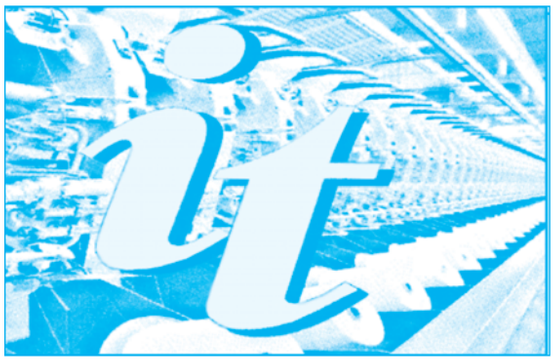

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Study of antimicrobial property of knitted spacer fabric treated with 1-Tetradecanaminium, N,N-dimethyl-N-[3-(trimethoxysilyl)propyl], chloride

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MICHAEL RODRIGUES G. THILAGAVATI

ABSTRACT – REZUMAT

Study of antimicrobial property of knitted spacer fabric treated with 1-Tetradecanaminium, N,N-dimethyl-N-[3-(trimethoxysilyl)propyl], chloride

The current study helps to understand the efficacy of antimicrobial treatment done on a weft-knitted spacer fabric. The antimicrobial agent used in the study is from the class of quaternary ammonium salts. The fabric is evaluated for antimicrobial efficacy. It is also cross-compared with the drug and some advanced wound dressings available in the market for its antimicrobial and anti-biofilm activity.

Knitted spacer fabric treated with 1-Tetradecanaminium, N,N-dimethyl-N-[3-(trimethoxysilyl)propyl], chloride (QAS) shows good antimicrobial properties and is shown to exhibit a broad range of antimicrobial effects against gram-positive bacteria, gram-negative bacteria and also fungus and yeast. The rapidity of killing and durability of microbial activity make it a very suitable material for infection control in applications like wound care materials. The spacer fabric can behave as foam in the management of exudates in wounds.

The efficacy of this material compared with other dressing materials yields substantial evidence of its activity as a wound dressing material when it comes to management of microbial contaminations including biofilm prevention and disruption. Such material can find use in the management of chronic wounds and is a subject matter of further studies with clinical evidence.

Keywords: *spacer fabric, knitted, antimicrobial, QAS, biofilm*

Studiul proprietăților antimicrobiene ale distanţierelor tricotate tratate cu clorură de 1-Tetradecanaminiu, N,N-dimetil N-[3-(trimetoxisilil)propil]

Studiul actual ajută la înțelegerea eficacității tratamentului antimicrobian efectuat pe un distanţier tricotat. Agentul antimicrobian utilizat în studiu este din clasa sărurilor cuaternare de amoniu. Materialul textil este evaluat pentru eficacitatea antimicrobiană. De asemenea, este comparat cu medicamentul și cu unele pansamente avansate disponibile pe piață pentru activitatea sa antimicrobiană și anti-biofilm.

Distanţierul tricotat tratat cu clorură de 1-Tetradecanaminiu, N,N-dimetil-N-[3-(trimetoxisilil)propil]- (QAS) prezintă proprietăți antimicrobiene și dovedeşte că are o gamă largă de efecte antimicrobiene împotriva bacteriilor gram pozitive, bacteriilor gram negative și, de asemenea, împotriva fungilor şi levurilor. Rapiditatea uciderii și durabilitatea activității microbiene îl fac un material foarte potrivit pentru controlul infecțiilor în aplicații, precum materialele de îngrijire a rănilor. Materialul distanțier se poate comporta ca spumă în managementul exsudatelor din răni.

Eficacitatea acestui material, în comparație cu alte materiale de pansament, oferă dovezi substanțiale ale activității sale ca pansament în cazul gestionării contaminărilor microbiene, inclusiv prevenirea și perturbarea biofilmului. Un astfel de material poate fi utilizat în gestionarea plăgii cronice și este subiectul unor studii ulterioare cu dovezi clinice.

Cuvinte-cheie*: material distanţier, tricot, antimicrobian, QAS, biofilm*

INTRODUCTION

The antimicrobial property of textiles is a subject matter of great importance in modern days. It finds a wide application in various areas from usages like apparel, hygiene clothes, and protective barrier textiles to areas as broad as medical textiles. There are various underlying technologies of the primary mode of action of these technologies. The rise of antimicrobial technology in textiles has helped conventional use textiles to expand its usage in the field of applications like, medical, pharmaceutical, protective, engineering, agricultural, and food industries. The choices of antimicrobial agents, and treatment techniques on textiles are guided mainly by the efficacy of testing and the durability of the treatment after repetitive laundry washes. Various methods are employed for the development of antimicrobial fabrics from impregnation to coatings and surface grafting to in-situ polymerisation [1–3]. Surface modifications with unconventional methodologies like plasma, gamma radiations and electron beam bombardment are also widely studied [2].

Microorganisms like Bacteria are essentially made up of semi-permeable cell walls. If the cell wall is disturbed externally for any reason, the bacterial cell cannot survive. This property is used as the basic mechanism of bactericidal activity of textiles. There can be other ways by which the cell content can be interfered with and made ineffective for the bacteria to replicate. In such a case the bacteria remains alive

but does not replicate. This phenomenon of antibacterial activity is termed a bacteriostatic property of textiles. Thus the word bactericidal is used when the bacteria is killed, whereas the term bacteriostatic is used when the bacteria is not allowed to replicate and grow in numbers. Both these activities are called antibacterial activity of textiles. In general, almost all bactericidal agents act as bacteriostatic agents at lower concentrations [1].

The literature cites that the modes of action of the antimicrobial agents' preliminary are as below [1]:

- Protein coagulation of the microbes.
- Disruption of the cell wall of microbes causing the contents of the cell to be exposed/damaged.
- Removal of free sulphydryl group essential for the functioning of enzymes.
- A compound resembling the essential substrate of the enzyme diverts or misleads the enzyme essential for the metabolism of the cell and causes cell death.

The most common category of the chemicals/compounds that are employed to make any textiles antibacterial is either of one of the below as depicted in table 1.

The most conventional practices used to bind the antimicrobial agent on textiles are [1]:

– fibre reaction and formation of metastable bonds;
– interaction with thermosetting agent;
– formation of co-ordination compound (Binders/Linkers);
– ion exchange methods;
– high energy radiations – In-situ grafting/polymerisation.

When one looks at the antimicrobials that are commonly used for textiles, except the metal ions or natural materials like chitosan, not many are preferred in wound dressing applications because the compound is expected to touch breached skin. The biggest concern with these compounds is that the compound may leach into the wound along with the wound dressings during its usage. It may cause cell toxicity and interfere with the normal wound-healing mechanism of the body. Such interaction in the wound is not desirable. Certain interactions can hinder normal wound healing conditions of the wound, even if they are very effective in fighting the microbial burden on the wound.

Silver seems to be the most commonly used compound when it comes to wound dressing applications of dressings. Some of the most prominent wound dressing materials that are based on silver-based antimicrobial technology are [1]:

– Acticoat – A nanocrystalline Silver based resin;
– AlphaSan – Silver Sodium hydrogen zirconium phosphate, for silver ions release;
– Actisorb Silver 220 – Silver ion-based dressing;
– Aquacel Agr – Sodium carboxymethyl cellulose with 1–2% Silver in ionic form;
– Novaron – Zirconium Silver phosphate, for silver ion release.

The main difference between microbes and bacteria is that microbes represent microscopic organisms. The most common of the seven groups of microbes are bacteria, archaea, protozoa, algae, fungi, viruses, and multicellular animal parasites. On the other hand, bacteria are a form of single-celled microbes.

All type of antimicrobial agents listed in table 1, needs to be leached from the dressing to go into the wound and encounter the microbes in the wound and on the dressing. Hence toxicity of the product becomes a crucial matter. Ideally, If they can be immobilised on the dressing and the sphere of influence of

Table 1

COMMON TYPE OF ANTIMICROBIAL AGENTS USED IN TEXTILES [2,3]

Type	Action	Merits	Demerit	Applications
Ag and other metals like Gold, copper etc.	Producing reactive oxygen species, demolition of protein, lipid and DNA	Effective and durable	Chance of depletion	Cotton, Wool, Silk, Polyester, Nylon and regenerated Cellulose
QACS	Formation of the complex with microbes, denaturing protein, and disturbing DNA to reduce propagation	Effective and durable	Often hazardous	Cotton, Polyester, Nylon and Wool
Polybiguanide	Damaging lipids, leakage of cytoplasmic sources	Effective and durable	Large amount required	Cotton, Polyester and Nylon
Triclosan	Prohibiting lipid biosynthesis, cell membrane integrity depletion	Effective and durable	Breaks into toxic dioxin	Polyester, Nylon, Polypropylene, Cellulose acetate and Acrylic
N-halamines	Binding with microbes, preventing enzymatic and metabolic processes	Effective and durable	Needs regeneration, and can cause odour	Cotton, Polyester, Nylon and Wool
Chitosan	Blocking protein synthesis, obstructing transportation of solutes toward cells	Eco-Friendly	Poor durability, opposing effect on handle	Cotton, Polyester, and Wool

the antimicrobial action can be extended, then the fullest potential of the compound can be exploited, without compromising the cell toxicity matter.

Quaternary ammonium salts (QAS) have a promising future as antimicrobial agents for textiles as they can be immobilised on the surface of textiles and have been studied to cause no bacterial resistance built up due to the unique nature of its kill which is attributed to physical rupture of the cell wall of microbes.

As per the literature, the antimicrobial compound (QAS) is bonded by silanol (a hydrolyzed silane) and it is covalently bonded to receptive surfaces (chemisorption). This bonding is then made even more durable by the silanol functionality, which homopolymerises (bonds to its neighbouring molecule). After the molecule has homopolymerised, it becomes an integral and permanent part of the product even on materials with which it cannot react covalently [4]. Figure 3 shows the matrix of cross-polymerized chemicals and its mechanism of action. Thus after treatment, cationic sites are created on the base substrate that acts as an active layer of swords [5, 6].

As this agent is positively charged (cations) and microbes are negatively charged, nearby the microbes are drawn into the active surface of the antimicrobial agent and killed. The active component responsible for the microbial kill is the edge that blows the microbes, the long molecular chain acts like a sword that pierces the cell membrane of all microbes that come in contact with it [5, 7].

This stabbing and an “electrocution” of the anionic biochemical in the membrane of pathogens resulting from the positive charge means that the antimicrobial will be fully effective as long as the surface of the treated substrate remains intact. Since it is not consumed and does not dissipate, the antimicrobial's active portion is not depleted and continues to control microbial growth. The mechanism of action is physical control, unlike chemical controls as seen in the case of leaching biocides and drugs [6]. Figure 3 shows the schematic diagram of the mechanism of microbial kill.

