothes can be seen from afar and then one look at the quality, price or brand name. The brand name is also very important, as it is the second most common answer. As other, the respondent stated the colour of the clothes, the clothing material and the fact that the clothes are displayed in the exhibition.
Where do shoppers get information about fashion clothing brands was our next question.
The table 8 shows that shoppers get the most information about brands on the Internet, which is logical, since the Internet has become an important factor in all other areas in the last decade. Friends and fashion shows are also an important source of information. The most common way to get information about brand is from newspaper and mail sent to home. As

Table 8

GETTING TO KNOW THE FASHION CLOTHING BRANDS	
Source of information	**Numberof answers (%)**
On the Internet	28
From friends	21
In fashion shows	16
From clothing sellers	11
On television	10
From newspapers	5
From mail sent to home	5
Other	4

other, respondents cited leaflets and outdoor advertising.

We were also interested how customers are loyal to individual brands.

Table 9

LOYALTY TO BRAND NAME	
Loyalty	**Number of answers (%)**
Very loyal	35
Loyal until I find a better brand	35
I am not loyal because brands are not important to me	16
I am not loyal because I like to constantly change brands	14

The results showed that customers are very loyal to individual brands or are loyal at least as long as they do not find a better brand. It is therefore important that companies invest heavily in brand names and build a brand identity.

Trademark counterfeiting is widespread in the world, especially in the fashion brand of clothing and footwear. Replies of respondents to this question are shown in the table 10.

Nearly three quarters of respondents believe that trademark counterfeiting is ethically controversial, which is a positive thing. Buying a fake product instead of a recognized brand is a harmful act, because it can hide the exploitation of children and the possible use of toxic substances. It is an illegal act and through the Internet sale of counterfeit goods, it is spreading even faster. That is why it is important for consumers to be aware of what they are doing when they buy fake products.

Table 10

TRADEMARK COUNTERFEITING	
Trademark counterfeiting is	**Number of answers (%)**
Ethically controversial	74
Not ethically controversial	20
I do not know	6

Finally, we asked respondents about buying fake brands. 37% respondents said they had already purchased a fake brand and 62%) had never bought.

Despite the fact that the majority believe that purchase, of a fake brand is ethically controversial, as many as 37% have purchased such products. Maybe that is so because the original products are much more expensive and more difficult to get it.

However, counterfeiting is also, in some ways, theft, as counterfeiters violate intellectual property laws. If someone buys such products, they can support the exploitation of children and finances illegal activities.

CONCLUSIONS

Fashion offers the consumers the ability to express individuality and has been constantly changing and bringing about novelties throughout history. A successful fashion clothes brand must evoke positive feelings for the consumer, and must represent confidence, quality, reliability and prestige. Therefore, companies need to design and build strong brands, with a clear identity. In the fashion industry, brands are particularly important as competition is high and businesses need to attract and retain new customers. Successful branding requires a good knowledge of consumers and their purchasing processes.

In the fashion industry, understanding the concept of fashion marketing is extremely important, as companies face great competition from new products. The domestic supply of clothing is relatively modest. The main reason is that in Slovenia there are just a few Slovenian clothes brands of average quality that would be accessible to most consumers. We have some top designers who design prestigious fashion clothes for only a handful of individuals. The supply of foreign clothing brands is very good in Slovenia, because Slovenia is part of the European Union, where the range of different fashion clothing brands is huge from all over the world.

REFERENCES

[1] Easey, M., *Fashion marketing. In: Wiley-Blackwall*, Oxford, John Wiley & Sons, Ltd., Publication, 2009

[2] Ismail, A.R., Spinelli, G., *Effects of brand love, personality and image on word of mouth: The case of fashion brands among young consumers,* In: Journal of Fashion Marketing and Management, 2012, 16, 4, 386–398

[3] Surchi, M., *The temporary store: a new marketing tool for fashion brands*, In: Journal of Fashion Marketing and Management, 2011, 15, 2, 257–270

[4] Goworek, H., *An investigation into product development processes for UK fashion retailers: A multiple case study*, In: Journal of Fashion Marketing and Management, 2010, 14, 4, 648–662
[5] Burstiner, I., *Basic retailing*, In: Boston, Richard D. Irwin, Inc Homewood, 1991
[6] Berman, B.R., Evans, J.R., *Retail Management: In: A Strategic Approach (12th Edition),* Prentice Hall, 2012
[7] Kaczorowska-Spychalska, D., *Shaping Consumer Behaviour in the Fashion Industry by Interactive Communication Forms*, In: Fibres & Textiles in Eastern Europe, 2018, 26, 4, 13–19
[8] O'Cass, A, McEwan, H., *Exploring consumer status and conspicuous consumption*, In: Journal of Consumer Behaviour, 2004, 4, 1, 25–39
[9] O'Cass, A., Siahtiri, V., *Are young adult Chinese status and fashion clothing brand conscious?* In: Journal of Fashion Marketing and Management, 2014, 18, 3, 284–300
[10] Han, Y.J., Nunes, J.C., Dre`ze, X., *Signalling status with luxury goods: the role of brand prominence*, In: Journal of Marketing, 2010, 74, 4, 15–30
[11] Aagerup, U., Scharf, E.R., *Obese models' effect on fashion brand attractiveness*, In: Journal of Fashion Marketing and Management, 2018, 22, 4, 557–570
[12] Dofles, G., *Mode & Modi*, In: Zagreb, Golden marketing, 1997
[13] Kutsenkova Z., *The Sustainable Future of the Modern Fashion Industry*, In: Honour's Theses and Capstone Projects, 2017, 21

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Quality yarn index using AHP and Fuzzy method

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ABSTRACT – REZUMAT

Quality yarn index using AHP and Fuzzy method

*The yarn quality depend***s** *on many parameters: characteristics parameters, mechanical and physical properties. Making the hypothesis that the quality of the yarn is a multicriteria problem, in this paper, we propose a new method to determine the Quality Yarn Index QYI based on Analytic Hierarchy Process AHP and Fuzzy theory.*
A questionnaire was designed for experts of each field (weaving and knitting) to evaluate the relative importance for each property to determine coefficients of the AHP matrix.
Results revealed that matrix coefficients changed with yarn application (weft or warp weaving and knitting)
The QYI can be used in any application, where a rapid decision is needed, to evaluate the global quality of yarn and to make a comparison between different yarn qualities.

Keywords: *yarn quality index, mechanical properties, physical properties, Fuzzy AHP*

Determinarea indicelui de calitate al firelor folosind metoda AHP Fuzzy

Calitatea firului depinde de mulți parametri: caracteristici mecanice și fizice. Bazându-ne pe ipoteza conform căreia calitatea firului este o problemă multicriterială, în această lucrare, propunem o nouă metodă de determinare a indicelui de calitate a firului QYI bazat pe Procesul de ierarhie analitică AHP și teoria Fuzzy.
A fost conceput un chestionar pentru experții din fiecare domeniu (țesătorie și tricotaje), pentru a evalua importanța relativă pentru fiecare caracteristică, cu scopul de a determina coeficienții matricei AHP.
Rezultatele au redat modificarea coeficienților matricei odată cu schimbarea domeniului de utilizare al firelor (țesere și tricotare în bătătură sau urzeală).
QYI poate fi utilizat în orice aplicație, acolo unde este necesară o decizie rapidă, pentru a evalua calitatea globală a firelor și pentru a face o comparație între diferiți indici de calitate ai firelor.

Cuvinte-cheie: *indice de calitate al firelor, caracteristici mecanice, caracteristici fizice, Fuzzy AHP*

INTRODUCTION

The Textile yarns are used in a wide range of applications: warp and weft weaving, knitting, garment industry. The Quality of yarn directly affects the yield of production and the quality of the final product. For a long period, yarn quality was qualified through its strength [1–6].
Quality of yarn is a multi-criteria problem that needs the simultaneous satisfaction of a lot of properties (mechanical, physical properties …)
Yunus [7] proposed a yarn quality index considering yarn strength, elongation, and uniformity. This index was used in some research papers to optimise the quality of waste yarn [8–9].
Souied [10] proposed a method based on Soft Computing Technique to predict the Global Yarn quality from that of fiber.
Recently, Wannssi proposed to use AHP method to optimise the global quality of yarns with different waste ratio taking into account the fiber price [11].
In the textile industry, it is very useful to use a Global Quality Index, especially when purchasing in order to make a rapid comparison between yarn quality from different suppliers and when comparison of a new yarn quality to standard is necessary. This Index should be determined according to customer satisfaction criteria that varies from one final product application to another.
In this paper, we propose a new method to determine the Quality Yarn Index QYI based on Analytic Hierarchy Process AHP and Fuzzy theory.
A questionnaire was designed for experts of each field (weaving and knitting) to evaluate the relative importance for each property to determine coefficients of the AHP matrix.

Materials and methods

Yarn Quality Index

According to Yunus [7], a Yarn quality Index can be expressed by the following formula:

$$YQI = \frac{YSt \times YEl}{YCv} \tag{1}$$

where *YSt* is Yarn Strength, *YEl* – Yarn Elongation, *YCv* – Yarn Uneveness.
This index has many advantages, it is simple and takes into account most of the important properties of yarn but also has disadvantages:

– Some other important properties of the yarn are missing (Neps, Hairiness, Elasticity…);
– The index considers that all the properties have the same importance (weight = 1).

Taking into account, these remarks, we propose in our study a new empirical index of yarn quality. This index can be expressed by the following formula:

$$YQI = \sum_{i=1}^{n} WGi\ GPi \qquad (2)$$

$$\sum_{i=1}^{n} WGi = 1 \qquad (3)$$

where *GPi* is Global property *i* of the yarn (Dynamometric property, Uneveness, Hairiness…), *WGi* – Weight of the global property *I*, *n* – Number of yarn properties to take into account.

Each global property *GPi* can be expressed as a function of Relative Properties of the yarn *RPj* (for example the Global property of the yarn: dynamometric properties, can be expressed by the relative properties: tenacity, breaking elongation and elasticity).

$$GPi = \sum_{j=1}^{mi} WRji\ RPji \qquad (4)$$

$$\sum_{j=1}^{mi} WRji = 1 \qquad (5)$$

where *RPji* is Relative property *j* of the Global property *i* of the yarn, *WRji* – Weight of the relative property *j* to the global property *i* of the yarn, *mi* – Number of relative properties related to the global property *I* of the yarn.

The objective of our study is to propose an appropriate approach based on AHP and Fuzzy methods to determine respectively the weights of Global properties of the yarn WGi and the weights of relative properties WRji based on customer satisfaction and final application of the yarn (weaving, knitting…).

Fuzzy AHP process

AHP is a common multi-criteria decision making method. It is developed by Saaty [12] to assist in solving complex decision problems by capturing both subjective and objective evaluation measures. The fuzzy AHP method includes the uncertain (imprecise) judgment of experts by utilizing linguistic variables (table 1). Recently many researchers have used this approach in various areas [13–15].

In fuzzy AHP, $\breve{A} = (\breve{a}_{ij})$ is a fuzzy pairwise comparison judgment matrix, with $\breve{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ the pairwise comparisons between the elements *i* and *j* and a triangular fuzzy number where l_{ij} and u_{ij} are the lower and upper limits respectively and m_{ij} the modal value and $l_{ij} \le m_{ij} \le u_{ij}$. If $l_{ij} = m_{ij} = u_{ij}$ it is considered a non-fuzzy number by convention. The membership function μ_x is defined as:

$$\mu(x) = \begin{cases} \frac{x}{m-l} - \frac{l}{m-l}, & x \in [l,m] \\ \frac{x}{m-u} - \frac{1}{m-u}, & x \in [m,u] \\ 0, & otherwise \end{cases} \qquad (6)$$

Table 1

FUZZY AHP METHOD		
Preference of pairwise comparisons	**Fuzzy scale**	**Fuzzy reciprocal scale**
Just equal	(1,1,1)	(1,1,1)
Very weakly more important	(1/2,1,3/2)	(2/3,1,2)
Weakly more important	(1,3/2,2)	(1/2,2/3,1)
Moderately more important	(3/2,2,5/2)	(2/5,1/2,2/3)
Strongly more important	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more important	(5/2,3,7/2)	(2/7,1/3,2/5)

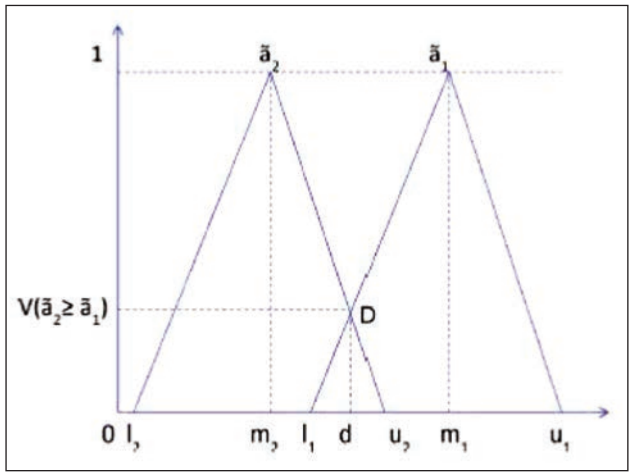

Fig. 1. Intersection between $\tilde{a}_1$ and $\tilde{a}_2$

The procedure for applying fuzzy AHP is as follows [16,17]:

- Define the hierarchical structure of the decision problem.
- Make pairwise comparisons of criteria at the same level of hierarchy using fuzzy numbers to construct the matrix $\breve{A}$.
- The fuzzy synthetic extent value (Si) with respect to the i^{th} criterion is defined as:

$$\widetilde{S}_i = \sum^{m} \widetilde{a}^j_{g_i} \times \left[\sum^{n}\sum^{m} \widetilde{a}^j_{g_i}\right]^{-1} \qquad (7)$$

where g_i are the goals of the hierarchy and $\widetilde{a}^j_{g_i}$ is a triangular fuzzy number of the decision matrix $\breve{A}$ with *n* objects and *m* goals.

- The degree of possibility is calculated by:

$$V(\tilde{a}_2 \ge \tilde{a}_1) = hgt(\tilde{a}_1 \cap \tilde{a}_2) = \mu_{\tilde{a}_2}(d) = \\ = \begin{cases} 1, & \text{if } m_2 \ge m_1 \\ 0, & \text{if } l_1 \ge u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases} \qquad (8)$$

Where *d* is the ordinate of the highest intersection point *D* between $\mu_{\tilde{a}_1}$ and $\mu_{\tilde{a}_2}$.