The current study helps to understand the efficacy of antimicrobial treatment done on a weft-knitted spacer fabric. The antimicrobial agent that is been used in this study is a quaternary ammonium salt. The fabric is evaluated for its antimicrobial efficacy and is cross-compared with the drugs and some advanced wound dressings available in the market for its antimicrobial and anti-biofilm activity.

MATERIALS AND METHODS

Materials

The spacer fabric used in this study was made by the technique of weft-knitted spacer fabric production. It is constructed with the use of Polyethylene terephthalate [PET] and polyurethane yarns in the composition of 90% Polyethylene terephthalate and 10% Polyurethane. The fabric is produced on a 24 gauge interlock knitting machine by spacer knitting technology. The structure has three distinct surfaces. The face is knitted by the cylinder needles with Polyethylene terephthalate yarn of 150/108 D and the back is knitted by the dial needles with Polyethylene terephthalate yarn of 150/108 D. The middle layer is made up of 40 D Monofilament Polyethylene terephthalate yarns that connect the front layer (cylinder loops) with the back layer (dial loops). 40 D polyurethane yarn is used as the elastomeric yarn to impart stretch to the structure. The Cylinder to dial height on the machine decides the space between the face and back layers of the fabric and hence it is optimally set to have 1.8 mm height of the fabric. The material is three-dimensional (3D) in its construction, unlike conventional gauze dressings. Figure 1 shows the image of the spacer fabric along with a cross-sectional view of the material.

It must be noted that Polyethylene terephthalate is a known biocompatible material. Further, it is a very stable material against biofluids of the wound and it does not deteriorate in long-term usage. Hence the material can be a good choice when used in wound care requirements. Table 2 enlists the details of the fabric construction.

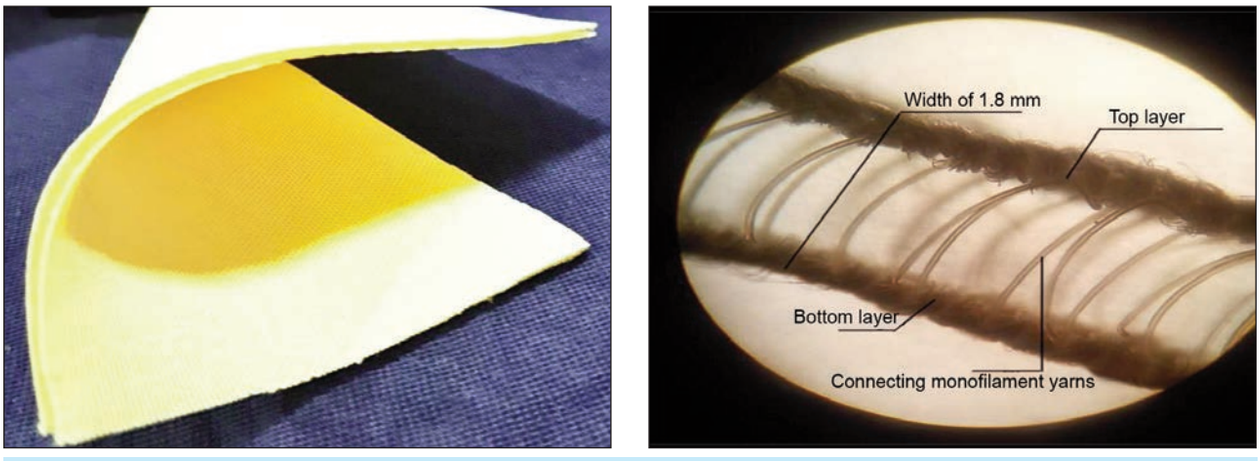


Fig. 1. Image of spacer fabric with a cross-sectional view of the material

Table 2

CONSTRUCTION DETAILS OF SPACER FABRIC	
Property	**Value**
Fabric content	90% PET/ 10% Polyurethane
Yarn at the face of the fabric	150/108 D Polyester filament yarns
Separator yarn at the centre	40 D, monofilament yarn
Yarn at the back of the fabric	150/108 Polyester filament yarns
Polyurethane yarn	40 D
GSM of fabric	300
Fabric thickness	1.8 mm

Methods

The fabric was impregnated [1] in a padding bath containing 15 gpl solution of Quaternary Ammonium Salt (QAS) called 1-Tetradecanaminium, N,N-dimethyl-N-[3-(trimethoxysilyl)propyl]-,chloride (DMTAC as abbreviated in this article). The chemical was procured from Sigma Aldrich-India. Various stabilizers and linking primers were used along with pH-balancing chemicals. The most common linkers used for such compounds are amino acids.

The fabric was squeezed under the stenter mangles and then it was dried and cured in the stenter frame at 180°C for around 35 seconds of residence time. After treatment, the fabric was washed at 40°C with a wetting agent and dried at 140°C. The fabric after treatment was an active antimicrobial fabric. Figure 2 shows the schematic representation of the process used for the treatment of knitted spacer fabric. The active component of QAS is supposed to be cross-linked on the surface of the spacer fabric imparting it the antimicrobial property. The mechanism of kill is documented in literature as the physical rupture of the pathogen's cell wall by long aliphatic chains of the cross-linked chemical [5].

The textile material thus formed is evaluated for various physical properties as listed in the table 3.

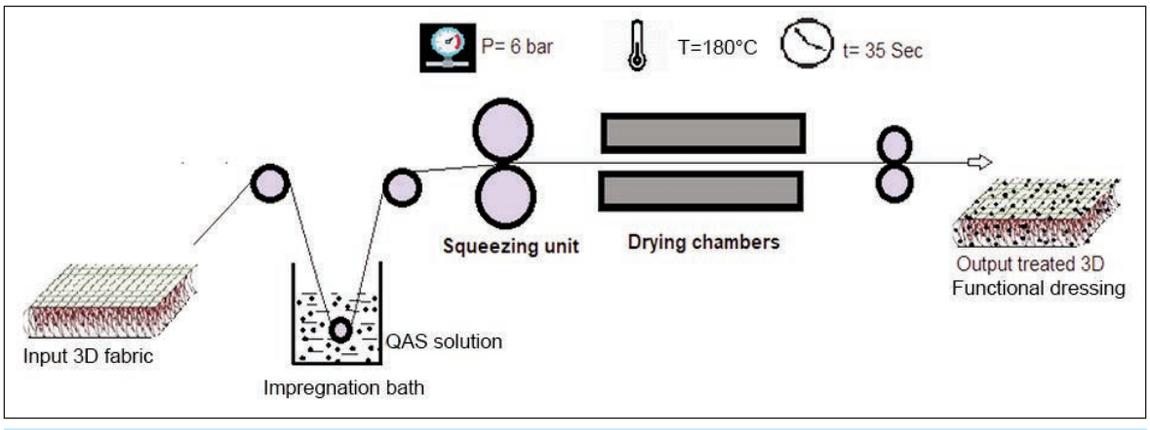


Fig. 2. Schematic representation of the manufacturing process

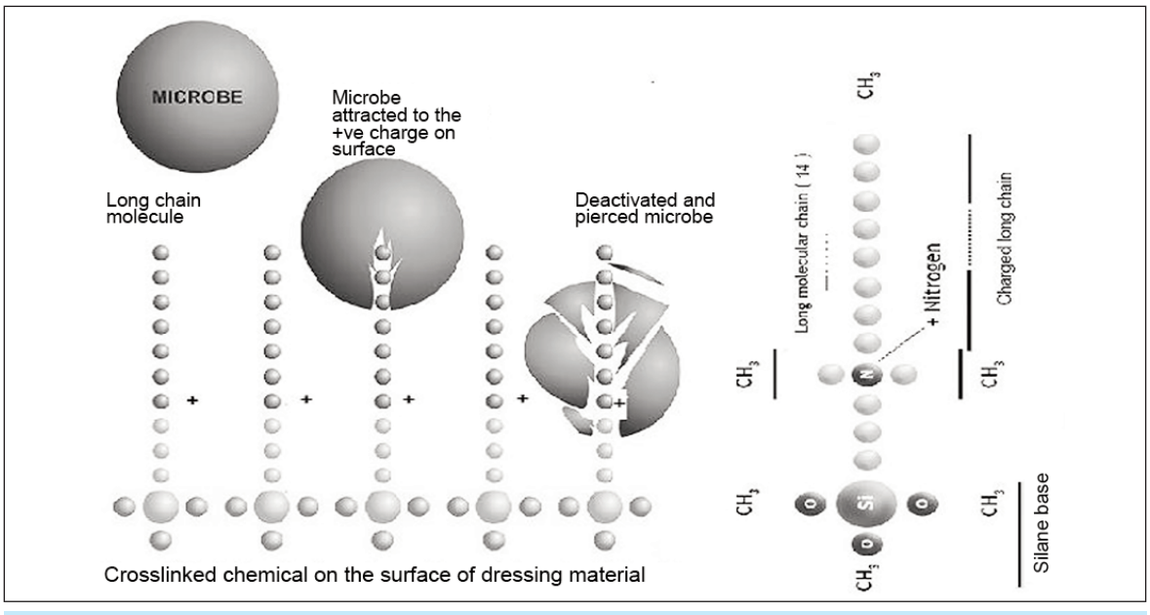


Fig. 3. Schematic representation of the mechanism of microbial Kill (Source: Aegis Microbe Shield System)

Table 3

PHYSICAL PROPERTIES OF THE ANTIMICROBIAL SPACER FABRIC			
Property	**Instrument used**	**Method/Standard used**	**Value**
Weight	GSM cutter- Weigh Scale	GSM	298
Air permeability	Air permeability tester	ASTM D 737	110 $cm^3/cm^2/s$
Elasticity	Extension relaxation method	British Pharmacopeia (BP)	43%
Stiffness (Bending length)	Stiffness tester	BS 3356	4.3 cm
Overall moisture management capacity	Moisture management tester	AATCC 195	0.6033
Water vapour permeability	Water vapour permeability tester	ASTM E 96-95 Option B	2203 $Gm/Met^2/24$ h
Water vapour resistance	Sweating hot plate method	ISO 11092	4.7423 M^2Pa/W
Water holding capacity	Gravimetric	On weight method (OWF)	360%
Synthetic blood holding capacity	Gravimetric	On weight method(OWF)	538%
Bursting strength	Bursting strength tester	ASTM D 3746	183 PSI
Tearing strength	Elmendorf tester	ASTM D 1424	14.1 lbf

Figure 4 shows the chemical reaction depicting the Cross-linking and binding of DMTAC on the Surface of PET spacer fabric. It can be seen that the DMTAC molecule not only gets bonded on the surface of PET fibre but also gets cross-bound with each other to form a 3D matrix through – Si-O-Si-bonds.

Methodology of evaluation

FESM micrographs

FESM (Field emission scanning microscopy, ZEISS, Germany EVO Model) was conducted at various magnification levels of the spacer fabric to obtain micrographs of the structure. The images were obtained for the structure before and after cross-linking of QAS on the surface of the structure.

Quantitative evaluation of antimicrobial activity (ASTM E2315)

The treated spacer fabric was evaluated for quantitative values of antimicrobial activity by ASTM E2315 [4] for three gram-positive bacteria, three gram-negative bacteria and yeast. Various contact periods were used to understand the broad spectrum effect spread over a long period

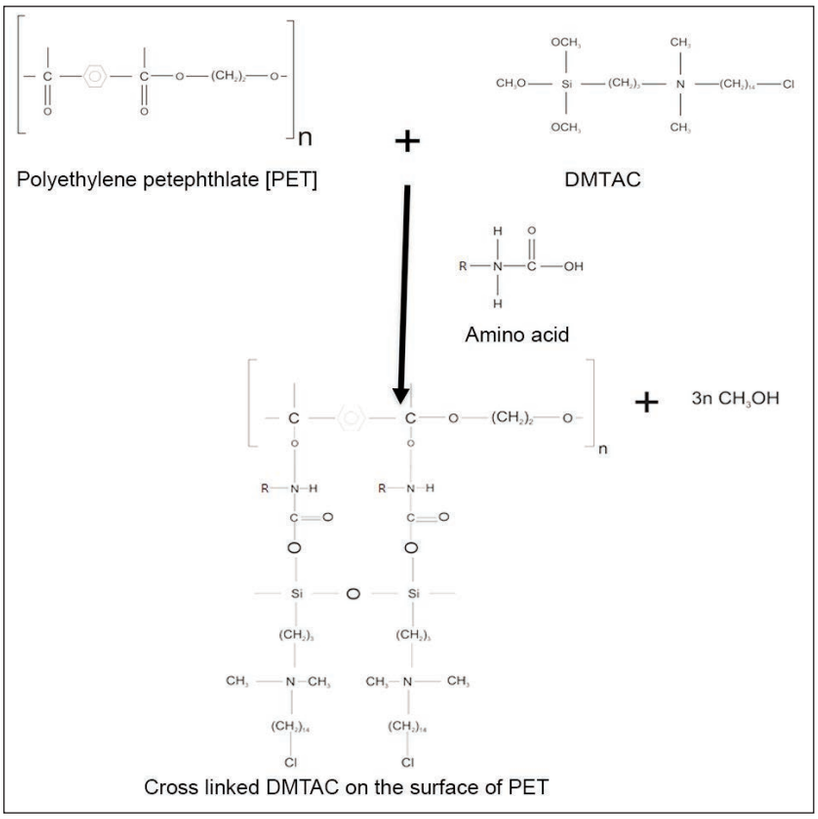


Fig. 4. Chemical reaction depicting the cross-linking and binding of DMTAC on the Surface of PET spacer fabric

The rapidity of microbial kill by ASTM D 6329-98

This test was performed to analyse the rapidity of killing microorganisms. As per standard protocol followed, the test was conducted for Staphylococcus Aureus ATCC 12600 and *Escherichia Coli* NCIM 2065. The test was also conducted to test the rapidity of killing the most drug-resistant strain called methicillin-resistant staphylococcus aureus (MRSA) ATCC 43300. Table 4 summarises the results of the test.

Antimicrobial effectiveness testing USP 51

The effectiveness of antimicrobial testing was evaluated using the test method, which is defined in US Pharmacopeia Standards chapter 51 most commonly known as USP 51. Though the method is widely used for liquid preservative contents, it also is useful to assess the effectiveness of the bactericidal activity of surfaces. Especially so where

challenge organisms are cultured on the surface of the component and then the washing of surface growth is taken to know the viable count of extract and compared with the zero time readings to study the preservative action of the subject matter [8, 9].

Evaluation of efficacy with comparator technologies

The efficacy of treated antimicrobial spacer fabric concerning various parameters like broad range microbial kill, rapidity of kill and long durability of kill of microbes makes this material suitable for applications like antimicrobial wound care dressing. Such properties are essential in wound dressing to tackle the infections that may hamper the normal wound healing cycle [10–12]. Hence the microbicide efficacy of this treated spacer fabric was evaluated with the two most common dressing technologies available in the advanced wound care market. One material was a polyester spacer fabric with silver-based antimicrobial and the other was cotton-based gauge dressing with QAS named Polydiallyldimethylammonium chloride (pDADMAC).

Table 4

COMPARATOR TECHNOLOGIES OF ANTIMICROBIAL WOUND DRESSINGS USED IN THE STUDY

Test item code	Technology	Material form
Reference 1	Elemental Silver-based antimicrobial	Polyester knitted spacer fabric
Reference 2	QAS - pDADMAC	Cotton mesh
Test Item	QAS - TMDAC	Polyester knitted spacer fabric

In this various studies like the Disc Diffusion test, Broth test rate of kill and biofilm prevention and disruption assay were performed.

RESULTS AND DISCUSSIONS

FESM Micrographs

FESM (Field emission scanning microscopy) was conducted at various magnification levels of the spacer fabric structure to obtain micrographs of the structure. The images were obtained for the structure before and after cross-linking of DMTAC on the surface of the structure. It can be seen from figure 5 that there is a layer of cross-bonded chemicals on the surfaces of the yarns. Micrographs A and C also shows clearly the presence of the monofilament yarn between the groups of multifilament yarns. This coated layer of DMTAC is now immobilised on the surface of the spacer fabric that is present on all layers i.e. on both the faces and also the middle interconnecting layer of fabric.

Quantitative evaluation of antimicrobial activity (ASTM E2315)

ASTM E 2315 method of quantitative assessment of antimicrobial activity for 3-gram positive strains, 3-gram negative strains and yeast was done [7]. The

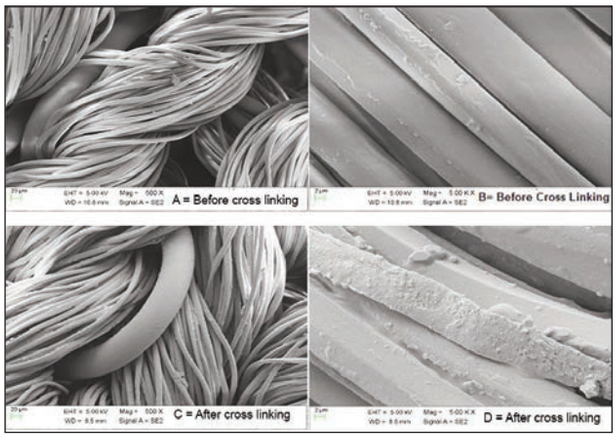


Fig. 5. FESM Images of the material before and after QAS cross-linking

positive control used was sterile nonwoven polyester viscose wipes saturated with Neolone P.E-Phenoxyethanol and the negative control was untreated sterile nonwoven polyester viscose wipes.

In this method, a control tube using nutrients was prepared without inoculation of microorganisms. The bacterial culture is added in 10 ml sterile nutrient broth and vortex and let to stand still for 15–20 min. This was then diluted with a suitable medium to 1×10^6 organisms (CFU/ml).

The treated knitted spacer fabric is cut to size such that it is capable of absorbing 1.0 +/– 0.1 ml standard inoculum. The positive and negative controls are also made ready. The test item, positive control and negative control are placed inside sterile screw cap bottles. The test inoculum (1 ml) was added to the surfaces of the items using a Micropipette. The contact time of one hour, 1 hour, 4 hours, 24 hours and 48 hours was used in the study. After the study time, the specimen was transferred into a 250 ml culture bottle and 100 +/– 1 ml of 0.05 % neutralizing solution was added and shaken vigorously for 1 minute. Serial dilutions (10^o, 10^1, 10^2 and 10^3) were done with sterile water. The dilution is plated on suitable nutrient agar plates for bacteria and fungus. The Incubation of 36 hrs at 37°C for bacteria and 5–7 days at 25°C for fungus was done. After incubation, the number of colonies was counted and noted for different contact times. The evaluation was done by reporting the number of microbes recovered on the 0^{th} contact time and the required contact time.

The percentage reduction of microbes was counted as per the below formula:

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

Where R is percentage reduction, A – the number of microbes recovered from the inoculated treated test specimen swatches in the jar incubated over the desired contact period and B – the number of microbes recovered from the inoculated treated test specimen swatches in the jar immediately after inoculation (at “0” contact time).

Table 5

QUANTITATIVE ASSESSMENT OF ANTIMICROBIAL ACTIVITY OF TREATED SPACER FABRIC					
S.no	**Test organisms**	**% of reduction**			
		1 hour	**4 hour**	**24 hour**	**48 hour**
1	*Staphylococcus aureus* ATCC 6538	99.99	99.99	99.9999	99.9999
2	*Listeria monocytogenes* ATCC 19115	99.99	99.99	99.9999	99.9999
3	*Enterococcus faecalis* ATCC 29212	99.99	99.99	99.9999	99.9999
4	*Escherichia coli* ATCC 25922	99.99	99.99	99.9999	99.9999
5	*Pseudomonas aeruginosa* ATCC 15442	99.99	99.99	99.9999	99.9999
6	*Klebsiella pneumoniae* ATCC 4352	99.99	99.99	99.9999	99.9999
7	*Candida albicans* ATCC 10231	90	90	99.9999	99.9999

Time-based kill results for different strains show that the kill rate is at least 4 log reduction within 1 hour except for *Candida albicans* yeast which as per literature needs long-duration contact for effective kill.

Table 5 shows that knitted spacer fabric has excellent broad-spectrum antimicrobial activity.

As seen in the literature survey it can be evidenced that the antimicrobial action of the QAS is attributed to its surface action after it is immobilized on the surface of the textile. Irrespective of the class of pathogen, the mechanism of killing is effective in the physical lyses of the pathogen [5, 10]. The study shows a relatively lower percentage of kills in short intervals of time for a yeast called Candida albicans, as it needs more incubation times for the yeast, which is a known medical fact.

The test results show that the treated spacer fabric is showing good antimicrobial activity for a broad range of microbes for an extended period of 48 hours as studied by ASTME 2315.