- The minimum degree of possibilit of $V(\tilde{S}_j \ge \tilde{S}_i)$ for $i, j = 1, 2, ..., n$ is calculated:

$$V(\tilde{S}_j \ge \tilde{S}_1, \tilde{S}_2, ..., \tilde{S}_n) = V(\tilde{S}_j \ge \tilde{S}_1) \text{ and } V(\tilde{S}_j \ge \tilde{S}_2) \\ \text{and } ...\ V(\tilde{S}_j \ge \tilde{S}_n) = \min V(\tilde{S}_j \ge \tilde{S}_i),\ i = 1, 2, ..., n \qquad (9)$$

- If $\acute{d}(A_i) = \min V(\tilde{S}_j \geq \tilde{S}_i)$ for $j = 1, 2, ..., n$ and $j \neq i$. The weight vector is:

$$W = (\acute{d}(A_1), \acute{d}(A_2), ..., \acute{d}(A_n))^T \tag{10}$$

- Via normalization, the normalized weight vectors are given as follow:

$$W = (d(A_1), d(A_2), ..., d(A_n))^T \tag{11}$$

- Notice that $\acute{A}$ is considered consistent if $\acute{A} \times W = n \times W$.
- The consistency ratio (CR) is calculated from as:

$$CR = \frac{CI}{RCI} = \frac{Consistency\ Index}{Random\ Consistency\ of\ A} \tag{12}$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{13}$$

where λ_{max} is equal to the sum of the elements of the column vector $\acute{A}W$.
RCI is generated by a random matrix of similar dimension. Random consistency index (RCI) for the matrix of the order of 1 to 15 as shown in table 2.
If *CR* is less than 0.1, the judgments given in a comparison matrix are adequa.

Table 2

RANDOM CONSISTENCY INDEX [12]

N	1,2	3	4	5	6	7	8	9	10
RCI	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

RESULTS AND DISCUSSION

Contrary to knitting fabric technology where only one set of yarns are used, in woven fabric manufacturing two types of yarns are needed: warp and weft yarns. To ensure the quality of each kind of fabric, different yarn properties are required.
Most of the spinners work continuously to predict and translate a set of requirements for spinning guidelines that satisfy weaver and knitters standards.

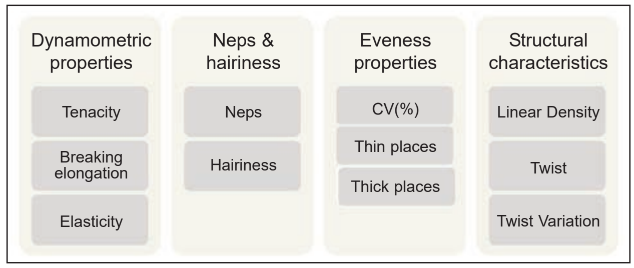

Fig. 2. Hierarchical Structure of Yarn Properties

For this purpose, a fuzzy AHP model has been developed to assess the yarn importance for the three yarn types: warp, weft, and knitting.
Firstly, the weight of each yarn properties will be determined and then for each application, a Global Yarn Quality index will be defined.
Based on literature review then spinners, weavers and knitters managers interviewing, four main criteria were defined for the most important yarn properties required for weaving (wrap and weft) and knitting technologies: Dynamometric properties, Neps & Hairiness, Evenness properties, and structural characteristics. Within each main criterion, there are various sub-criteria to which we assign specific descriptors (figure 2).
Two experts provided judgments for each yarn types: warp, weft, and knitting. These experts used for obtaining the fuzzy numbers have over ten years' experience in weaving and knitting fields. Fuzzy numbers have been used to assign weightings to the criteria and sub-criteria. They were asked to evaluate the importance of the criteria and sub-criteria applying the triangular fuzzy scale shown in table 1. The pairwise comparison matrix for the criteria given by the experts is shown in table 3.
Upon completing the model analysis, the criterion with the highest weightage was found for each yarn employment: weaving warp, weaving weft and knitting yarn (table 4). It was found that the dynamometric property is the most important criterion throughout. It is worth noting that the mechanical properties of the yarn affect both mechanical properties of fabric and

Table 3

PAIRWISE COMPARISON MATRIX OF CRITERIA (TWO EXPERTS)

Properties	Dynamometric properties			Neps & hairiness			Evenness properties			Structural characteristics		
	Warp yarn	Weft yarn	Knitting yarn	Warp yarn	Weft yarn	Knitting yarn	Warp yarn	Weft yarn	Knitting yarn	Warp yarn	Weft yarn	Knitting yarn
Dynamometric properties	(1,1,1)	(1,1,1)	(1,1,1)	(1/2,1,3/2)	(1/2,1,3/2)	(1,1,1)	(3/2,2,5/2)	(1/2,1,3/2)	(1,1,1)	(2,1,3/2)	(3/2,2,5/2)	(1,1,1)
	(1,1,1)	(1,1,1)	(1,1,1)	(3/2,2,5/2)	(1,3/2,2)	(3/2,2,5/2)	(1/2,1,3/2)	(1/2,1,3/2)	(1,3/2,2)	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)
Neps & hairiness				(1,1,1)	(1,1,1)	(1,1,1)	(1,3/2,2)	(1,1,1)	(1,1,1)	(3/2,2,5/2)	(1/2,1,3/2)	(3/2,2,5/2)
				(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(3/2,2,5/2)	(1,1,1)	(1/2,1,3/2)
Evenness properties							(1,1,1)	(1,1,1)	(1,1,1)	(1/2,1,3/2)	(1/2,1,3/2)	(3/2,2,5/2)
							(1,1,1)	(1,1,1)	(1,1,1)	(3/2,2,5/2)	(1/2,1,3/2)	(2,5/2,3)
Structural caracteristics										(1,1,1)	(1,1,1)	(1,1,1)
										(1,1,1)	(1,1,1)	(1,1,1)

Table 4

WEIGHT OF THE GLOBAL PROPERTIES WGI FOR THE DIFFERENT YARNS USED						
Properties	**Weaving warp yarn**		**Weaving weft yarn**		**Knitting yarn**	
	Weight	Rank	Weight	Rank	Weight	Rank
Dynamometric Properties	0.297	1	0.270	1	0.433	1
Neps & hairiness	0.288	2	0.152	3	0.249	3
Evenness Properties	0.221	3	0.317	2	0.283	2
Structural characteristics	0.192	4	0.258	4	0.033	4
Consistency ratio (CR)	0.049		0.065		0.020	

yarn breakage during the process of transformation. For example, a yarn with high tenacity leads to a fabric with high tenacity. On the other hand, when the elasticity of the yarn decreases the probability to cause breakage in weaving preparation (for example) increases.

Evenness Properties is the second important criterion for both weaving weft and knitting yarn with a weight of (0.317) and (0.283), respectively.

A defect on yarn affects both yield of production (for example when the number of thin places increases the yield of knitting process decreases) and final declassification of fabric (Fabric with a high rate of defects will be considered as a poor quality product).

All these conclusions are in agreement with previous studies [18–20].

The variation in the weight values can be explained by the difference in the final use of the yarn.

For example, mechanical constraints applied to warp yarns during weaving are more important than that for weft yarns.

Figure 3 presents the relative weight and the ranking of each property studied for the three yarn employments. Since *CR* is less than 0.1, the consistency ratio of *Ǎ* is acceptable [16, 17]. Results indicate for each yarn the characteristic that spinner or knitter should give the priority to improve the quality and therefore, the customer satisfaction.

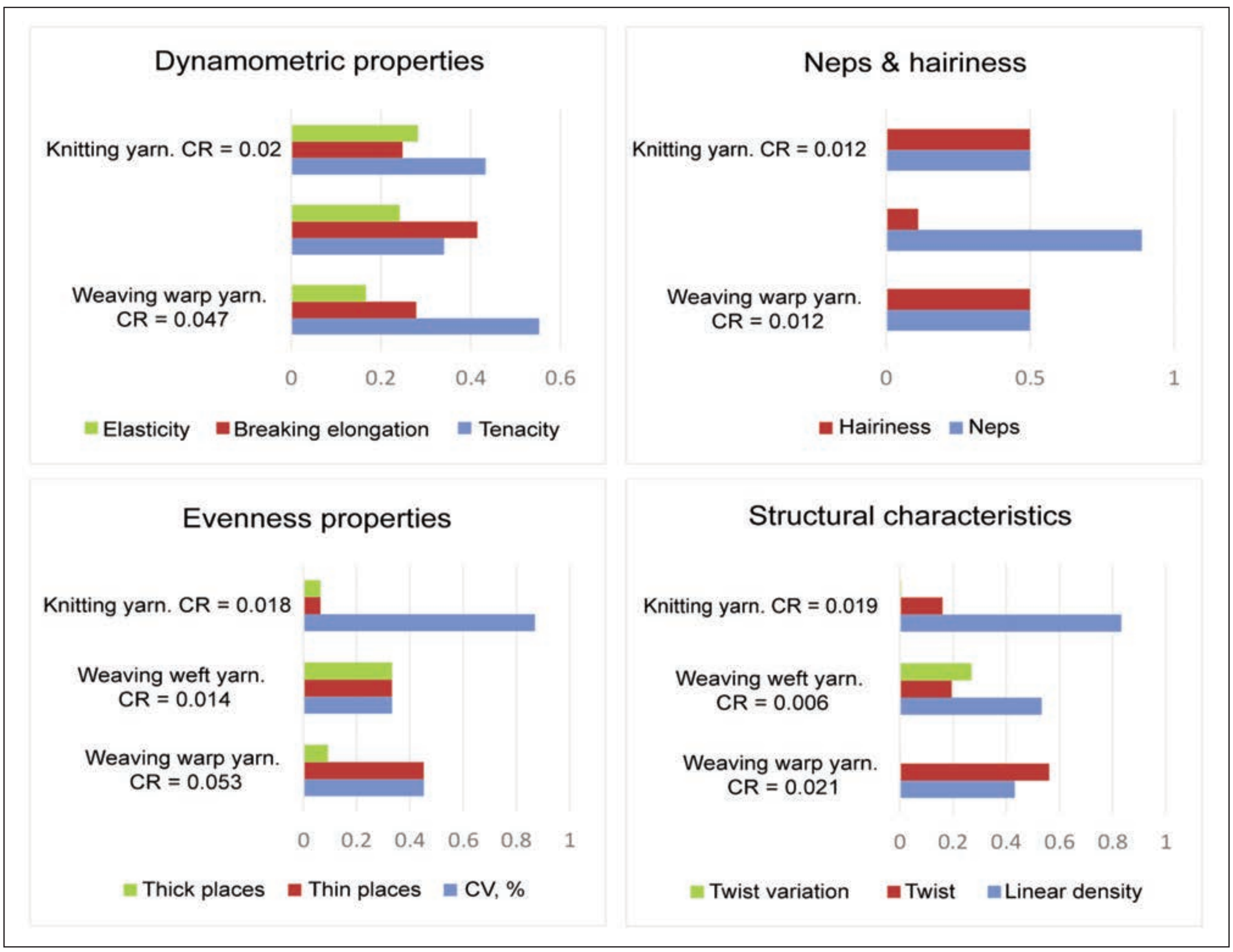

Fig. 3. Weights and ranking of sub criteria

CONCLUSION

The evaluation of the global quality of the yarn is a multi-criteria problem. In many cases, especially when we make a survey to optimise the properties of yarns, we need a Global Quality Index.

In this paper, we used the 'new approach' Analytic Hierarchy Process AHP and Fuzzy theory to determine a simple Quality Yarn Index QYI taking into account important properties of the yarn and their weights.

This same approach can be used in other textile fields when different properties affect the quality of the final product.

Further studies are necessary to apply the method for a specific application (optimization of the quality of waste yarn for example).

REFERENCES

[1] Cheng, L., Adams, D.L., *Yarn strength prediction using neural networks. Part1: Fiber properties and yarn strength relationship*, In: Text. Res. J., 1995, 65, 9, 495–500

[2] Ramesh, Mc., Rajamaniachan, R., Jayaraman, S., *The prediction of yarn tensile properties by using artificial neural networks*, In: Text.Res. J.,1995, 86, 459–468

[3] Sette, S., Boullart, L., Vangenhove, L., Kiekens, P., *Optimizing the fiber-to-yarn production process with a combined neural network / Genetic Algorithm Approach*, In: Text. Res, J., 1997, 67, 2, 84–92

[4] Rangaswamy, R., Hassen, M.S., Jayaraman, S., *Analysis of the modeling methodologies for predicting the strength of Air-Jet spun yarns*, In: Text. Res. J., 1997, 67, 39–44

[5] El Mogahzy, Y., Broughton, Jr.R., Lynch, W.K., *A statistical approach for determining the technological value of cotton using HVI fiber properties*, In: Text. Res. J., 1990, 59, 495–500

[6] Pan, N., Hua, T., Qiu, Y., *Relationship between fiber and yarn strength*, In: Text. Res. J., 2001, 71, 960–964

[7] Yunus, M., Rhman, F., *Micronaire Effects*, In: Text. Asia., 1990, 13, 58–61

[8] Halimi, M.T., Ben Hassen, M., Sakli, F., *Effect of cotton waste and spinning parameters on rotor yarn quality*, In: Journal of the Textile Institute, 2007, 98, 5, 437–442

[9] Halimi, M.T., Ben Hassen, M., Sakli, F., *Influence of spinning parameters and recovered fibers from cotton waste on the uniformity and hairness of rotor spun yarn*, In: Journal of Engineered Fibers and Fabrics, 2009, 4, 3, 36–44

[10] Souid, H., Sahnoun, M., Babay, A., Cheikrouhou, M., *A Generalized Model for Predicting Yarn Global Quality Index*, In: The Open Textile Journal, 2012, 5, 8–13

[11] Wanassi, B., Azzouz, B., Ben Hassen, M., *Sustainable Denim Yarn: Quality-Cost Analysis and Analytic Hierarchy Process (AHP) Optimization*, In: AATC Journal of Research, 2018, 5, 4, 17–24

[12] Saaty, T.L., *Fundamentals of decision making and priority theory with the analytic hierarchy process*, Pittsburgh, PA: RWS Publications, 1994

[13] Prakash, C., Barua, M.K., *Integration of AHP-TOPSIS method for prioritizing the solutions of reverse logistics adoption to overcome its barriers under fuzzy environment*, In: Journal of Manufacturing Systems, 2015, 37, 599–615

[14] Dweiri, F., Kumar, S., Khan, S.A., Jain, V., *Designing an integrated AHP based decision support system for supplier selection in automotive industry*, In: Expert Systems With Applications, 2016, 62, 273–283

[15] Chan, F.T.S., Kumar, N., *Global supplier development considering risk factors using fuzzy extended AHP-based approach*, In: Omega, 2007, 35, 4, 417–31