The rapidity of microbial kill by ASTM D 6329-98

This test was performed to analyse the rapidity of killing microorganisms. As per standard protocol (ASTMD 6329-98) followed, the test was conducted for *Staphylococcus Aureus* ATCC 12600 and *Escherichia Coli* NCIM 2065. The test was also conducted to test the rapidity of killing the most drug-resistant strain called methicillin-resistant *Staphylococcus Aureus* (MRSA) ATCC 43300. Table 6 summarises the results of the test.

From the test, it is clear that the antimicrobial spacer fabric exhibits the property of instantaneous kill when it comes in contact with microbes. The kill property is also seen in a very drug-resistant strain like MRSA. This strain is called a superbug because it has become resistant to many known and commonly used antibiotics. This is essentially because the mechanism of kill as documented for the QAS is the physical rupture of the cell wall of pathogens. Irrespective of the resistance built up for the drugs, it still is vulnerable to the physical rapture.

Antimicrobial effectiveness testing USP 51

In this test method, the challenge microorganisms used were *Candida albicans* ATCC10231, *Aspergillus brasiliensis* ATCC16404, *Escherichia coli* ATCC8739, *Pseudomonas aeruginosa* ATCC9027 and *Staphylococcus aureus* ATCC6538. Table 6 shows the % kill rate of microbes over some time up to 28 days.

The test results show that the antimicrobial effect of the treated spacer fabric is effective for up to 28 days. The efficacy does not drop for a long period. This is in line with the literature findings that claim that the antimicrobial once bonded to the surface of the textile is not depleted as it is not consumed in the process of microbial kill [5]. Hence the spacer fabric may be used for applications that need extended protection against microbes.

Evaluation of efficacy with comparator technologies

Disc Diffusion Test

Ciprofloxacin, a known antibiotic was used as positive control for evaluation. Discs marked as positive Control (C), Test Item (TI), Reference 1 (Ref1) and Reference 2 (Ref2) were cut and placed on 90 mm

Table 6

RAPIDITY OF KILL ASTM D 6329-98 OF TREATED SPACER FABRIC									
Test organism	**Inoculum strength**	**Test organism's kill rate at specific time intervals (%)**							
		30 sec	**1 min**	**10 min**	**30 min**	**1 hrs**	**4 hrs**	**8 hrs**	**12 hrs**
Staphylococcus Aureus ATCC 12600	$1.06x0^6$ CFU/0.5 ml	-	99.47	99.97	99.99	99.99	99.99	99.99	99.99
Escherchia Coli NCIM 2065	$1.06x0^6$ CFU/0.5 ml	-	99.48	99.98	99.99	99.99	99.99	99.99	99.99
MRSA ATCC 43300	$1.02x0^6$ CFU/0.5 ml	99.25	99.52	99.98	99.98	99.99	99.99	99.99	99.99

Table 7

USP 51 ANTIMICROBIAL EFFECTIVENESS OF TREATED SPACER FABRIC				
Test organism	**Inoculum concentration (CFU's/ml) results**	**% Kill rate seen over some time**		
	Start Concentration	**Day 7**	**Day 14**	**Day 28**
P.aeruginosa	$2.00x10^7$	100.0	100.0	100.0
E. coli	$3.00x10^7$	100.0	100.0	100.0
S. aureus	$11.00x10^6$	100.0	100.0	100.0
Candida albicans	$2.00x10^6$	99.99	99.99	99.99
Aspergillus Niger	$1.00x10^6$	100.0	100.0	100.0

agar plates spread with 100 µl of ~10^8 CFU/ml of each bacterial strain and incubated at 37±1°C for 24 hours and zone of inhibition (ZOI) i.e radius in mm around the discs were measured using a transparent ruler [11, 12].

The test organisms used were *Escherichia coli* (E. coli) ATCC 25922, *Pseudomonas aeruginosa* (P. aeruginosa) ATCC 9027, *Staphylococcus aureus* (S. aureus) ATCC 25923, *Candida albicans* (C. albicans) ATCC90028. The same strains were used in all the comparator studies.

The positive control in the case of fungus was Flucanazole which is a known fungicidal drug. The findings of the ZOI in comparison to positive controls as listed in table 8.

From table 8, it is clear that there is no significant zone of inhibition seen around the treated fabric as against known antibiotics and fungicidal compounds. This may be attributed to the fact that the cross-bonding of DMTAC on the surface of the fabric gives it a three-dimensional cross-linked matrix structure. This is called immobilisation of the DMTAC on the surface of the spacer fabric. Due to this immobilisation, the active ingredient does not leach from the surface of the fabric, unlike the drugs. A small zone seen around the material may be attributed to quorum sensing, which is the cell-to-cell communication in bacterial flora, which hints at the vulnerable bacteria near the hazard zone to stay away from the hazard and maintain distance [13–15].

After the above assay, the content then was transferred to the nutrient broth and continued incubation at 37±1°C for 24 hours and plated on nutrient agar plates to measure the residual number of microbes in the discs. Mean Log_{10} CFU/ml of broth was plotted for Control (C), Test Item (TI), Ref 1 and Ref 2 discs by using one-way analysis of variance (ANOVA) followed by Dunnett's Multiple

Table 8

ZOI COMPARATORS AGAINST KNOWN ANTIBIOTIC AND FUNGICIDAL COMPOUND			
Test organisms	**Name of the test item**	**ZOI (mm)**	
		Mean	**SD**
E. coli ATCC 25922	treated spacer fabric	0.00	0.00
	Ciprofloxacin – 1 µg/Disc	11.00	1.00
P. aeruginosa ATCC 9027	Treated spacer fabric	1.2	0.40
	Ciprofloxacin	9.50	0.50
S. aureus ATCC 25923	Treated spacer fabric	0.00	0.00
	Ciprofloxacin	11.55	0.95
C. albicans ATCC90028	Treated spacer fabric	0.9	0.65
	Flucanazole – 25 µg/Disc	3.60	0.40

Comparison Test, P<0.05 were chosen as the criterion for statistical significance. Figure 6 shows the bacterial load reduction with a 6 mm disc with known drugs (Ciprofloxacin) whereas figures 7 to 9 show the comparator with Ref1 and Ref2 when tested with different challenge microorganisms for a 12 mm disc.

From the study, it can be seen that the treated spacer fabric exhibits very efficient antimicrobial inhibition properties when compared with known drugs for

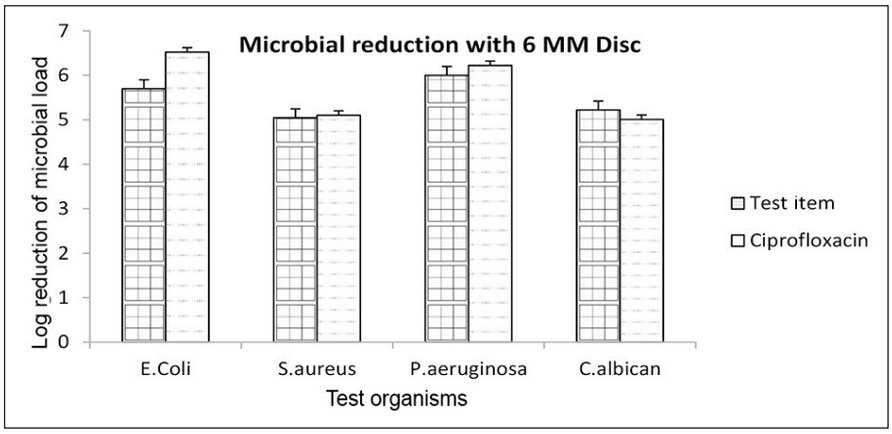


Fig. 6. Microbial load reduction on the treated spacer fabric compared to Ciprofloxacin

different strains of microbes that are gram-positive, gram-negative and yeast.

In comparison with dressing material with elemental silver and the compound pDADMAC, the treated spacer fabric has a very efficient activity for different strains of microbes that are gram-positive, gram-negative and yeast. It is because of this property of microbial load reduction the treated spacer fabric can be used in areas like as wound dressing material.

Broth test – Time rate of Kill

In this method, 15 millimetres (mm) discs of Test Item (TI), Ref 1 and Ref 2 were cut and placed into 24 well plates containing ~10^7 CFU/ml in a nutrient broth of *P. aeruginosa* and *S. aureus* respectively and incubated at 37±1°C. Control (C) tubes were incubated with only ~10^7 CFU/ml in a nutrient broth of *P. aeruginosa* and *S. aureus* respectively. After incubation, the broth was sampled at 1, 5, 15, 30 and 60 minutes plated on agar plates and incubated for 24 hours at 37±1°C. The mean Log_{10}CFU/ml of broth was plotted for C, TI, Ref1 and Ref 2 discs by using one-way analysis of variance (ANOVA) followed by Dunnett's Multiple Comparison Test. $P<0.05$ was chosen as the criterion for statistical significance. Figures 8 and 9 show the effect of time on the kill properties of the materials.

The time rate of kill study shows that the treated antimicrobial spacer fabric exhibits similar properties in terms of its kill when compared with reference and reference 2. Hence it can be considered at par with infection-reducing properties of the established advanced antimicrobial wound dressing.

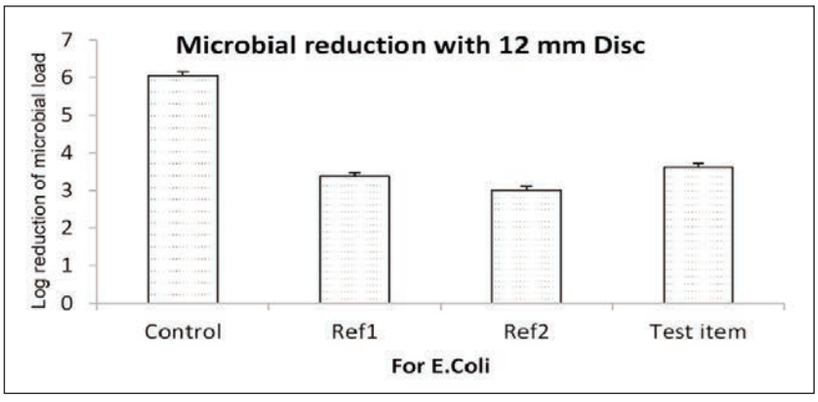


Fig. 7. Microbial load reduction comparisons with comparators for *E. coli* organism

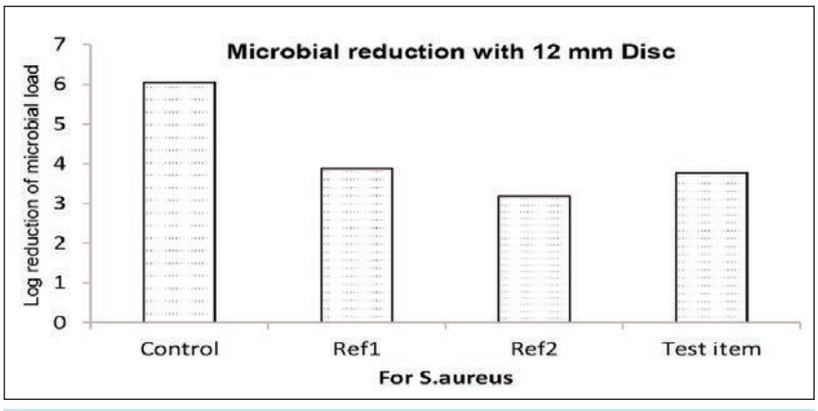
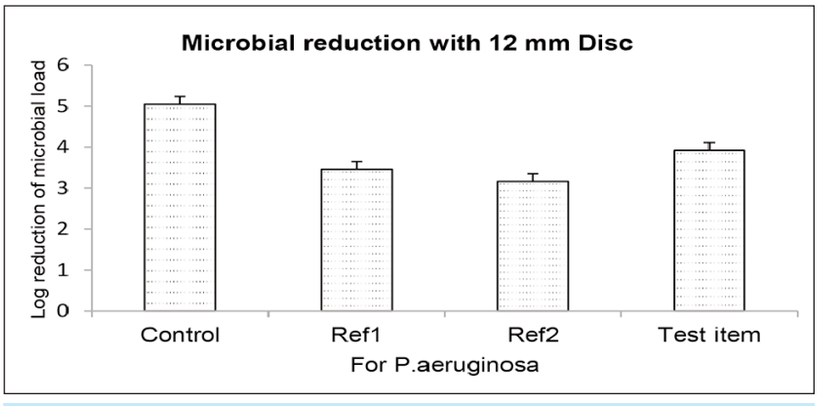


Fig. 8. Microbial load reduction comparisons with comparators for *S. aureus* organism



9. Microbial load reduction comparison with comparators for *P. aeruginosa* organism

Biofilm prevention and disruption assay

Biofilms are described as complex microbial communities. The microorganisms synthesize and secrete a protective matrix that attaches the biofilm firmly to a living or non-living surface [16]. Biofilms are dynamic heterogeneous communities that are continuously changing [15].

They may consist of a single bacterial or fungal species, or more commonly, may be poly microbial, i.e. contain multiple diverse species of microbes [16, 17].

In short, a biofilm can be described as bacteria embedded in a thick, slimy barrier of sugars and proteins that is very difficult to penetrate. The biofilm barrier acts as a protective layer against the microorganisms from external threats. Almost all chronic wounds have biofilm formed in them.

For this study, two assays were made one was a prevention assay and the other was a disruption assay. In this method, 15 millimetres (mm) discs (to cover the entire surface area of each well) of Test Item (TI),

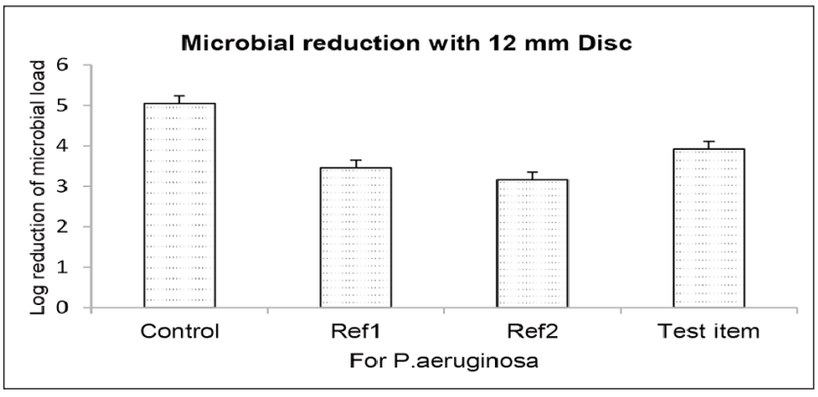


Fig. 10. Microbial load reduction comparison with comparators for *C. albican* organism

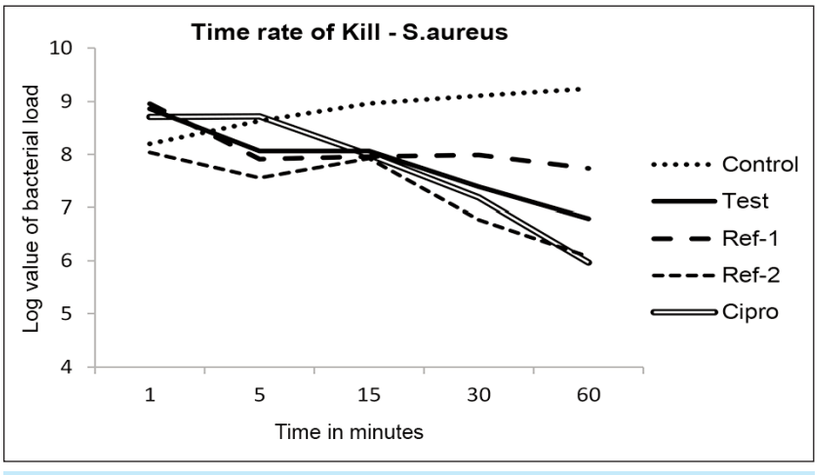


Fig. 11. The time rate of kill of treated spacer fabric with comparators for *S. aureus*

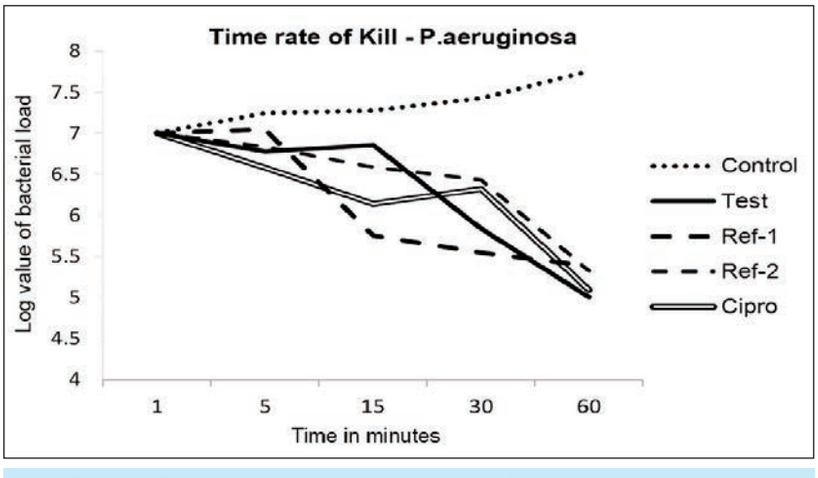


Fig. 12. Time rate of kill of treated spacer fabric with comparators for *P. aeruginosa*

Ref 1 and Ref 2 were cut and placed into 24 well plates containing ~10^7 CFU/ml in Tryptic Soy Broth (TSB) of P. aeruginosa and S. aureus respectively and incubated at 37±2°C for the Prevention assay. Similarly, 15 millimetre (mm) discs of Test Item (TI), Ref 1 and Ref 2 were cut and placed into 24 well plates containing overnight grown culture of P. aeruginosa and S. aureus respectively in TSB and further incubated for 24 hours at 37±2°C for the Disruption assay. Culture control (C) contained only ~10^7 CFU/ml in Tryptic Soy Broth (TSB) in both the Prevention and Disruption assay.

After incubation, the contents were removed and washed four times with Phosphate buffer saline (pH 7.2). A 500 µl of 0.1% crystal violet stain was added to each well and incubated for 20 minutes at room temperature, washed and dried. Subsequently, 500 µl of ethanol supplemented with 2% acetic acid was added to each well for 30 min. The Optical Density (OD) of stained adherent Biofilm was obtained by using a Tecan plate reader at 570 nm wavelength Mean optical density (OD) of C, TI, B and T discs by using one-way analysis of variance (ANOVA) followed by followed by Dunnett's Multiple Comparison Test. $P<0.05$ was chosen as the criterion for statistical significance. Figures 13 and 14 show the findings for the prevention assay and figures 15 and 16 show the findings for the disruption assay.

Higher optical density (OD) signifies a high amount of biofilm formation which is an extracellular matrix secreted when the planktonic bacteria proliferate and attach to surfaces. Known drug ciprofloxacin is a proven biofilm prevention as well as biofilm targeting entity. Hence the OD is seen to be the least among all the comparators. The silver-based dressing also shows good activity for *S. aureus*. This may be due to the free leaching of silver ions from the dressing.

In comparison, the developed spacer fabric shows comparable biofilm prevention properties in comparison to elemental silver and pDADMAC. This means when used in wound management, they would not go to the stage where biofilms are formed. It helps in the prevention of biofilm formation.

In case of biofilm disruption, especially for *P. aeruginosa* strain the treated spacer fabric is capable of disrupting the formed biofilm. Thus the material can be seen as a promising solution for the application of new wound dressings.