[16] Carnero, M.C., *Multicreteria for maintenance benchmarking*, In: Journal of manufacturing systems, 2014, 33, 303–321

[17] SeongKon, L., Gento, M., SangKon, L., JongWook, K., *Prioritizing the weights of hydrogen energy technologies in the sector of the hydrogen economy by using a fuzzy AHP approach*, In: International Journal of Hydrogen Energy 2011, 36, 1897–902

[18] Zulfikar, A.M., Tanveer, H., Mumtaz, H.M., *Selection of Yarn for the Predefined Tensile Strength of Cotton Woven Fabrics*, In: Fibers and Polymers, 2011, 12, 2, 281–9287

[19] Pelin, U., Mustafa, E., Diren, M., *Predicting Properties of Single Jersey Fabrics Using Regression and Artificial Neural Network Models*, In: Fibers and Polymers, 2012, 13, 1, 87–95

[20] Levi, A., et al., ISCIS 2006, LNCS 4263, 325–333

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Implementation of image processing techniques as a tool for form analysis of Romanian folk elements

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ABSTRACT – REZUMAT

Implementation of image processing techniques as a tool for form analysis of Romanian folk elements

The present paper proposes a method for an effective analysis of Romanian folk motifs using two basic algorithms – Radius-Vector function (RV) and Principal Component Analysis (PCA). For a better accuracy of the analysis, a combination of these methods has been proposed. The authors selected few Romanian folk motifs (embroidered on blouses*, skirts called "poale", front aprons called "zadii", sleeveless vest) from Bihor, Arad, and Maramures Counties. The vectorization of traditional motifs was made by GIS software.*

Keywords: *traditional folk costumes, folk motives, Radius-Vector function, Principal Component Analysis (PCA)*

Implementarea tehnicilor de procesare a imaginilor ca instrument pentru analiza formei elementelor tradiționale românești

Lucrarea de față propune o metodă pentru analiza eficientă a motivelor populare românești folosind doi algoritmi de bază – funcția Radius-Vector (RV) și Analiza componentelor principale (PCA). Pentru o mai bună precizie a analizei, a fost propusă o combinație a acestor metode. Autorii au selectat câteva motive tradiționale românești (brodate pe cămăși, poale, zadii, veste) din județele Bihor, Arad și Maramureș. Vectorizarea motivelor tradiționale a fost realizată folosind Software-ul GIS.

Cuvinte-cheie: *costume populare tradiționale, motive populare, funcția Radius-Vector, Analiza componentelor principale (PCA)*

INTRODUCTION

By its beauty and remarkable artistic value, the folk costumes can be transformed into the best ambassador of Romania. Unfortunately, today's authenticity is increasingly replaced by kitsch, the interest in preserving, putting to good use and transmitting the material of cultural treasure is fading away. Therefore, much of our cultural dowry is disappearing. Although they have a great variety of shapes and ornaments, the traditional costumes from Crisana (Bihor, Arad County) and Maramures have not been studied enough and exploited thoroughly. That is why we believe that we should do everything in our power to preserve the traditional motifs found in the costumes of these ethnographic areas, in order to preserve and promote them, thus saving them from being extinct. This approach is seen as a symbol for redeeming the past for a sustainable future of the traditional motives and a way to convey the love for the inherited beauty of the past, finally yet very important to develop the feeling of local pride.

The digitization of cultural heritage and Romanian traditional motifs is an activity that has gained great momentum over the past two decades together with the development of computing technology. Today it is very common to obtain vector information through digitization. Along with vectors and associated databases, the digital images have become the core component of GIS [1–3]. In recent years, GIS software has been used to map historical objects, restore artefacts and map folklore areas.

In the present paper, were analysed the traditional motifs (embroidered on shirts underskirts, apron, embroidered sheepskin vest or traditional pouches) from Bihor, Arad, and Maramures Counties, Romania. GIS software was used for vectorization of traditional motifs. This software is able to create vector features from raster interactively or with the help of automated tools, comparable to the quality of the results obtained with the more common software products used for this purpose, Inkscape, Adobe Illustrator, Corel Draw.

The main aim of this paper is to propose a method for effective analysis of Romanian traditional motifs. In the analysis of the folk elements, two basic algorithms – radius-vector function (RV) and principal component analysis (PCA) were used. In order to improve the accuracy of the analysis of these elements, a combination of these methods has been proposed.

MATERIAL AND METHODS

Material

From Maramureș to Oltenia, from Banat to Dobrogea, from the Crișurilor county to Muntenia and Moldova, the Romanian costume unity manifests itself in all domains of its essential aspects. From the raw materials used, from the tailoring and the structure of the various pieces, up to the ornament used, the symbols sewn on Romanian folk costumes are classified into: vegetal symbols (fruits, flowers, leaves, plants); abstract symbols (anthropomorphic, zoomorphic or cosmic); geometric symbols (points, straight lines, interrupted lines, or zigzag lines, crossed lines, the rhombs, squares and triangles), and the chromatics is characterized by freshness and harmony [4, 5]. With regard to the folk costumes from the western part of Romania, the line and the composition of the costume show some deviations from the authentic type of Romanian clothing by the white cotton skirt that is wide and creased, the apron that is only worn in front and with the short shirt worn without a girdle, and large men tights (long peasant trousers) [4]. However, the ornamentation of Romanian traditional motifs and technical systems of seams and fabrics is preserved [4, 6–10].

The motifs of the folk costumes from Crisana (Bihor and Arad) and Maramures were vectorized, motives that were found embroidered on blouses, skirts called „poale", front aprons called „zadii", sleeveless vest (30 traditional motifs/region or a total of 90 elements). Figures 2, 3 and 4 represent the folk elements that were used. The GIS system was used for vectorization of folk elements.

Fig. 1. Map of the studied folk costumes from (Bihor, Arad and Maramureș) [9]

Folk elements from Bihor County are presented in figure 2.

Folk elements from Arad County are presented in figure 3.

Folk elements from Maramures County are presented in figure 4.

Methods

In the present work, a survey was conducted on consumer opinion. In order to assess the forms of Romanian folklore elements 180 respondents from Romania filled in the survey. They were arbitrarily chosen no matter of their age, work, gender, education, employment. All respondents know the reason for the survey and the motivation behind using the information that was obtained. The study was led through a Google Forms survey, since it is a free Google

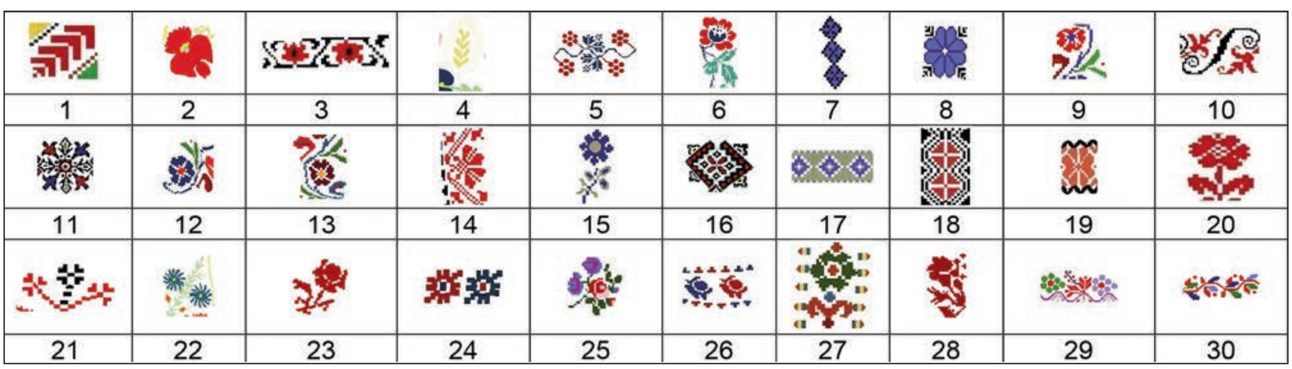


Fig. 2. Folk elements from Bihor County

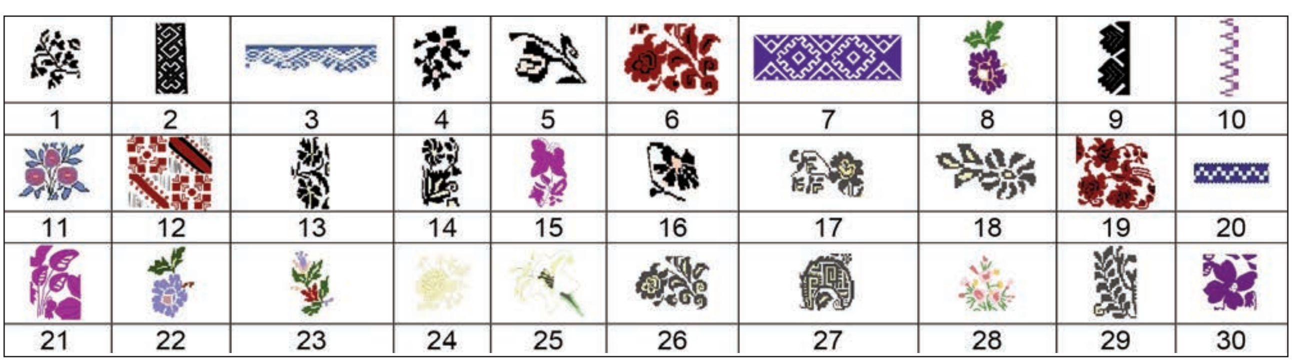


Fig. 3. Folk elements from Arad County

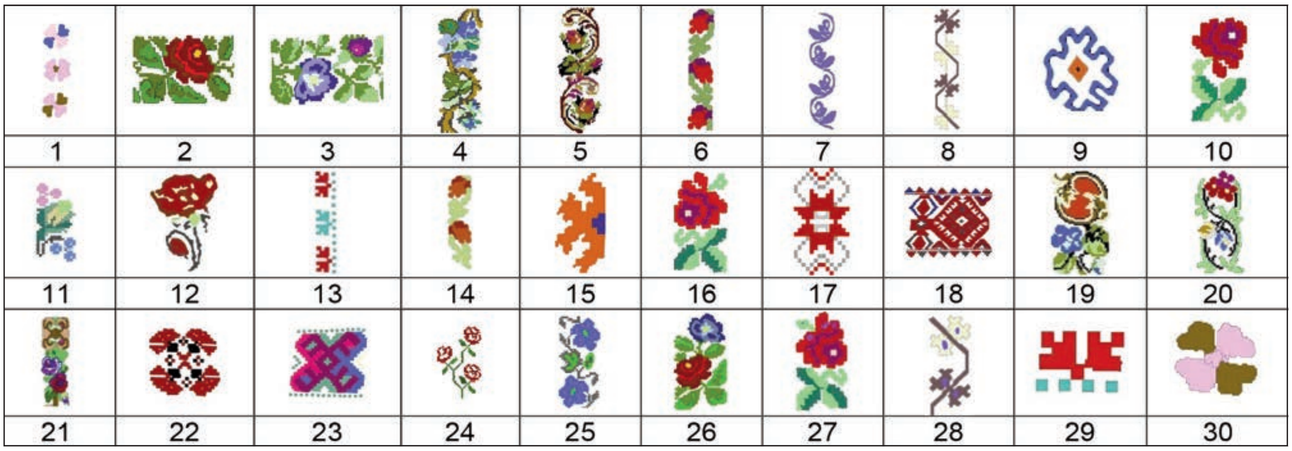


Fig. 4. Folk elements from Maramures County

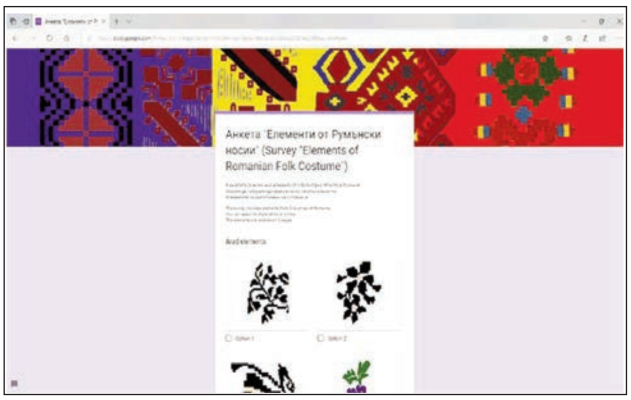


Fig. 5. Survey in Google Forms

online tool application that can be conducted on the Internet by a cell phone, tablet or a desktop computer. The results are processed by the ABC investigation technique [11]. The information is gathered into three classes A, B and C. In class A fall 0–75% of the data, 75–95% in class B and 95–100% in class C. The elements that fall into class A have the highest percentage of choice by respondents. In the analysis of the folk elements, two basic algorithms are used: radius vector function (RV) and principal component analysis (PCA). A combination of these methods is proposed in order to improve the accuracy of the analysis of this element's analysis.

Descriptions by radius – vector function

A radius vector function is used that reflects the vector's magnitude dependence from a particular point in the interior of the object at any point of the boundary to its slope relative to the positive axis *X* of the coordinate system [12]. The radius vector function is typically assumed to be the distance from a reference point that is the center of mass to the contour [12,13]. When the slope θ varies from 0^o to 360^o, then the vector fully traverses the boundary of the contour, and the resulting function $R = f(\theta)$, where R is the vector size and it can be used as a description of the shape of the object [13].

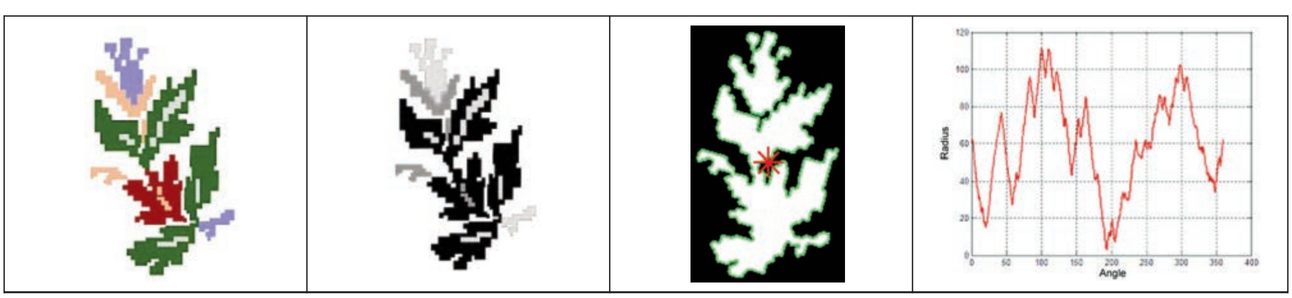
The radii of the center of mass are calculated for each individual point in the contour of the object:

$$r_i(\theta) = \sqrt{(x_1 - x_i)^2 + (y_1 - y_i)^2}, \; i = 1 \ldots 360 \qquad (1)$$

where r_i is the radius at a given angle θ, x_1, y_1 – coordinates of the object's center of gravity, x_i, y_i – coordinates of a point on the outline of the object.

The actions on this phase are repeated, with the slope θ changing from 0^o to 360^o. From each value of θ, the found value of r and the coordinates (x_i, y_i) of the relevant point of the boundary of the object are remembered. Thus, the radius vector function $R = f(\theta)$ for the particular object is obtained in tabular form.

Stages of an algorithm for radius-vector function are presented in figure 6. From the original image B (RGB) component is extracted. Then it is converted



a *b* *c* *d*

Fig. 6. An algorithm for extraction of Radius-vector function: *a* – original image; *b* – B(RGB) colour component; *c* – image re-orientation, contour and centroid; *d* – radius-vector function

to a binary image with threshold 0.9. Filter with type "disk" is used with radius 2. Radius-vector function is calculated according to methodology, presented in [14]. Parameters that describe folk elements are calculated according to formulas in table 1, where: d-short axis; D – long axis; A_e – element area; P_e– perimeter; A_{ideal} – ideal area of an ellipse, calculated by short and long axis; A_{mr}– area of a minimum rectangle, calculated by long and short axes.

The principal component analysis 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 [15].

The principal component analysis creates an orthogonal coordinate system where the axes are arranged according to the dispersion in the original data to which the relevant major component and the dispersions in the principal values refer. In the data covariance matrix K:

$$K = E\left[(x - \bar{x})^T \left[(x - \bar{x})\right]\right] \quad (2)$$

The simple variant of PCA has some disadvantages if data is highly overlapped.

PCA method is used to reduce the amount of data and analysis of the radius-vector functions and for the selection of informative coefficients that describe the form of folklore elements [15].

All of the analysis was made with a level of significance alpha = 0.05.

RESULTS AND DISCUSSION

The results for calculated parameters of the elements are presented in table 2. Coefficient of variation (CV) is calculated as a ratio between standard deviation (SD) and mean value of the elements (CV = SD/mean). If it is under 30% then the values of parameters are close to one another. It is clearly seen that areas ratios have coefficient of variation under 30%, which means that the folk elements from these three Romanian regions have the same area ratios. The analysed elements significantly differ in their coefficients as form, eccentricity, ovality. PCA analysis of the coefficients that describe folk elements show that *Kf* (coefficient of form) and *K*1 (eccentricity) describe 99% of the variance of the data. These coefficients are significant for analysis of consumer choices

Table 1

PARAMETERS OF FOLK ELEMENTS [16]			
Parameter	**Formula**	**Parameter**	**Formula**
Coefficient of form, K_f	$K_f = \frac{P_e^2}{A_e}$	Roundness, R	$R = \frac{1}{c}$
Eccentricity, K_1	$K_1 = \frac{D}{d} \times 100$	Area ratio, K_A	$K_A = \frac{A_e}{A_{ideal}}$
Ovality, c	$c = \frac{P_e^2}{4\pi A_e}$	Area ratio, K_{AM}	$K_{AM} = \frac{A_e}{A_{mr}}$

Table 2

PARAMETERS OF FOLK ELEMENTS							
County	**Parameter / Descriptive statistics**	**Kf**	**K1**	**c**	**R**	**KA**	**KAM**
Arad	min	86.85	105.13	6.91	0.02	0.50	0.39
	max	618.65	252.24	49.23	0.14	0.96	0.75
	mean	**266.77**	**158.20**	**21.23**	**0.06**	**0.70**	**0.55**
	SD	133.24	40.07	10.60	0.03	0.10	0.08
	CV	0.50	0.25	0.50	0.54	0.15	0.15
Bihor	min	38.91	105.38	3.10	0.01	0.37	0.29
	max	860.41	685.24	68.47	0.32	0.94	0.74
	mean	**300.35**	**188.55**	**23.90**	**0.08**	**0.65**	**0.51**
	SD	218.58	124.59	17.39	0.08	0.16	0.12
	CV	0.73	0.66	0.73	0.97	0.24	0.24
Maramures	min	35.23	109.75	2.80	0.03	0.37	0.29
	max	492.93	557.75	39.23	0.36	0.94	0.74
	mean	**138.86**	**255.67**	**11.05**	**0.14**	**0.78**	**0.61**
	SD	102.49	149.47	8.16	0.09	0.14	0.11
	CV	0.74	0.58	0.74	0.63	0.18	0.18

Note: Kf – coefficient of form; K1 – eccentricity; c – ovality; R – roundness; KA – area ratio; KAM – area ratio; min – minimum; max – maximum; SD – standard deviation; CV – coefficient of variation.

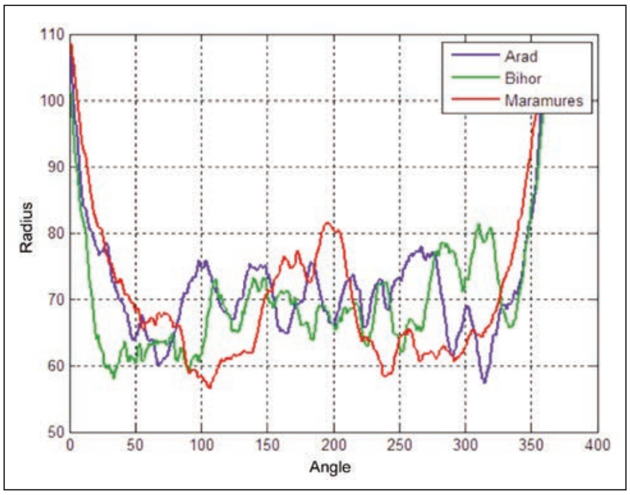


Fig. 7. Mean values of radius-vector functions of elements from three Romanian Counties

of elements. According to the results obtained by ABC analysis, Arad elements with *Kf* = 245.77±133.96 and *K*1 = 164.62±42.59 (mean ± standard deviation) are most selected by respondents from the survey. *Kf* = 418.72±239.96 and *K*1 = 238.82±174.84 for Bihor elements, *Kf* = 173.93±124.32 and *K*1 = 210.09±±63.23 for Maramures. These results correspond to those obtained in other Balkan countries, presented in [16] where authors have found that consumers in Bulgaria prefer folklore elements with a high value of coefficient of form.

Mean values of radius vector functions of elements from three Romanian counties are presented in figure 7. The radius-vector functions differ just like the other parameters that describe folklore elements. The elements of Arad and Bihor have close radius vector functions, whereas those from Maramures differ from the other two areas. Arad and Bihor are near on the map, and their form descriptions have visually the same character of change. It is hard to distinguish the elements from these three regions directly by their RVs.

To reduce the amount of data of the RVs, principal components – simple (PCA) was used. First three principal components describe 97.4% of the variance of radius-vector functions that is why the first three components are chosen. Figure 8 presents the results from principal component analysis of radius-vector functions. When using a simple variant of PCA in the separation of folk elements classes – their region of origin, the obtained results prove the statement of Haenlein [17] that the simple PCA variables are strongly dependent and directly correspond to raw data.

The folklore elements most selected by respondents in the survey, with a higher percentage of choice, are presented in the material and methods part.

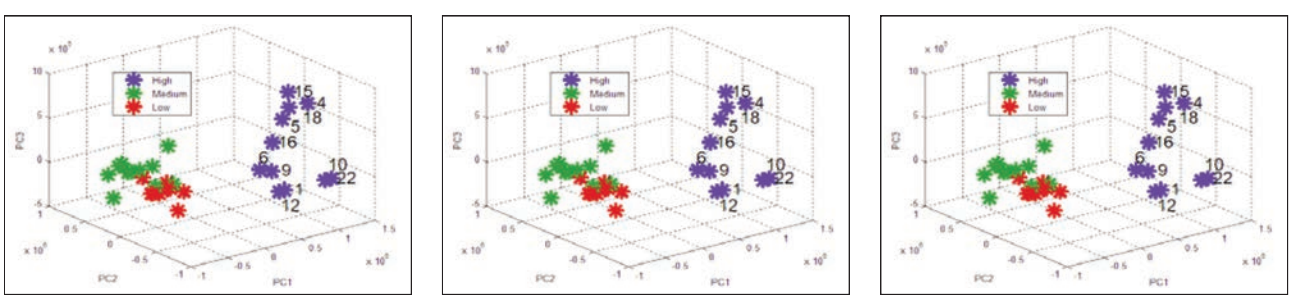
The method proposed here for the analysis of consumer opinion by reduced data of radius-vector functions of folklore elements improves the methods of analysis proposed by [16] and [18], where the authors use forms and radius-vector functions only as descriptors of folklore elements that can be used for their storage in specialised databases. The method proposed here uses less amount of data – only three principal components for every folklore element and it is also a suitable tool for analyzing the consumer opinion needing less processing time, for example 10 seconds in direct implementation of radius-vector functions, compared to 3 seconds with 3 principal components for every element.

CONCLUSION

The results obtained represent a key feature in the use of PCA. Its effectiveness depends mainly on the object being studied and the methods used to reduce the amount of data.

A combination between radius-vector function and PCA has been proposed in the analysis of folk elements and consumer preferences. This combination is a new tool for the analysis of these elements considering the reduction of the amount of data. The practical implementation of the results obtained in this paper is going to solve the problem that most of the results presented in the articles published so far could not solve, meaning that they only contain theoretical aspects and do not aim to analyse the traditional motifs. Vectorization of folklore elements from raster images will improve the analysis of the external aspect of the traditional motifs analysed according to their size, shape, color, condition and lack of visual defects.

In order to reduce the amount of data and accelerate the computational process, in the future, the method



a *b* *c*

Fig. 8. Principal component analysis of radius-vector functions: *a* – Arad; *b* – Bihor; *c* – Maramures

can be used in digital databases containing a collection of Romanian folk elements.

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REFERENCES

[1] Herman, G.V., *Using Geographical Information (GIS) System for Management of Flood Risks in the Somes Plain*, In: Cross-Border Partnership with Special Regard to the Hungarian – Romanian – Ukrainian Tripartite Border, Book Editors Ioan Horga, Istvan Suli Zakar, Publishing House University of Debrecen Press, 2010, ISBN 978-606-10-0153-8, 175–179

[2] Romocea, T., Oneț, A., Sabău, N.C., Oneț, C., Herman, G.V., Pantea, E., *Change of the groundwater quality from industrial area Oradea, Romania, using Geographic Information Systems (GIS)*, In: Environmental Engineering & Management Journal (EEMJ), 2018, 17, 9, 2189–2199

[3] Ilieș, A., Wendt, J.A, Ilieș, D.C., Herman, G.V., Ilieș, M., Deac, A.L., *The patrimony of wooden churches, built between 1531 and 2015, in the Land of Maramureș, Romania*, In: Journal of Maps, 2016, 12, 597–602

[4] Romanian Folk Costumes, by Ethnographic Regions, Available at: http://www.romanianmuseum.com/Romania/aboutRomania.html [Accessed on December 1st 2018]

[5] Mocenco, A., Olaru, S., Popescu, G., Ghituleasa, C., *Romanian folklore motifs in fashion design*, In: Annals of the University of Oradea, Fascicle of Textiles, Leatherwork, 2014, XV, 1, 63–68

[6] Dunăre, N., *Port popular din Bihor*, Editura de stat pentru literatură şi artă, Bucharest, 1957

[7] Colta, R., *Portul popular din judeţul Arad*, Editura Etnologică București, 2014, ISBN 978-973-8920-69-9, Available at: https://vdocuments.net/elena-rodica-colta-portul-popular-din-judetul-arad-editura-.html [Accessed on December 1st 2018]

[8] Dogaru, O., *Ornamentele si croitul costumului popular din județul Maramureș*, Editura Comitetului de Cultura si Educatie Socialista al Judetului Maramures. Centrul de indrumarea a creatiei populare si a miscarii artistice de masa, 1984, 201

[9] Ilies, A. (coordinator), Baias, S., Baias, I., Blaga, L., Buhaș, S., Chiriac, A., Ciocan, J., Dăncuș, M., Deac, A., Dragoș, P., Dumitrescu, G., Gaceu, O., Godea, I., Gozner, Maria, Grama, V., Herman, G., Hodor, N., Hurley, P., Ilieș, D., Ilieș, G., Ilieș, M., Josan, I., Leșe, G., Măduța, F., Mojolic, D., Morar, C., Olaru, M., Stașac, M., Stupariu, M., Sturza, A., Ștefănescu, B., Tătar, C., Vârnav, R., Vlaicu, M., Wendt, J., *Crisana-Maramures. Atlas geografic al patrimoniului turistic/Geographical atlas of tourism heritage*, Editura Universității din Oradea, 2014, ISBN 978-606-10-1298, 302

[10] Indrie, L., Stan, O., Doble, L., *Romanian traditional patterns reinterpreted and stylized using computer graphics programs,* International Conference eRA-10, 2015, 48-52, Textile and wearable technologies session, 23–25 September 2015, Atena, Greece

[11] Chandra Bose, D., *Inventory management*, PHI Learning Private Limited, New Delhi, India, 2006, ISBN-81-203-2853-1

[12] Kang, S., Ahmad, M., Chun, J., Kim, P., Park, J., *Modified Radius-Vector Function for Shape Contour Description*, In: Laganá, A., Gavrilova, M.L., Kumar, V., Mun, Y., Tan, C.J.K., Gervasi, O., (eds) Computational Science and Its Applications – ICCSA 2004, ICCSA 2004, Lecture Notes in Computer Science, 2004, 3046, 940–947

[13] Pavlidis, T., *Algoritms for Shape Analysis of Contours and Waveforms*. In: IEEE Trans, Pattern Analysis and Machine Intelligence, 1980, 2, 4, 301–312

[14] Penchev, S., *Shape Description of Grain Sample Elements*, In: Proceedings of Anniversary Scientific Conference "40 Years Department of Industrial Automation", University of Chemical Technology and Metallurgy, Bulgaria, 2011, 125–128

[15] Mladenov, M., Penchev, S., Deyanov, M., *Complex assessment of food products quality using analysis of visual images, spectrophotometric and hyperspectral characteristics*, In: International Journal of Engineering and Innovative Technology (IJEIT), ISSN: 2277-3754, 2015, 4, 12, 23–32

[16] Elnashar, E., Zlatev, Z., İşmal, Ö., Mahale, G., *Bulgarian national folk elements for the contemporary fashion,* In: Innovation and entrepreneurship*,* 2017, 5, 2, 78–88

[17] Haenlein, M., *A Beginner's Guide to Partial Least Squares Analysis*, In: Understanding Statistics, 2004, 3, 4, 283–297

[18] Zlatev, Z., Dolapchieva, G., *Processing and analysis of images of folk costume from southeastern Thrace,* In: Textile and apparel, 2017, 8 (LXIV), 16–22

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Textile packaging waste in the context of implementing the concept of circular economy

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ABSTRACT – REZUMAT

Textile packaging waste in the context of implementing the concept of circular economy

At European level, there are concrete measures regarding waste management in the circular economy, and these refer to: mandatory recycling rates for different categories of waste: plastics, glass, metals, paper and cardboard as well as biodegradable waste; the obligation to redesign the products in order to increase the proportion of raw materials resulting from recycling and to increase the degree of recycling of products, in order to consider them as secondary raw materials; promoting and stimulating the reuse of products; increasing the recycling rate of municipal waste by 2030 to a minimum of 65%; increasing the recycling rate of packaging waste by 2030 to a minimum of 75%; reduction of food wastage and implicitly of the resulted food waste by 50% by 2030.
The large amount of packaging waste determined the taking of legislative measures that defined the obligations of packaging producers/distributors, recycling objectives and the waste management hierarchy.
New targets for the recycling of packaging waste predict a growth to 65% in 2025 and 70% in 2030 [1].
Textile packaging waste is an important link in the integrated management of waste whose recovery contributes to the conservation and improvement of natural capital.