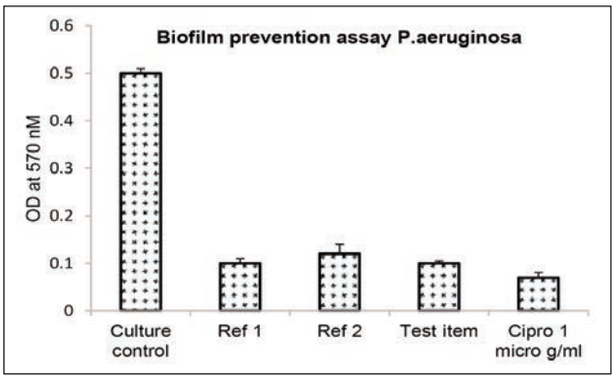


Fig. 13. Comparison of Biofilm Prevention assay for *P. aeruginosa*

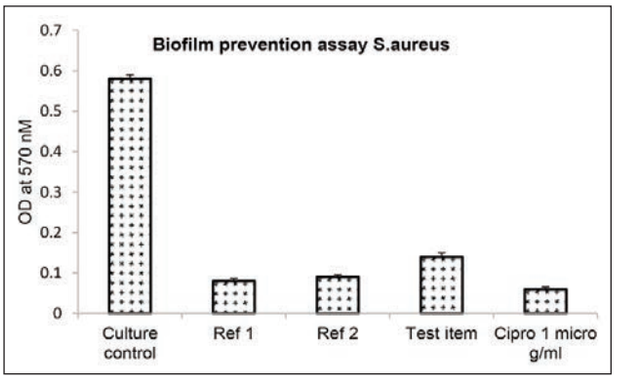


Fig. 14. Comparison of Biofilm Prevention assay for *S. aureus*

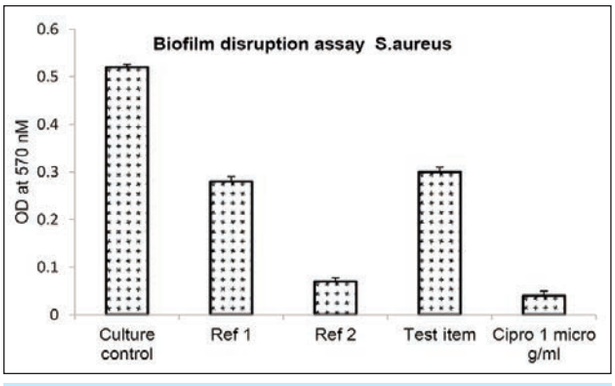


Fig. 15. Comparison of Biofilm Disruption assay for *S. aureus*

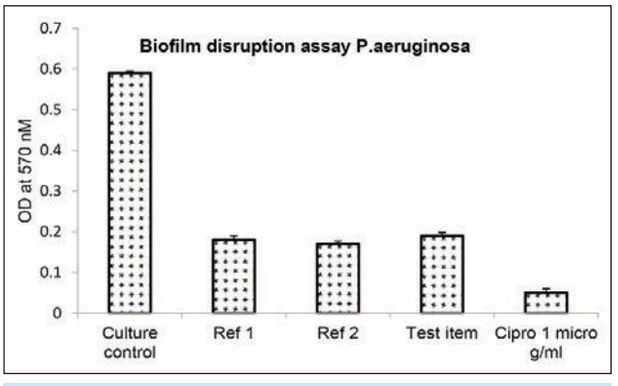


Fig. 16. Comparison of Biofilm Disruption assay for *P. aeruginosa*

CONCLUSION

Knitted spacer fabric treated with QAS has shown good antimicrobial properties in this study. It is seen that the treated fabric with DMTAC exhibits a broad range of antimicrobial efficacy against gram-positive bacteria, gram-negative bacteria and also fungus and yeast. The rapidity of kill was seen to be very effective even against resistant strains like MRSA. It was also seen that the fabric had good biofilm prevention and biofilm disruption actions. This is a very important property when the fabric is used as a wound dressing. Chronic and infected wounds are hard to heal because of the biofilms present in them. The antimicrobial and anti-biofilm properties exhibited by this dressing make it a suitable material for infection control in wound dressings. This spacer material can also behave as foam in the management of exudates in wounds. The efficacy of this material compared with other dressing materials yields substantial evidence of its superior activity as a wound dressing material when it comes to management of microbial contaminations including biofilm prevention and disruption. Such material can find use in the management of chronic wounds and is a subject matter of further studies with clinical evidence.

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Statistical analysis of textile structures based on conductive yarns

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ABSTRACT – REZUMAT

Statistical analysis of textile structures based on conductive yarns

This work presents a series of textile structures fabricated by weaving and knitting using insulating, conductive and antistatic yarns. The physical-mechanical (thickness, water vapour permeability, mass and air permeability), electrical (electrical resistivity), and morphological (SEM, EDAX) properties of the textile structures were analysed to highlight their application potential in interactive products. The statistical analysis of the correlations between physical-mechanical and electric properties was conducted by correlation analysis using the electrical surface resistivity values as dependent variables and the mass (M), thickness (δ) and water vapour permeability (Pv) as independent variable.

Keywords: *textile, conductive, interactive, resistivity*

Analiza statistică a structurilor textile pe bază de fire conductive

Această lucrare prezintă o serie de structuri textile realizate prin țesere și tricotare utilizând fire izolatoare, conductive și antistatice. Au fost analizate proprietățile fizico-mecanice (grosime, permeabilitate la vaporii de apă, masă și permeabilitate la aer), electrice (rezistivitatea electrică) și morfologice (SEM, EDAX) ale structurilor textile pentru a evidenția potențialul de utilizare în cadrul unor produse interactive. Analiza statistică a corelațiilor dintre proprietățile fizico-mecanice și electrice a fost efectuată prin analiza coeficientilor de corelație utilizând ca variabile dependente valorile rezistivității electrice de suprafață și masa (M), grosimea (δ) și permeabilitatea la vapori de apă (Pv) ca variabilă independentă.

Cuvinte-cheie: *textil, conductiv, interactiv, rezistivitate*

INTRODUCTION

In general, woven or knit materials fabricated with conductive yarns can be used as e-textiles, such as transmission lines or heating textile-based copper filaments, or as antistatic materials or odour absorbers (filaments based on carbon coating). E-textiles can generate heat, transmit electrical signals or be used as storage energy materials [1, 2].

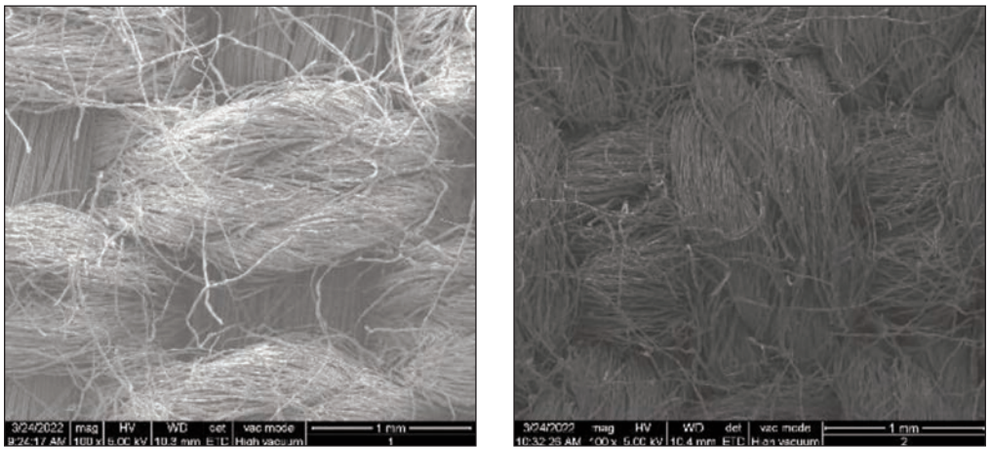
It is well known that heat can generate changes in the volume resistivity of 3D textiles or the electrical surface resistance of the 2D surfaces of fabrics or 1D conductive yarns. The electrical charge and discharge of antistatic fabrics can be controlled by weaving electrically conductive fibres into the fabric and by the density of these yarns in the weft or warp directions [3–5]. The utilization of antistatic textiles for pressure sensor manufacturing has been presented in numerous studies [5–12], and it is still a challenge for many researchers to achieve position detection or gait evaluation [12]. In addition, nanomaterial-based carbon black or graphene can be used for the development of textile coatings [13, 14], antistatic yarns and fibres with segmented structures or coated with graphene/carbon black [15–18]. Some studies indicate that CNT-coated yarns can be used as wefts, core-spun metallic yarns can be used as electrodes and polyester with yarns in the warp direction [19–22] or copper filaments [23–26] can be used as heating textiles [27, 28].

EXPERIMENTAL METHODS

Fabrics were generated with experimental textile structures (P1–P12) of weaving (P1–P3, P6–P12) and knitting (P4–P5) using insulating, conductive and antistatic yarns. Physical-mechanical, electrical (table 1) and morphological (table 3) evaluations of the fabrics were carried out in the laboratory to highlight the application potential of these materials in interactive products. The surface electrical resistivity was measured using a PRS-812 Prostate Resistance Meter based on concentric electrodes. Table 1 presents the physical-mechanical and electrical characteristics of the tested fabrics and knitwear. Table 2 shows the connections between the textile structures and the fibrous composition of the yarns. The surface morphology of the fabrics and knitwear made with yarns with electroconductive properties was investigated by scanning electron microscopy (table 3). Figure 1 shows the SEM images of samples P1 (figure 1, *a*) and P2 (figure 1, *b*) using 100x magnification, and figures 2 and 3 show the EDAX spectra of the fabric variants P1 (figure 2) and P2 (figure 3). Figures 4–7 show the 3D representations of surface

Table 1

PHYSICAL-MECHANICAL AND ELECTRICAL PROPERTIES												
Tests	**Samples**											
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**
Mass (g/m^2)	372.4	383.6	304.4	405.2	519.6	135.6	156.4	158	161.2	167.2	168.8	161.6
Density Du (no. of yarns/10 cm)	224	224	170	-	-	176	170	180	170	174	175	180
Db (no. of yarns/10 cm)	120	120	84	-	-	190	210	170	170	174	170	180
Thickness δ (mm)	1.388	1.413	1.056	2.311	2.564	0.532	0.55	0.52	0.53	0.51	0.52	0.50
Water vapour permeability Pv (%)	26.8	26.3	28.5	29	27.1	27.1	26.94	25.28	28.60	26.38	28.65	26.71
Air permeability Pa	116.9	122.8	1141	2305	435.6	1141	932.6	999.9	1580	1206	1843	1095
at 100 Pa ($l/m^2/sec$)	407.7	223.9	1799	3890	743.6	1799	1473	1640	2527	1960	2917	1824
Knit density Do	-	-	-	42	79	-	-	-	-	-	-	-
Dv				64	90							
Surface resistivity ρ (Ωm)	5.46×10^{13}	4.39×10^{13}	6.19×10^{13}	2.10×10^{13}	1.21×10^{13}	2.27×10^{13}	3.52×10^{13}	2.6×10^{13}	**1.2×10^{12}**	**8.4×10^{12}**	1.32×10^{13}	5.10×10^{13}



a *b*

Fig. 1. SEM images of samples P1 and P2: *a* – SEM image – sample P1 based on viscose filamentary yarn coated with carbon; *b* – SEM image – sample P2 based on 100 % cotton