Keywords: *circular economy, textile packaging, waste, requirements, mapping recovery options*

Deșeurile de ambalaje textile în contextul implementării conceptului de economie circulară

La nivel european există măsuri concrete în ceea ce priveşte managementul deşeurilor în economia circulară, iar acestea se referă la: rate de reciclare obligatorii pentru diferite categorii de deşeuri: mase plastice, sticlă, metale, hârtie şi carton, precum şi deşeuri biodegradabile; obligativitatea reproiectării produselor pentru creşterea proporţiei materiilor prime rezultate din reciclare şi pentru creşterea gradului de reciclare a produselor, cu scopul de a le considera drept materii prime secundare; promovarea şi stimularea reutilizării produselor; creşterea ratei de reciclare a deşeurilor municipale până în anul 2030 la minim 65%; creşterea ratei de reciclare a deşeurilor de ambalaje până în anul 2030 la minim 75%; reducerea risipei alimentare şi implicit a deşeurilor alimentare rezultate cu 50% până în anul 2030.
Cantitatea mare de deșeuri de ambalaje a determinat luarea de măsuri legislative care au definit obligațiile producătorilor/distribuitorilor de ambalaje, obiectivele de reciclare și ierarhia de gestionare a deșeurilor.
Noi obiective privind reciclarea deșeurilor de ambalaje prevăd o creștere de 65% până în 2025 și de 70% până în 2030.
Deșeurile de ambalaje din materiale textile sunt o verigă importantă a managementului integrat al deșeurilor a căror valorificare contribuie la conservarea și îmbunătățirea capitalui natural.

Cuvinte-cheie: *economie circulară, ambalaje din materiale textile, deșeuri, cerințe, mapare opțiuni de valorificare*

INTRODUCTION

“Humanity’s 21st century challenge is to ensure that every person has the resources they need to meet their human rights, while collectively we live within the ecological means of this one planet”.

The circular economy, which is based on the phrase “produce-consume-reuse”, proposes a new way of rethinking the use of resources, so as not to affect the environment as so far, nor future generations of the Earth. Therefore, in recent years, a new concept has become popular internationally, in view of the fact that it presents an efficient alternative with improved performance compared to the linear economy [1].

The linear economy caterpillar turns into circular economy butterflies. Cradle-to-cradle thinking is what characterizes the circular economy.

The famous “butterfly chart” developed by the Ellen MacArthur Foundation encapsulates the principles of a circular economy and the “meshes” that make it up (figure 1).

“Based on the principle of designing out waste from products and services, a circular economy is restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times”.

Basically, this chart is based on three main principles:

- conservation and improvement of natural capital by managing and balancing renewable source flows, where the general purpose is regeneration;
- resource optimization, where regeneration, distribution and optimization of products and materials in both technical and biological cycles, is the main target;
- promoting the implementation of the point of view of the system that aims to design all negative externalities.

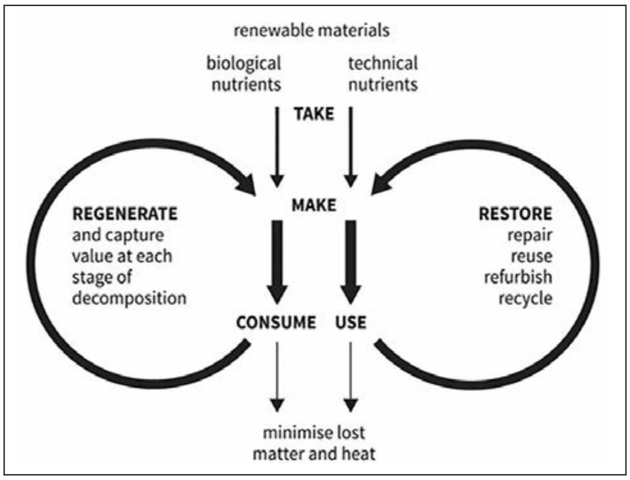

Fig. 1. Butterfly diagram – materials flows [2]

The secret of using organic nutrients endlessly is that we must ensure that they are not harvested faster than nature regenerates them and recover the multitude of valuable sources as they fall into life cycles and also the production design must be done in ways that render nature. In contrast, products made using technical nutrients, such as metals and synthetic fibres, do not naturally decompose, so they must be designed to be restored.

The inclusion of the social dimension increases the complexity of the diagram (figure 2) establishing a new golden rule of priorities, respectively [3]:

BioSphere > HumanSphere > TechnoSphere

By inserting the "Humansphere" area in the "Butterfly Diagram" you get a different but extremely positive image of "our role" in the future: the transition from the negative-Anthropocene epoch (negative-Anthropocene era) in which humans are the cause of ecosystem disorders, to a new positive-Anthropocene era in which humans reconstitute ecosystems (figure 2).

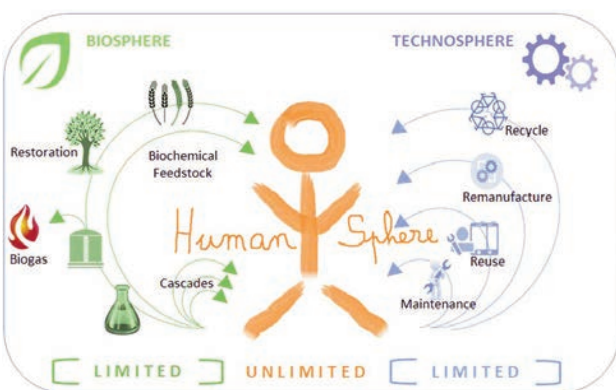

Fig. 2. Adapted butterfly diagram [4]

Humans-as-a-Resource

In relations with the Biosphere, Humans are incorporated as a critical component of nature's regeneration, ensuring the preservation of diversity, regeneration and renewal of biological cycles.

Humans = Nature

Humans-as-a-Service

In their relationship with the Technosphere, humans represent the endless energy needed to maintain the stock of materials used for the longest possible period in the economy.

Humans = Power

The Humansphere and its business models are about "integration" [4].

Humans have to play their key roles at two levels:

– Humans are embedded into natural cycles with the aim of re-building our ecosystem;
– Humans are embedded into techno-cycles with the aim of maintaining the value of our techno-system.

The consequences of the new type of economy include minimizing the consumption of natural resources, reducing carbon emissions and optimizing costs regardless of their nature, developing opportunities in the business environment and creating jobs [5].

This economy that produces zero waste is a circuit in which, from the design phase, everything is designed in such a way that what enters a product or process, falls into two categories: either it is a biodegradable component, or it is a component with 100% recycling potential [6].

Waste recycling is essential in this circular process because it ensures the link between the initial and final point of the process, by transforming waste materials into raw materials for other production processes.

OPTIONS FOR RECOVERY OF WASTE FROM TEXTILE PACKAGING

The national legislation in the field establishes that the principles regarding the management of packaging and packaging waste are valid for all packaging placed on the market, regardless of the material from which they were made and how they are used in economic, commercial or household activities.

Aspects related to manufacturing, composition of the packaging and the reusable or recoverable nature of the packaging are essential requirements for packaging materials (table 1).

At the CE level, options mapping for the circular economy 3.0 concept includes four types of essential loops of different lengths: long length R7-9 (with well-organized places), medium length R4-6 (with new business models) and short length R0-3 (with a key role for consumers and non-profit activities) (figure 3) [8].

The 9Rs for packaging waste management can be generically grouped into three main areas that involve the use of a smart design, materials from sustainable sources, and activities to close the life cycle (figure 4).

The concept of integrated textile waste management is based on two key questions, respectively:

a) What is the most environmentally beneficial option for textile waste management?

Table 1

SPECIFIC REQUIREMENTS FOR PACKAGING [7]	
Specific essential requirements for the manufacture and composition of the packaging	– the packaging shall be so manufactured as to limit its volume and weight to the minimum necessary to ensure the required level of safety, hygiene and acceptability for both the packaged product and the consumer; – the packaging will be designed, manufactured and marketed in a way that allows its reuse or recovery, including recycling, and minimizes the negative impact on the environment; – the packaging shall be manufactured with the aim of minimizing the content of toxic substances and materials and other hazardous substances in the packaging material and its elements, substances that can be found in the emissions, ash or leachate resulting from the processes of disposal of packaging waste.
Specific essential requirements concerning the reusability of a package	– the physical properties and characteristics of the packaging must allow several rotations under the expected normal conditions of use; – the reused packaging must be prepared, as appropriate, to meet the health and safety requirements; – packaging that can no longer be reused must become recoverable packaging waste.
Specific essential requirements for the recoverability of packaging	– the packaging must be manufactured in such a way as to allow, when it becomes packaging waste, a certain percentage of the weight of the materials used to be recycled. Setting this percentage may differ depending on the type of material used in the manufacture of the package; – the packaging must be manufactured in such a way as to allow, when it becomes packaging waste, that the packaging waste treated for energy recovery has a minimum calorific value that allows the optimization of energy recovery**;** – the packaging must be manufactured in such a way that, when it becomes packaging waste, the packaging waste treated for composting is sufficiently biodegradable; – the biodegradable packaging must be manufactured in such a way as to allow, when it becomes packaging waste, a physical, chemical, thermal or biological decomposition, so that most of the material is transformed into carbon dioxide, biomass and water.

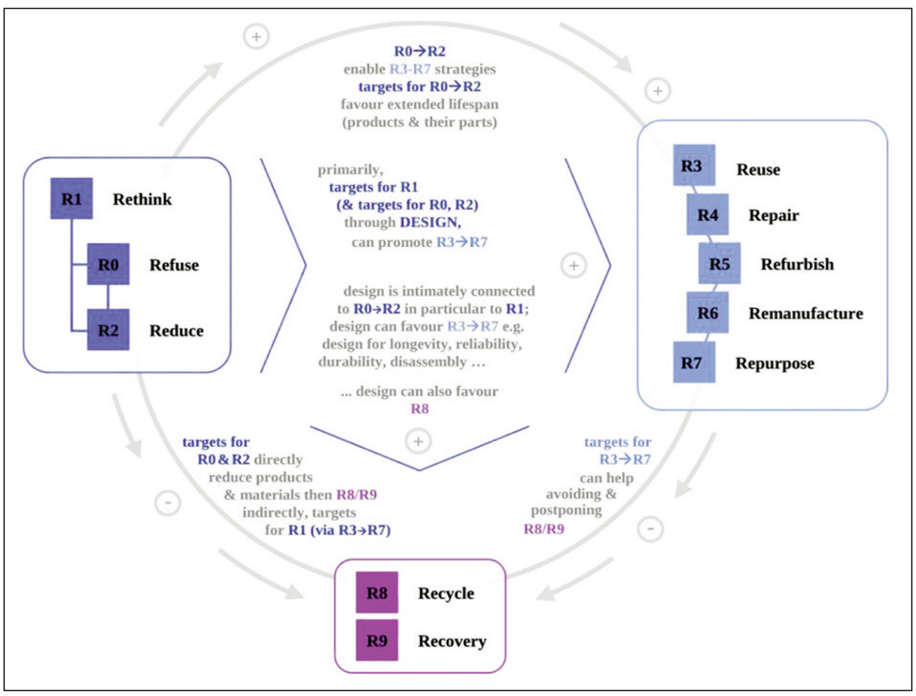

Fig. 3. Correlations among targets [8]

b) Which social indicators are the most relevant and important in assessing the social impact on textile waste management?

In the case of textile packaging, the most commonly used are woven or non-woven textile structures made of natural fibres (cotton, organic cotton, jute, hemp, wool) or chemical fibres/yarns (polypropylene, HDPE).

With the objectives of maximizing the value of resources and minimizing waste and its impact on the environment, packaging waste made of textile materials that are not contaminated with foreign substances or food waste, after the application of prevention and minimization measures, can be recovered by recycling technologies by going through the following steps (figure 5).

DISCUSSION

At the European level there are concrete measures regarding the waste management in the circular economy and these refer to: mandatory recycling rates for different categories of waste, mandatory redesign of products, promotion and stimulation of product reuse, increase the recycling rate of municipal waste by 2030 to a minimum of 65%, increase the recycling rate of packaging waste by 2030 to a minimum of 75%, the reduction of food wastage and implicitly of the resulted food waste by 50% by 2030.

Textile packaging waste is a potential source of raw materials under the conditions of:

Fig. 4. Concept 9R in packaging waste management [9]

- implementation of a closed loop value chain;
- observance of the principles specific to the packaging waste management activity;
- compliance with the essential requirements regarding the manufacture and composition and the reusable and recoverable character of the packaging;
- modelling the causes and effects of waste production based on the ability to look at packaging products on the cycles of design, production, consumption, use and disposal, including interactions with sustainability;
- printing science and innovation of a more open, collaborative and international character – open innovation, open science, openness to the world;
- investments to deal with the technologies of the future;
- conducting social awareness and education activities = sustainable consumer.

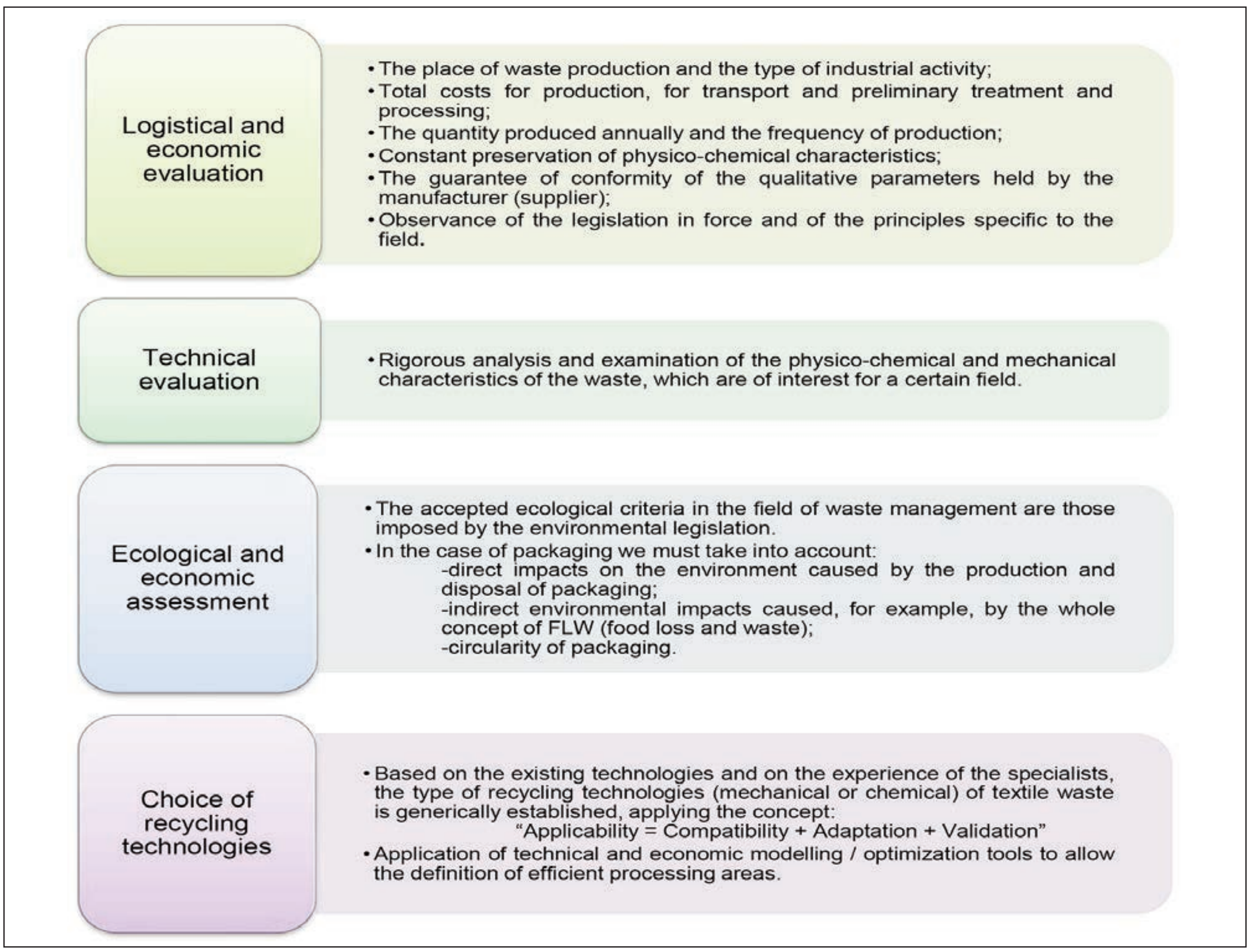

Fig. 5. Matrix for processing packaging waste from textile materials – stages

CONCLUSIONS

– The society of the future will be more and more oriented towards the individual and his needs, which will be more and more complex and varied, in the context in which diversity, equal opportunities, creativity, transparency and flexibility will represent the most important values of the future society.

– The consumer society, along with the global population growth trend, the intensification of the urbanization process, the development and dissemination of information and communication technology, the continuous increase of the living standard, the reduction of the product life cycle have contributed to the increase of volume and diversification of waste flows.

– In the conditions of sharp decline in natural resources, rapid deterioration of air, water, soil quality and damage to natural ecosystems, international concerns about waste management have become dynamic in identifying the best solutions and technologies. In this context, waste management has become a fundamental issue of future socio-economic developments, representing an essential element of a circular economy.

– Implementing the integrated management of packaging waste has a permanent component, that of capitalizing on the results of scientific and technological research and continuing activities in the field of future technologies to underpin the construction of a Romanian model of the circular economy.

ACKNOWLEDGEMENTS

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REFERENCES

[1] European Commission, *Circular Economy: New rules will make EU the global front-runner in waste management and recycling,* Press Release, 22 May 2018, Available at: https://ec.europa.eu/commission/presscorner/detail/en/IP_18_3846 [Accessed on March 2020]

[2] Raworth, K., *Why we need to move toward an economy that can regenerate itself*, In: IDEAS.TED.COM, 11 April 2018, Available at: https://ideas.ted.com/why-we-need-to-move-toward-an-economy-that-can-regenerate-itself/ [Accessed on March 2020]

[3] Lemille, A., *HumanSphere added [Circular Economy 2.4]*, 15 November 2016, Available at https://www.linkedin.com/pulse/humansphere-added-circular-economy-24-alexandre-lemille [Accessed on March 2020]

[4] Lemille, A., *HumanSphere Business Models [Circular Economy 2.5],* 30 November 2016, Available at: https://www.linkedin.com/pulse/humansphere-business-models-circular-economy-25-alexandre-lemille [Accessed on March 2020]

[5] Reciclăm Împreună, *Economia circulară – De la resursă – la deșeu – la resursă,* 2020, Available at: http://reciclamimpreuna.ro/economia-circulara/ [Accessed on March 2020]

[6] ECOTIC, *Episodul 1: Ce este economia circulara?, 2020,* Available at: https://www.ecotic.ro/welcome-change/economie-circulara/episodul1/ [Accessed on March 2020]

[7] ECOROM Ambalaje*, Deseurile de ambalaje – Ghid legislativ*, 2010, Available at: http://ecoromambalaje.ro/wp-content/uploads/GHID_legislativ_pentru_producatori-nou.pdf [Accessed on March 2020]

[8] Morseletto P., *Targets for a circular economy,* In: Resources, Conservation & Recycling*,* 2020, 153, https://doi.org/10.1016/j.resconrec.2019.104553

[9] Henkel Company, *Expanded strategic framework promoting a circular economy*, Press Release, 2018, Available at: https://www.henkel.com/press-and-media/press-releases-and-kits/2018-09-03-henkel-announces-ambitious-targets-for-sustainable-packaging-873418 [Accessed on March 2020]

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ICT new tools for a sustainable textile and clothing industry

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ABSTRACT – REZUMAT

ICT new tools for a sustainable textile and clothing industry

Sustainability in the textile and clothing industry is seen as a subject of the major producers, with many brands divulging their concern about protecting people and the environment and adopting an environmental friendly communication approach. For companies in the textile and clothing sector (especially SMEs), the circular economy provides an opportunity to create new profit streams, increase their resilience to volatile input costs, and support their efforts to become completely sustainable and socially responsible.

EU textile and clothing industry needs a flexible workforce that can respond to the development and to the globalised market and the need for sustainable design and manufacturing in order to respond to the global demand for sustainable creative products. In this frame, it is important to have suitable tools to train the employees, to prepare them to deal with these new challenges, to enhance their knowledge, and to develop new skills and competencies for this new type of business. This paper introduces a new training toolkit, which will contribute to the training process of the personnel involved in the textile and clothing industry. This toolkit contains e-learning courses in six European languages, mainly various sources (books, video) and activities (quizzes and forums), which are uploaded and available on the Udemy platform.

Keywords: *sustainability expert, sustainable management, environmental performance, corporate social responsibility, circular economy*

Noi instrumente TIC pentru o industrie textilă și de îmbrăcăminte sustenabilă

Sustenabilitatea în industria textilă și de îmbrăcăminte este percepută ca o preocupare a marilor producători, multe mărci dezvăluind îngrijorarea lor cu privire la protejarea populației și a mediului și adoptarea unei abordări de comunicare ecologice. Pentru companiile din sectorul textile și îmbrăcăminte (în special IMM-uri), economia circulară oferă o oportunitate de a crea noi fluxuri de profit, de a-și spori rezistența la costurile volatile și de a-și sprijini eforturile de a deveni complet sustenabile și responsabile social.

Industria textilă și de îmbrăcăminte europeană are nevoie de o forță de muncă flexibilă care să poată răspunde dezvoltării și pieței globalizate și nevoii de proiectare și fabricație durabile, pentru a satisface cererea globală de produse creative sustenabile. În acest context, este important să existe instrumente adecvate pentru a instrui angajații, pentru a-i pregăti să facă față acestor noi provocări, pentru a acumula cunoștințe și pentru a dezvolta noi abilități și competențe pentru acest nou tip de afacere. Această lucrare introduce un nou set de instrumente de formare, care vor contribui la procesul de instruire a personalului implicat în industria textilă și de îmbrăcăminte. Acest set de instrumente conține cursuri de e-learning în șase limbi europene, în principal diverse surse (cărți, videoclipuri) și activități (teste și forumuri), care sunt disponibile pe platforma Udemy.

Cuvinte-cheie: *expert în sustenabilitate, management sustenabil, perfomanță de mediu, responsabilitate socială corporativă, economie circulară*

INTRODUCTION

The sustainability concept refers to the physical preservation of human societies and their cultures, institutions, social orders and regimes. Behavioural, cultural psychological and institutional factors influenced how individuals understand and implement their economic and environmental businesses and the need for sustainable goals and practices [1]. According to the European Commission, "Sustainable development means meeting the needs of the present while ensuring future generations can meet their own needs" [2].

Sustainability is no longer a concern of environmentalists and ecologists and has become a concern of individuals. Sustainability defines, in fundamental ways, the communities in which we live and is the source of renewable and non-renewable resources on which civilisation depends. Health and well-being, economy, and social life and safety, all require a high-quality environment [3]. Sustainable development

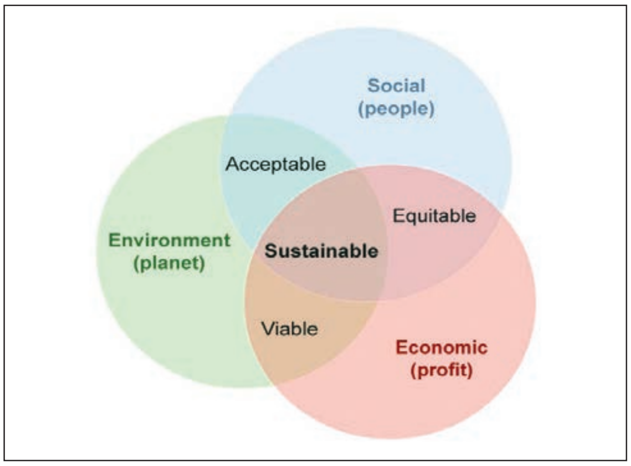

Fig. 1. The three pillars of sustainability [4]

has evolved as a concept through several decades of profound international scientific debate, and it has acquired distinct political connotations in the context of globalisation. The concept of sustainability consists of three pillars: economic, environmental, and social-also known informally as profits, planet, and people (figure 1) [4].

The textile and clothing industry is a part of the European manufacturing industry which has to become sustainable, too. This is a diverse and heterogeneous industry covering numerous activities. In 2019, the entire EU-27 T&C industry represented a turnover of € 162 billion and 160,000 companies, mainly SMEs [5–6].

The textile industry is, after oil, the second most polluting industry in the world. Many companies have understood the concept of "fast fashion" as a continuous production of clothing items and of control [7]. Ecological and social problems strongly affect the T&C market. The three main concerns are production ecology, human ecology and waste disposal [8]. In this context, the textile industry is committed to change its vision, to start on producing echo-friendly textiles and sustainable in order to face global competition [9].

Companies and consumers are more concerned about sustainability nowadays. The clothing industry is receiving more attention due to mass production and its significant impact on the planet. Fashion brands are introducing sustainable lines and circular economies in their business model to reduce their energy consumption, advocating for environmental protection and other activities [10].

The European Commission recently published the report "Mapping sustainable fashion opportunities for SMEs" which emphasises that the transformation of companies towards more sustainable and resource-efficient business models not only helps to protect the environment, but also provides a competitive advantage by creating important cost savings and boosting innovation for sustainability [11].

Also, the European Commission patronized different initiatives and projects in the field of sustainability, to help textile companies (SME's) and countries to reach new opportunities for their business (table 1).

In the Paris' Agreement [11] there are mentioned some key points to sustain SME's for adopting sustainable/circular business models, such as:

- **economic instruments** through tax incentives, grants and subsidies for sustainable initiatives,

Table 1

PROJECTS ON EUROPEAN LEVEL FOCUSED ON SUSTAINABILITY CONCEPT [11]	
Project title	**WORTH Pilot Project**
Partners	London College of Fashion, University of the Arts London; Institut Francais de la Mode; Euratex
Funder/s	Funded by the Competitiveness and Innovation Framework Programme (CIP) of the European Commission's Directorate General for Enterprise and Industry
Duration	2013–2015
Project link	http://www.pilot.worth-project.eu/project-design-craft-manufacturereurope/worth-projects-2.html
Summary of main focus/aims	Cross border innovation partnerships between manufacturing enterprises and designers, product innovation across Europe; Involved 79 SMEs and 34 European partnerships between designers and manufacturers, retailers, craftsmen, technology companies in fashion, textiles, jeweller, footwear, eyewear, furniture, fur, leather industries from different EU countries (and other CIP participating countries) for innovative product development, positioning in the market, presentation in trade fairs and exhibitions and IP rights support
Project title	**WORTH Partnership Project**
Partners	Textile Technology Institute AITEX, KEPA, IED, DAG Communication
Funder/s	COSME
Duration	Ongoing
Project link	https://www.worthproject.eu/
Summary of main focus/aims	Initiation and support for collaborations on the transnational level between designers and other creatives, SME's manufacturers and technology firms in the areas of fashion and textiles, footwear, furniture/home decoration, leather/fur, jeweller, accessories; focus on SME's and start-ups

Table 1 (continuation)

Project title	Textile and Clothing Business Labs (TCBL)
Partners	City of Prato, German Institutes for Textile and Fiber Research – Center for Management Research (DIFT), Instituto Superiore Mario Boella, Skillaware, The Open University, IMEC, Tavistock Institute, Materials Industrial Research & Technology Center S.A. (MIRTEC), Waag Society, Huddersfield & District Textile Training Company Ltd, The eInstitute (eZavod), Consorzio Arca, Unioncamere del Veneto (UCV), Hellenic Clothing Industry Association, Sanjotec – Centro Emresarial e Tecnológico, Clear Communication Associates Ltd, Oxford Brookes University, Association Reginnova NE, Centre Scientifique & Technique de l'Industrie Textile Belge, Institut Français de la Mode (IFM), Institut d'Arquitectura Avancada de Catalunya – Fundacio Privada (FabTextiles), Cleviria, Sqetch BV
Funder/s	H2020
Duration	2015-2019
Project link	https://tcbl.eu/
Summary of main focus/aims	Building an ecosystem of enterprises, innovation labs, service providers and business advisors to foster change in the textiles and clothing industry and explore innovative business models
Project title	**Trash2Cash (T2C)**
Partners	Centre for Circular Design, Chelsea School of Arts, University of the Arts London; RISE – Research Institutes of Sweden
Funder/s	H2020 NMP
Duration	2015-2018
Project link	https://www.trash2cashproject.eu/
Summary of main focus/aims	Create newly regenerated fibres from preconsumer and post-consumer waste

carbon taxes and penalties for non-sustainable operations, appropriate finance and grants, including repayable finance and patient capital;

- **information flows** through improving textiles collection and recycling statistics and reporting, creating knowledge and resource sharing platforms and connecting networks, sustainable businesses with suppliers, markets and funding opportunities, education for sustainability and public information campaigns;
- **regulatory instruments/policy** through creating clear end-of-waste criteria for textiles to facilitate upcycling of waste, mandatory EPR Schemes and harmonising regulations across EU and removing administrative barriers;
- **technological developments** through access to design and manufacturing tools, information on and access to emerging R&D e.g into recycling;
- **collaboration and mentoring schemes** through the enhanced cooperation of small and large players, alignment of values across the supply chain and dedicated mentoring for fashion start-ups.