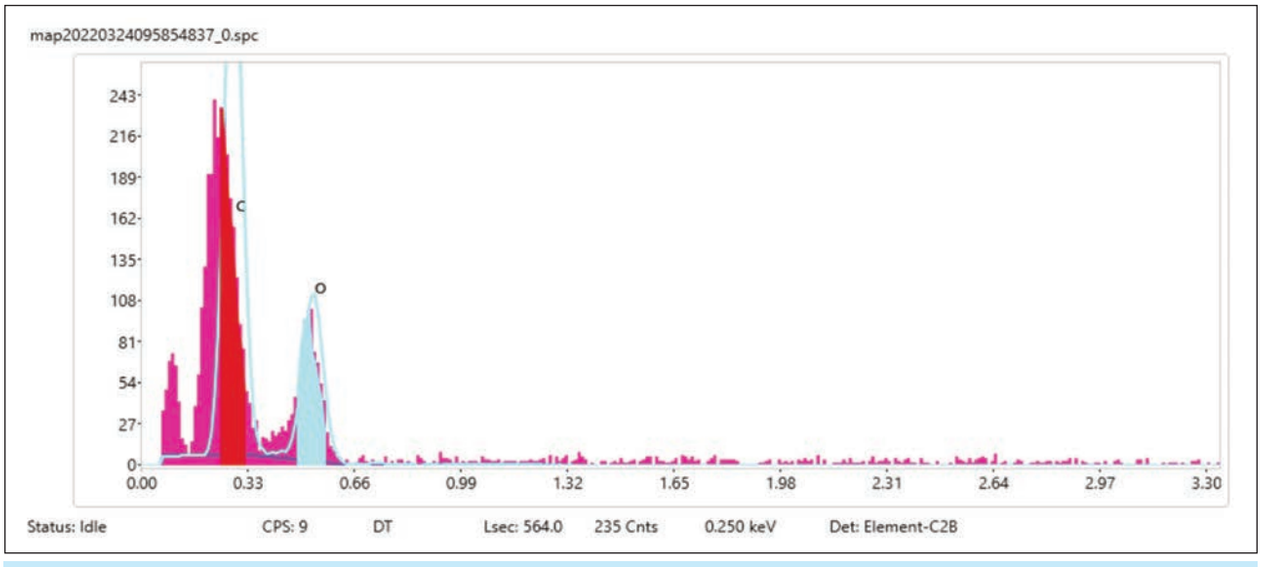
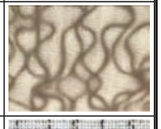
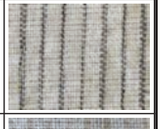
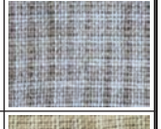


Fig. 2. EDAX of sample P1

Table 2

STRUCTURE AND FIBROUS COMPOSITION			
Sample	**Structure**	**Fibrous composition**	**Image**
P1	canvas	51.9% cotton + 48.1% viscose filamentary yarn coated with carbon	
P2	canvas	100% cotton	
P3	canvas, twisted threads inserted in the weft direction (cotton yarn + copper filament)	95.7% cotton + 4.3% metallic yarn	
P4	rib-knit 1:1 with metallic yarns	58.5% cotton+ 41.5% metallic yarn	
P5	double flat knit	white knit: 87.3% Pes + 12.7% Pa; interior: viscose filamentary yarn coated with carbon	
P6	canvas, carbon-coated viscose filament yarns (4 cotton yarns, 2 viscose yarns) inserted in the warp direction	90% cotton + 10% Viscose filamentary yarn covered with carbon	
P7	canvas	95% cotton + 5% filamentary yarn coated with carbon	
P8	canvas	92.9% cotton + 7.1% metallic yarn	
P9	canvas	80% cotton + 20% metallic yarn	
P10	canvas	86.4% cotton + 13.6% metallic yarn	
P11	canvas	73.7% cotton + 26.3% metallic yarn	
P12	canvas	89% cotton + 11% metallic yarn	

electrical resistivity as a function of thickness, water vapour permeability, mass and air permeability.

RESULTS AND DISCUSSION

Statistical analysis and discussion

To evaluate the relationship between the physical-mechanical and electric properties, correlation analysis was used. By analysing the values of the correlation coefficients (1, 2, 3) between the surface electrical resistivity vector and vectors such as the mass (M), thickness (δ) and water vapour permeability (*Pv*), the following was observed:

- The value of the correlation coefficient between the surface electrical resistivity and mass ($R(\rho, M)$ = 0.1745) was positive and indicated that there was a positive direct correlation, and the increase in the mass value per unit length generated an increase in the value surface electrical resistivity:

$$R(\rho, M) = \begin{vmatrix} 1.0000 & 0.1745 \\ 0.1745 & 1.0000 \end{vmatrix} \Leftrightarrow$$
$$\Leftrightarrow R1,2_{\rho,M} = R2,1_{\rho,M} = 0.1745 \quad (1)$$

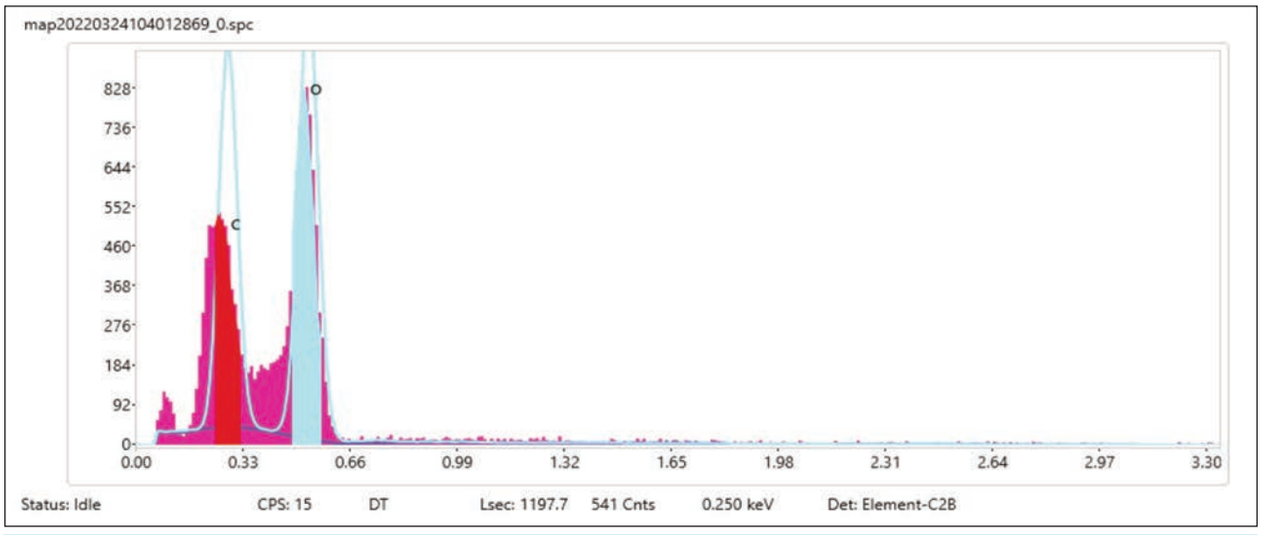


Fig. 3. EDAX of sample P2

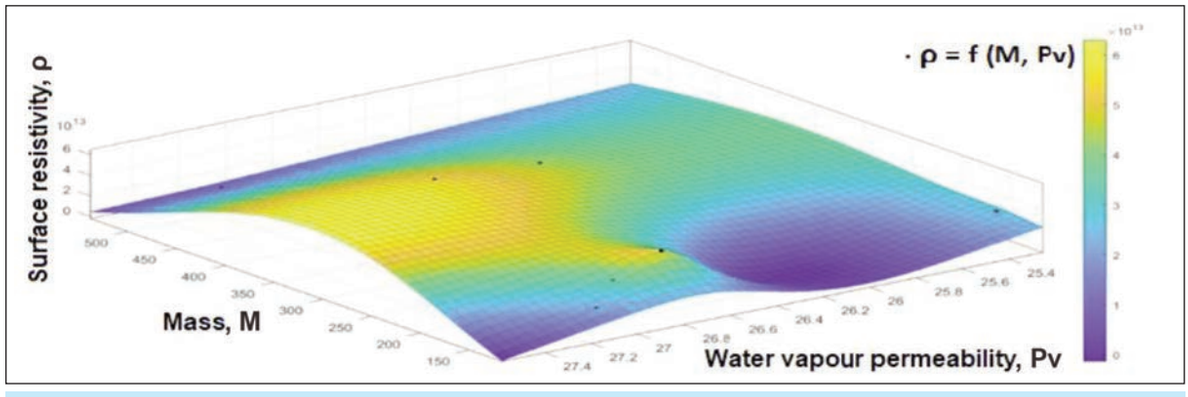


Fig. 4. 3D graphical representation of surface electrical resistivity (ρ) as a function of mass (M) and water vapour permeability (Pv)

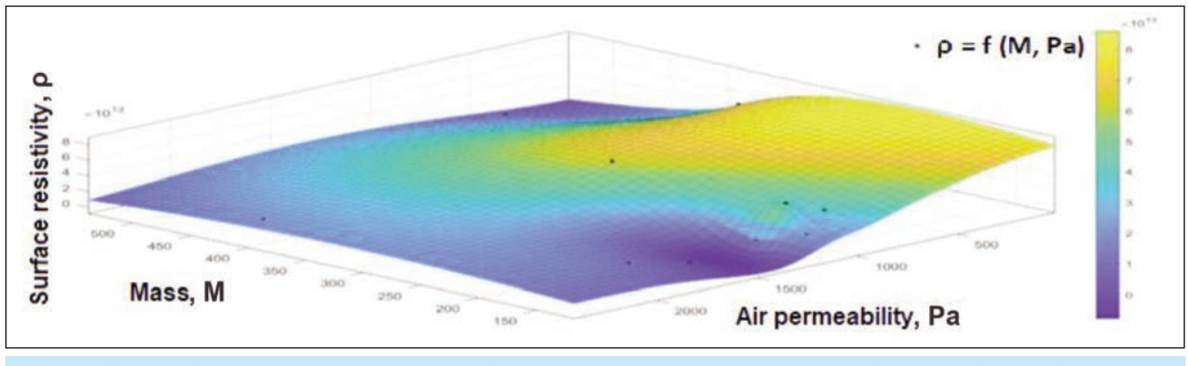


Fig. 5. 3D graphical representation of surface electrical resistivity (ρ) as a function of mass (M) and air permeability (Pa)

- The value of the correlation coefficient between the surface electrical resistivity and thickness ($R(\rho, \delta)$ = 0.0139) was positive and indicated that there was a direct positive correlation; as the thickness of the textile material increased, the resistivity value minimally increased. The surface electrical resistivity in this case can be defined as follows:

$$R(\rho,\delta) = \begin{vmatrix} 1.0000 & 0.0139 \\ 0.0139 & 1.0000 \end{vmatrix} \Leftrightarrow$$
$$\Leftrightarrow R1,2_{\rho,\delta} = R2,1_{\rho,\delta} = 0.0139 \quad (2)$$