These goals can be reached with a trained employee, who must have up-to-date skills and knowledge to be able to create sustainable products which have to meet the global market demands. It is rather challenging to take the employees from their workplace and to enrol them into a full training programme. It is also a known fact, that if the theory is combined with practice, the trainee's level of understanding increases, he becomes more confident and willing to learn and to apply what he was taught to.

At European level, several projects were or are focused to define the necessary and needed job profiles, and new qualifications, and adequate curricula were designed for these in order to train employees. The required curricula for bringing up-to-date or acquiring knowledge and skills is uploaded on different online educational platforms. In this and way, the learner has the possibility to personalise his training path, to select and combine which courses/ module he needs to study, to establish his goals and methods for reaching them.

In table 2 there are listed some European projects, in which it was or will be described and defined new jobs and/or qualifications, required nowadays and in the near future in the field of textile and clothing industry, and in which was developed the correspondent curricula for training the learners.

We can say that, at the European level, there are initiatives for helping SMEs to train and adapt employees (new jobs or qualifications) to the new economic requirements. As it is shown in table 1, the project ECO TEX is a European project which is focused on designing, developing and testing a new job qualification profile and corresponding training curricula on the subject of "How to implement circular economy techniques in Textiles Industry". This new job is based on the development of new skills and competences of the workforce, which will help the individual to face and deal with all new challenges.

METHODOLOGY FOR DESIGNING THE PROFILE OF "SUSTAINABILITY EXPERT"

For the textile and clothing sector companies (especially SMEs), the circular economy provides an opportunity to create new profit streams, increases their resilience to volatile input costs, and supports

Table 2

PROJECTS FOCUS ON NEW UPDATED PROFILES [12–14]	
Project title	**Skills4Smart TCLF Industries 2030**
Partners	Euratex, European Confederation of the Footwear Industry (CEC), COTANCE, CIAPE, CITEVE, Centrul National de Dezvoltare a Invatamantului Profesional si Tehnic (CNDIPT), TRAING CENTRE FOR THE BELGIAN TEXTILE INDUSTY-COBOT, CTCP – Centro Tecnológico do Calçado de Portugal, Hellenic Management Association, Fundación Estatal para la Formación en el Empleo, IVOC, INESCOP, UNITEX, PIN – SERVIZI DIDATTICI E SCIENTIFICI PER L'UNIVERSITÀ DI FIRENZE, POLITECNICO CALZATURIERO, SPIN360, Universitatea Tehnica Gheorghe Asachi din Iasi (TUIASI), Lodz University of Technology (TUL), Universitat Politècnica de Catalunya, PIRIN-TEX EOOD, Universitat de Lleida, VIRTUAL CAMPUS
Funder/s	Erasmus+
Duration	2018-2021
Project link	http://www.s4tclfblueprint.eu/
Summary of main focus/aims	Enhance the modernisation and competitiveness of the EU Textile, Clothing, Leather, and Footwear (TCLF) sectors through the development of a sustainable upskilling and reskilling strategy, which is supported by a communication campaign to attract social, economic and political actors. Identification of 8 new TCLF job profiles – and corresponding curricula (EQF and ECVET based) in line with the sector changing needs in short to longer-term. Design of 8 new courses including MOOCs/VOOCs or MOOCs (part online/in school) or serious games or similar tools
Project title	**Circular Economy Innovative Skills in the Textile Sector – ECOTEX**
Partners	Confederación de la Industria Textil – TEXFOR, CITEVE, Hellenic Fashion Industry Association (SEPEE), Riga Technical University (RTU), "Gheorghe Asachi" Technical University of Iasi (TUIASI)
Funder/s	Erasmus+
Duration	2017-2020
Project link	http://www.ecotexerasmus.eu/en/
Summary of main focus/aims	Design and implementation of an innovative and comprehensive training toolkit. The platform will focus on online training and will facilitate the dissemination of knowledge and sharing of experience. Moreover, it will serve as a medium for all stakeholders in the field to share concerns and advice, as well as promote employment opportunities. Define a professional profile for "Sustainability expert".
Project title	**Innovative design practices for achieving a new textile circular sector-Design4Circle**
Partners	Riga Technical University (RTU), "Gheorghe Asachi" Technical University of Iasi (TUIASI), ECORES SPRLP, Innovative Business Association of Furniture Manufacturers and related in the Murica Region (Amuebla), Footwear Technology Centre of Portugal (CTCP)., Textile Trade Association – Textile Cluster (TTA-TC)
Funder/s	Erasmus+
Duration	2018-2020
Project link	https://design4circle.eu/
Summary of main focus/aims	Design4Circle aims to cover the skill gaps in the eco-innovation of European Designers in textile and fashion products. Design4Circle will allow designers from the textile sector sectors to reduce environmental impact during the products life-cycle, and develop new and innovative businesses within the principles of the circular economy.
Project title	**Clothing Technician Profile Update via Education – CosTUmE**
Partners	CITEVE, MODATEX, ATP, INOVA+, AITEX, ASECOM, INCDTP, ASTRICO NE
Funder/s	Erasmus+
Duration	2018-2020
Project link	http://clothingtechnician.eu/
Summary of main focus/aims	Create a new and attractive Clothing Technician profile and qualification recognised in EU (PT, ES, RO) and to mobilise young people and adults in their professional qualification in the VET system, through the acquisition of necessary skills for textile and clothing industry, by the strong connection to fashion, technical textiles, home textiles, sustainability, the introduction of new materials and industry 4.0.

their efforts to become completely sustainable and socially responsible.

Skilled and well-qualified workers can play a critical role in addressing these barriers and creating opportunities to guide the shift to circularity. Indeed, the Textile Sector requires a more qualified workforce to deal with new technologies, stimulate innovation, ensure quality management and develop international strategies and marketing. Therefore, the availability of adequately skilled workers has become one of the major issues for the Textile industry as the majority of the companies still face the shortage of trained and qualified personnel in green and circular economy techniques, in both design and manufacturing.

In this framework, the project ECO TEX has as its main objective the development, design and implementation of an innovative and comprehensive training protocol, a work-based training ICT tool for the Textile Industry. This methodology is the result of joint work carried out under partnership. The methodology is characterised by the realisation of Textile Industry's needs for new education and training systems and tools for their existing and potential workforce in order to meet the demands and requirements of the market, for new designed sustainable products and circular economy guidelines performance.

To reach its goal, to define a new job qualification which will try to cover the gaps between the new business requirements and professional level of the workers, the project methodology was:

- Researching on anticipating skills based on evidence;
- Designing and defining the professional qualification profile of "Sustainability Expert" for textile and clothing sector;
- Development of a training toolkit able to cope with the identified training needs, according to European Common Framework on Vocation, Educational Training (ECVET);
- Development of innovative training units and e-learning courses;
- Development of a digital training platform as an innovative open distance – learning ICT tool and test the results.

The methodology used to anticipate the needed skills of a Sustainability Expert in the textiles and clothing sector was based on desk research employing qualitative methods by using a questionnaire with 5 sections:

- Section 1: General information about the company (company size; product/ service and location);
- Section 2: Information about the concept of sustainability – starting from the definition of Sustainability of the World Commission on Environment and Development;
- Section 3: Information on if companies consider the sustainability concept in their business strategy;
- Section 4: Why is sustainability important for companies;
- Section 5: What skills the Sustainability Experts should have – rank the importance of skills and competencies of the Sustainability Expert.

This questionnaire was applied in textile and clothing companies of the partner countries: Spain, Greece, Romania, Latvia and Portugal. All answers were analysed and interpreted, and the conclusions were used to design the training curricula needed for this new profile qualification.

In *section 2*, the respondents rank the importance of the followed syntheses:

– Environmental protection;
– Corporate Social Responsibility;
– Business Development;
– Health-Safety and Working Conditions;
– Minimization of resources consumption/zero emissions/circular economy.

By interpreting all data collected, the conclusions are: Health-Safety and Working Conditions are extremely important for the sustainability concept (over 60%), Environmental Protection (over 50%) and Business Development (over 40%) (figure 2).

Section 3 refers to the sustainability concept in the business: 95% of the companies consider sustainability in their business strategy. The respondents expressed their opinion regarding the existence of a sustainability officer: 53%of the interviewed companies answered positively, and 47% of the companies do not agree with such a position. They said that in this position the persons who are in charge of sustainability are either: R&D Project Manager, HR Manager, General Manager, HR/CSR Manager, CSR and Quality Coordinator.

Depending on the type of the company and their production, most of the companies are certified to one or more than one management systems/guidance The most recurrent management systems/guidance used by companies is ISO 9001; 52.6% of companies use the international standard that specifies requirements

Fig. 2. Sustainability concept in the business (major toipcs)

for a quality management system. The companies use the standard to demonstrate the ability to provide products and services that meet customer and regulatory obligations (figure 3). Also, 73% of the respondent companies consider that having a certified management system is essential and needed for achieving sustainable development in their business.

Mainly, 21% of companies are STeP by OEKO-TEX® (Sustainable Textile Production) certified, which is related to sustainability management in textile production. Other companies (10.5%) are certified SA 8000 (Social Accountability 8000), 7.8% are certified according to OHSAS 18000 – Occupational Health and Safety Assessment Series. The standard ISO 45001 substitutes the OHSAS 18001 standard.

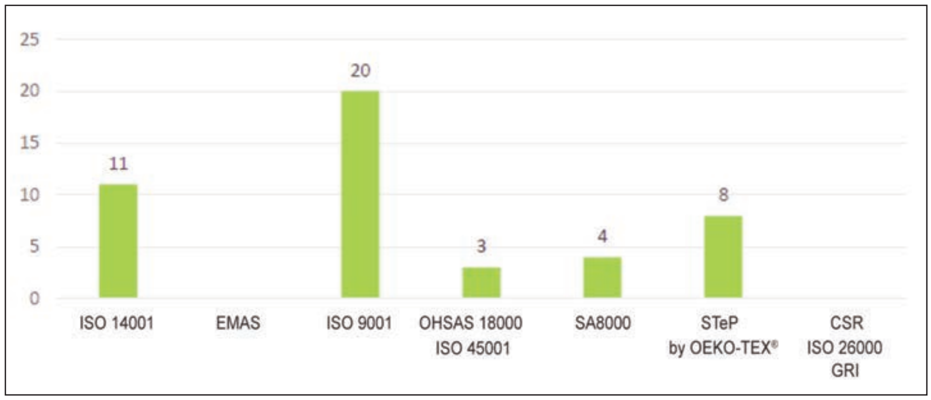

Fig. 3. Management system/guidance certification

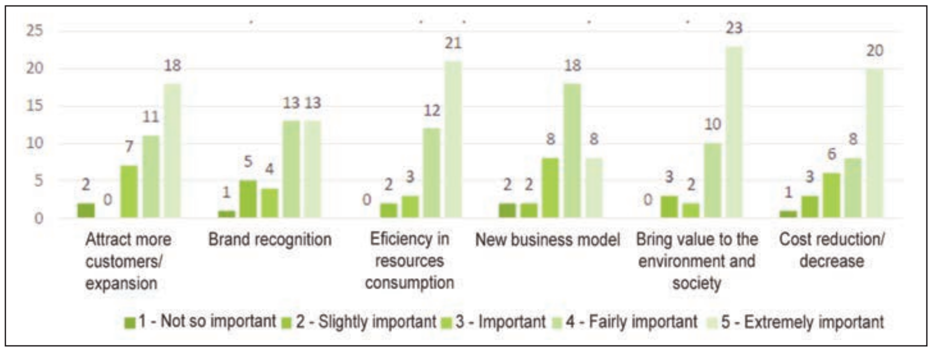

Fig. 4. Importance of sustainability for their company

Mainly, 73% of the respondent companies consider that having a certified management system is essential and needed for achieving sustainable development in their business.

In *Section 4,* the respondents have to appreciate the importance of the sustainability concept. The conclusions are: 60.5% of companies consider that the sustainability is *extremely important* in order to *Bring value to the environment and society*; 55.3% consider that sustainability is extremely important for the *Efficiency in resources consumption* and 52.6% mention the *Cost reduction*. Only 34.2% deem that sustainability is essential for *Brand Recognition* (figure 4).

In *section* 5, respondents are asked to list the competencies and skills considered fundamental for the sustainable expert profile (figure 5).

So, 68.4% of companies consider that the sustainable expert should have competencies and skills in *Sustainability (environmental, social and economic) Analysis and Management* as *extremely important.*

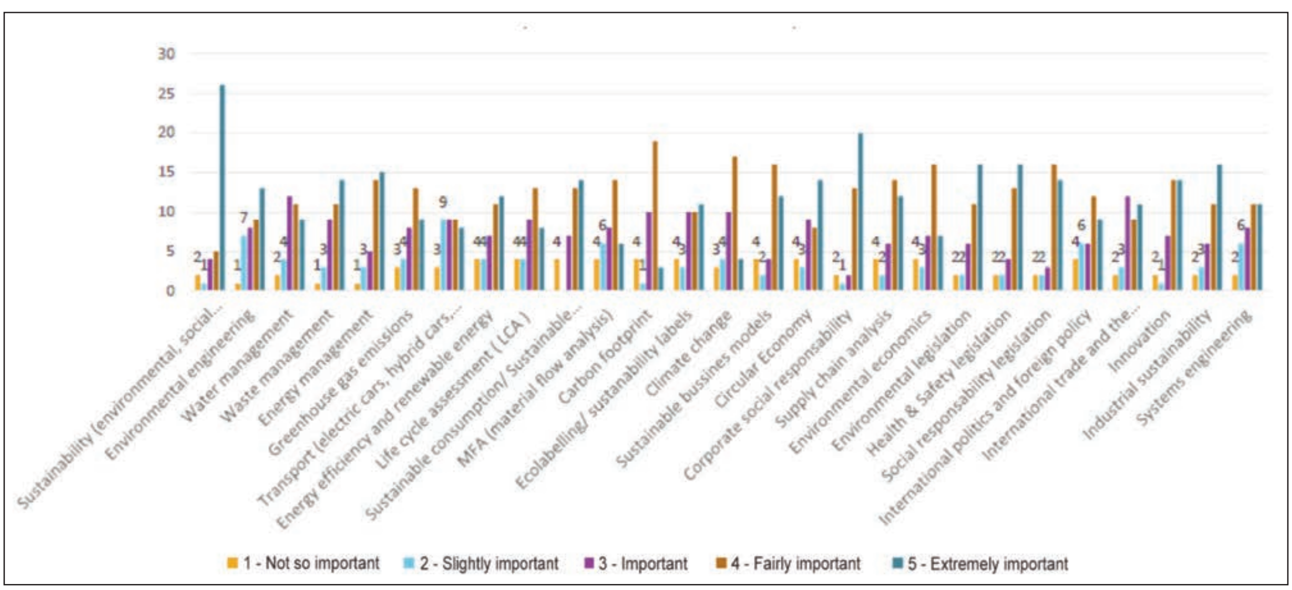

Fig. 5. Listed competencies and skills

52.6% of companies also mention *Corporate social responsibility;* 42.1% of companies consider *Environmental legislation; Health & Safety Legislation and Industrial Sustainability* as important and 39.5% of companies rate *Energy management* as *extremely important.* 50% of companies consider having skills in *Carbon footprint* as *essential;* 44.7% in *Climate change* and 42.1% of companies mention the *Sustainable business models, Environmental economics and Social responsibility legislation.*

The following skills and competencies were considered with *slight importance*:

– 23.7% of companies point to *Transport (electric cars, hybrid cars, fuel cells, biofuels, international transport, maritime transport);*
– 18.4% of companies mention *Environmental engineering*;
– 15.8% of companies indicate the *MFA (material flow analysis); International politics and foreign policy and Systems engineering.*

Bellow are shown skills and competencies that were ranked as *not so important* for the SE (10.5% of companies), *Energy efficiency and renewable energy, Life cycle assessment (LCA); Sustainable consumption/Sustainable procurement; Ecolabelling/sustainability labels; Circular economy; Supply chain analysis; Environmental economics.*

Respondents are increasingly aware of the demands of the market, consumers and their workers. They are investing more in the sustainable certification of their products and in the qualification of their workers in order to become more competitive. 95% of the companies consider that the *Sustainability Expert* should *hold a qualification.* Over 60% said that a Sustainability expert should hold a qualification, either a higher degree/master of professional degree.

In *section* 6, respondents had to express their opinion regarding online learning: 71% of the companies felt very confident or confident in online learning, and 29% answered “not confident”.

All answers were attentively interpreted and used to design the “Sustainability Expert” professional qualification profile for the Textile Sectors and the e-learning materials to train him. This person is recommended to:

- Have a bachelor’s degree, because he has to communicate and coordinate with management, shareholders, customers and employees to address sustainability issues.
- Develop, implement and evaluate programmes for the employers that support social, environmental, and economic sustainability objectives.
- Have outstanding skills in strategic planning, human resources management, and relationship-building.

The needed topics of training the employee for this new type of qualification are:

- Module 1 – Sustainable Management
- Module 2 – Environmental Performance
- Module 3 – Corporate Social Responsibility
- Module 4 – Circular Economy.

THE ECO TEX PROJECT TRAINING PLATFORM

The “Training Toolkit” fits the new qualification and targets all education and training entities and other agents related to training/employment (figure 6). The learning units/modules can be used separately for tailor-made training, and for other objectives in support of the implementation of sustainable manufacturing in textile and clothing SME’s.

The topics of the training platform is harmonised with the requirements of the European learning system. The courses/training units are developed with multidisciplinary modules, focused on [15]:

- Climate Change
- Circular Economy
- Certifications and Policies
- Manufacturing Systems
- Energy Management
- Environmental Legislation
- Sustainable Business Models.

The platform is developed and technically validated to make sure it accommodates all the needs identified. It enables users to have access to information and data for the enhancement of their skills, knowledge and competencies.

The Sustainability Expert course offers the learners long-term benefits of creating an efficient sustainability approach for their company/business, acknowledging the social and environmental impacts of production and consumption.

On the platform, the users have the possibility to:

- Follow the modules corresponding to the learning paths;
- Build their own self-customised learning paths in order to fill in their own skill and knowledge gaps, selecting the modules they find more appropriate (figure 7).

The learners have available quizzes which evaluate the level of understanding, and if they get good scores to all quizzes, they will be able to get the certificate of Sustainability Expert.

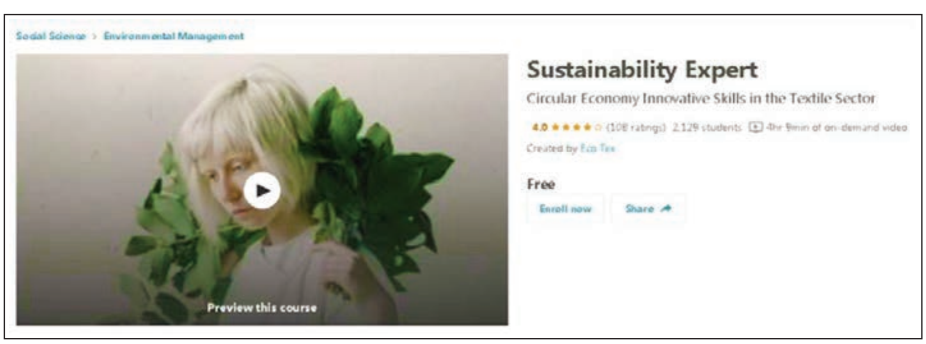

Fig. 6. ECO TEX project training platform [15]

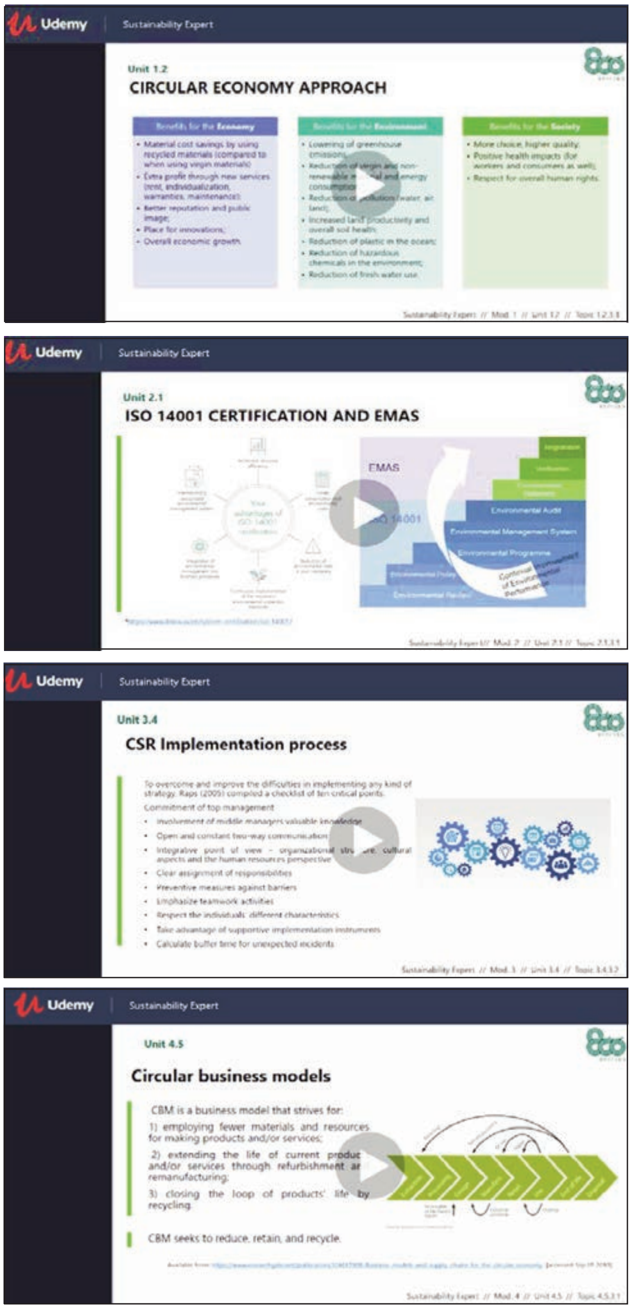

Fig. 7. Insights of the Sustainability Expert course

The platform has e-Courses, a forum for the exchange of news and information related to the sector and for connection with other users for the sector platforms such as EPALE.

The current research contributes to the natural uptake of the EU principles for EQF and ECVET through the production of new innovative curricula and its implementation in the web (e-learning platform) as a user-friendly modern tool for reaching out to the labour market (designers, managers, workers/engineers and students in fields related to textiles and clothing sector).

CONCLUSIONS

The ECO TEX project offers an instrument for training efficiently and adequately the staff of textile and clothing companies, in circular economy techniques and sustainability design and production. Thus, businesses and employers will not need to spend money, time and effort on, firstly, identifying the needed qualifications, skills and knowledge required for a competitive Sustainability Expert of the textiles sector, and secondly, for training their staff in order to be ready to meet the demands of internationalisation and competitiveness.

Moreover, the skills of the staff and business owners will be upgraded and matched directly to the labour market.

The content of the training units uploaded on the digital platform provides:

- the improvement and extension of high-quality learning opportunities, tailored to the needs of textiles and clothing industry;
- a new high-quality tool for training the staff of textiles SME's in the new business model, the circular one;
- the possibility to establish close cooperation between formal education providers and businesses in order to increase the market relevance of the proposed training toolkit;
- the creation of awareness for the need of a sustainable manufacturing strategy;
- the exploitation of results through European, national and local networks and platforms, enterprises, business organisations, guidance organisations, as well as other relevant media, within and outside Europe;
- the enlargement of networking between the partners.

The ICT tools are there to train the users by applying EQF principles directly. The e-learning content was prepared in six European languages (English, Spanish, Romanian, Portuguese, Latvian and Greek), with video explanations and multiple-choice tests in each module. The project outcomes had a good impact on various category of staff in the textile sector, business owners in this industry, students in fields related to the textile sector, individuals with interest in joining the textile sector, who participated in the multiplier events and in the project pilot phase.

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REFERENCES

[1] Caldwell, L.K., *The Concept of Sustainability: A Critical Approach*, In: Lemons, J., Westra, L., Goodland, R., (eds) Ecological Sustainability and Integrity: Concepts and Approaches. Environmental Science and Technology Library, Springer, Dordrecht, 1998, 13, https://doi.org/10.1007/978-94-017-1337-5_1

[2] European Commission, *Sustainable development*, Available at: http://ec.europa.eu/trade/policy/policy-making/sustainable-development/#_trade-agreements [Accessed February 2020]

[3] Ozek, H.Z., *Sustainability: Increasing Impact on Textile and Apparel Industry*, In: J. Textile Eng. Fashion Technol., 2017, 2, 5, 76, https://doi.org/10.15406/jteft.2017.02.00076

[4] Tedeschi, L., Muir, J.P., Fox, D.G., Riley, D.G., *Future implications for animal production: a perspective on sustainable livestock intensification*, In: Conference Proc. 52nd Annual Meeting Brazilian Society of Animal Science, 2015, 52

[5] EURATEX Annual Report 2018, The European Apparel and Textile Confederation, 2018, Available at: https://euratex.eu/wp-content/uploads/2019/05/Euratex-annual-report-2018-LR.pdf [Accessed on December 5th 2019]

[6] EURATEX Key Figures 2019, Available at: https://euratex.eu/wp-content/uploads/EURATEX-Facts-Key-Figures-2020-LQ.pdf [Accessed on June 2020]

[7] Malik, A., Akhtar, R., Grohmann, E., *Environmental deterioration and human health: Natural and anthropogenic determinants*, In: Environmental Deterioration and Human Health: Natural and Anthropogenic Determinants, 2014, 1, 421, http://doi.org/10.1007/978-94-007-7890-0

[8] Koszewska, M., *Social and Eco-labelling of Textile and Clothing Goods as Means of Communication and Product Differentiation*, In: Fibres & Textiles in Eastern Europe, 2011, 19, 4 (87), 20–26

[9] Poonam, K., Saroj, S.J.S., Neelam, M.R., *Eco – Textiles: For Sustainable Development*, In: International Journal of Scientific & Engineering Research, 2013, 4, 4

[10] Adıgüzel, F., Linkowski, C., Olson, E., *Do Sustainability Labels Make Us More Negligent? Rebound and Moral Licensing Effects in the Clothing Industry*, In: Muthu, S., Gardetti, M. (eds) Sustainability in the Textile and Apparel Industries. Sustainable Textiles: Production, Processing, Manufacturing & Chemistry, Springer, Cham, 2020, ISBN 978-3-030-38531-6, https://doi-org.am.e-nformation.ro/10.1007/978-3-030-38532-3_1

[11] European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, *Support Report Mapping Sustainable Fashion Opportunities for SMES*, May 2019, Available at: https://ec.europa.eu/growth/content/study-mapping-sustainable-fashion-opportunities-smes_en [Accessed February 2020]

[12] Skills4Smart TCLF 2030 project, Available at: http://www.s4tclfblueprint.eu/ [Accessed February 2020]

[13] ECOTEX project, Available at: http://www.ecotexerasmus.eu/en/ [Accessed February 2020]

[14] CosTUmE project, Available at: http://clothingtechnician.eu/ [Accessed February 2020]

[15] ECO-TEX Udemy platform, Available at: https://www.udemy.com/course/textilesustainabilityexpert/ [Accessed February 2020]

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