- The value of the correlation coefficient between the surface electrical resistivity and water vapour permeability ($R(\rho, Pv)$ = –0.1784) was negative and indicated that there was a negative inverse correlation; as the value of the water vapour permeability increased, the value of surface electrical resistivity decreased:

$$R(\rho,Pv) = \begin{vmatrix} 1.0000 & 0.1784 \\ 0.1784 & 1.0000 \end{vmatrix} \Leftrightarrow$$
$$\Leftrightarrow R1,2_{\rho,Pv} = R2,1_{\rho,Pv} = 0.1784 \quad (3)$$

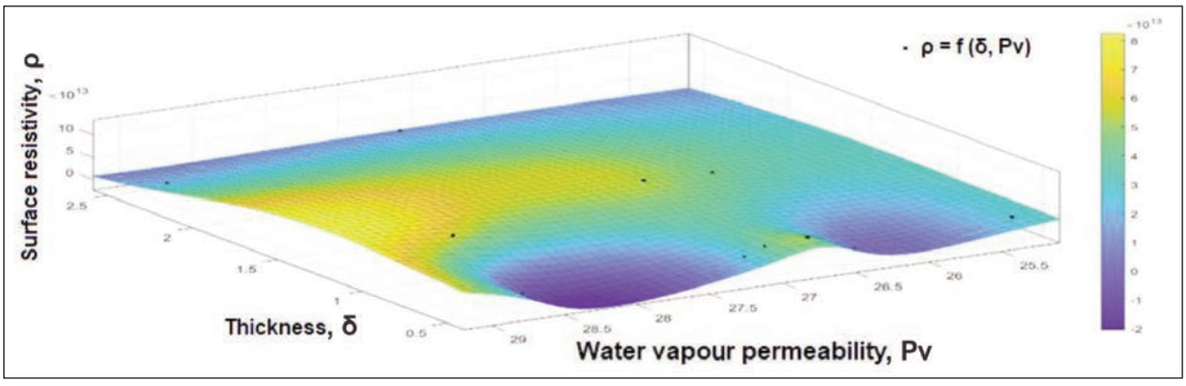


Fig. 6. 3D graphical representation of surface electrical resistivity (ρ) as a function of thickness (δ) and water vapour permeability (Pv)

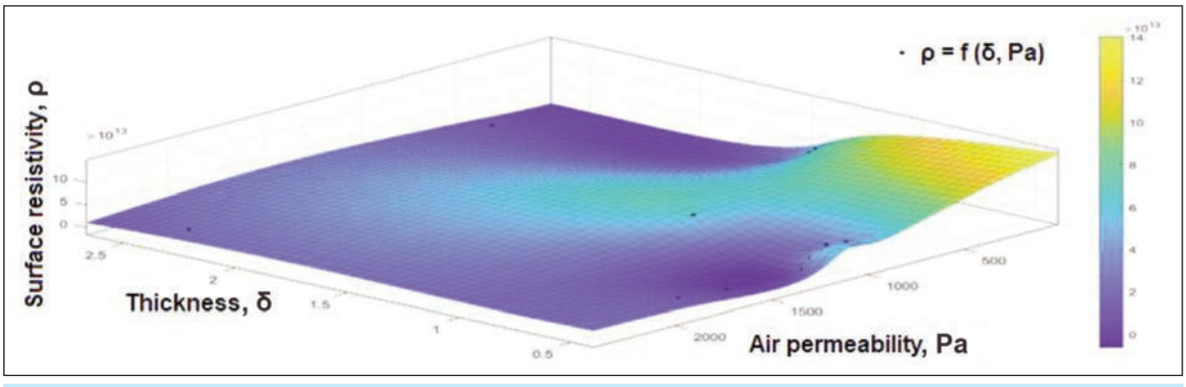


Fig. 7. 3D graphical representation of surface electrical resistivity (ρ) as a function of thickness (δ) and air permeability (Pa)

CONCLUSIONS

In conclusion, by analysing samples P1–P12, the following was deduced:

- There is an inverse relationship between the surface electrical resistivity and water vapour permeability. Because the surface electrical resistivity is the resistance to electrical current along the surface of an insulating material, increasing the vapour permeability (because of the atmospheric humidity or a lower yarn density in the weft or warp directions) generates a reduction in the surface electrical resistivity.
- With the surface electrical resistivity and mass, the respective thickness has a small positive correlation, which means that increasing the mass or thickness has a small effect on increasing the surface electrical resistivity.
- Samples P9 and P10 can offer antistatic protection because their surface resistivity falls within the range typical of materials with antistatic properties ($\rho \leq 10^{12}$ Ωm).
- Samples P1–P8, P11 and P12 can offer electrical protection because their surface resistivity falls within the range typical of electrically insulating materials ($\rho > 10^{13}$ Ωm).

ACKNOWLEDGEMENTS

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Decoding the fashion trend of sports shoes with empowered computer vision

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ABSTRACT – REZUMAT

Decoding the fashion trend of sports shoes with empowered computer vision

To adapt to the rapidly changing market and capricious trends, fashion brands need to understand trends and market conditions precisely and fast to produce marketable products. The traditional fashion trend analysis has relied heavily on the subjective judgement of experts, inevitably leading to biased decisions and is time-consuming. The development of computer vision and machine learning provides an objective and systematic approach to processing images and analysis of fashion products. However, most studies focus on clothing trends analysis, few are on shoe trends analysis. Hence, this study aimed to decode and analyse the fashion trend of sports shoes with empowered computer vision technology. In this paper, a dataset containing e-commerce images of sports shoes with precise annotations was established; then Mask-RCNN was utilized to classify and extract the shoe from the background image; a modified version of the K-means clustering algorithm was employed to detect the shoe colour. The results indicated that fashionable sports shoes and casual sports shoes were the most prevalent two styles. Besides neutral tones, yellow, red ochre and reddish orange were popular in casual sports shoes, fashion sports shoes and basketball shoes respectively and Atlantic Blue in board shoes and trainers. This study demonstrated the promising potential of computer vision and machine learning as a new method to analyse footwear fashion trends efficiently and economically.

Keywords: *fashion trend analysis, sports shoes, fashion attribute recognition, computer vision, machine learning, K means clustering*

Decodificarea tendinței în modă pentru pantofii sport cu tehnologie de viziune computerizată

Pentru a se adapta pieței în schimbare rapidă și tendințelor capricioase, brandurile de modă trebuie să înțeleagă tendințele și condițiile pieței cu precizie și rapiditate, pentru a produce produse comercializabile. Analiza tradițională a tendințelor modei s-a bazat în mare măsură pe judecata subiectivă a experților, ceea ce duce inevitabil la decizii părtinitoare și consumatoare de timp. Dezvoltarea viziunii computerizate și a învățării automate oferă o abordare obiectivă și sistematică a procesării imaginilor și analizei produselor de modă. Cu toate acestea, cele mai multe studii se concentrează pe analiza tendințelor de îmbrăcăminte, puține fiind efectuate pe baza analizei tendințelor de încălțăminte. Prin urmare, acest studiu și-a propus să decodifice și să analizeze tendința modei pentru pantofii sport cu tehnologie de viziune computerizată. În această lucrare, a fost stabilit un set de date care conține imagini de comerț electronic cu pantofi sport cu adnotări precise; apoi Mask-RCNN a fost utilizat pentru a clasifica și extrage pantoful din imaginea de fundal; a fost folosită o versiune modificată a algoritmului de grupare K-means pentru a detecta culoarea pantofului. Rezultatele au indicat că pantofii sport la modă și pantofii sport casual au fost cele mai răspândite două stiluri. Pe lângă tonurile neutre, ocru roșu și portocaliu roșiatic au fost populare în cazul pantofilor sport casual, pantofilor sport la modă și, respectiv, pantofilor de baschet, iar albastrul Atlantic s-a dovedit a fi popular la tenişi şi adidaşi. Acest studiu a demonstrat potențialul promițător al viziunii computerizate și al învățării automate ca nouă metodă de a analiza tendințele modei încălțămintei în mod eficient și economic.

Cuvinte-cheie*: analiza tendințelor modei, pantofi sport, recunoașterea atributelor modei, viziune computerizată, învățare automată, grupare K-means*

INTRODUCTION

Fashion trend represents the latest fashion elements such as styles, ornaments, shapes, and silhouettes, which is greatly influenced by political, economic, cultural and technological macro contexts of a certain time and determined fundamentally by consumers. With socio-economic and technological developments, fashion cycles are getting shorter fashion trends become more volatile and it is harder to predict than before. Additionally, consumers seek new styles more incessantly when stimulated by the short life cycle product models of fast fashion [1]. As consumers become more fashion-sensitive and demand becomes more diverse to showcase themselves to the fullest, fashion companies have to manufacture a large variety of products, which would not meet the consumer demand, thereby leading to problems such as heavy inventory and business loss [2]. Therefore, investigating fashion trends and changes in consumer behaviour precisely become a compulsory course in the fashion industry. Forecasting the fashion trend as precisely as possible was a challenge. Traditional short-term fashion forecasts heavily rely on the intuition of experts, which inevitably leads to biased decisions and is time-consuming [3].

Recently, fashion studies on fashion attribute detection and trend analysis have seen an increasing interest in the adoption of computer vision and machine learning [4], which provides an objective and systematic approach to processing images and analysis of fashion products and outfits efficiently. Earlier works [5] utilized SIFT, texture descriptors, colour in LAB, and skin probabilities to conduct feature extraction. Furthermore, Support Vector Machines(SVM) classifiers were trained to detect a wider range of 40 attributes. Bossard et al. [6] applied a Random Forest to classify the type of clothing and used several SVMs to train 78 attributes for recognizing the style of the clothing. With the development of deep learning, Liang et al. [7] developed two Convolutional Neural Networks (CNNs) and directly predicted the label masks to fully capture the complex correlations between structure and human appearance. Some state-of-the-art object detection algorithms like Faster R-CNN and Mask R-CNN were deployed for generating item proposals and classifying. Jia et al. [8] modified the Faster R-CNN model with ResNet 101 and ROI-align, additionally trained on a large-scale localization dataset with 594 fine-grained attributes to recognize fashion attributes. Shi et al. [9] modified Faster R-CNN and Mask R-CNN for recognizing attributes from images and videos respectively, thus recognising attributes such as textures, style, and design details and ultimately summarizing the fashion trend. Zhao et al. [10] applied Mask R-CNN to segment and classify clothing and used k-means clustering to extract colours, finally analysed fashion trends in colours, styles, other attributes and clothing combinations. All those deep learning algorithms showed better performance than the traditional method.

Several studies have explored how fashion trends changed from temporal and spatial perspectives by exacting cross-media fashion data [4, 11]. Chen et al. [12] investigated whether fashion trends at fashion shows influence streetwear. Getman et al. [13] visualized the patterns of baseball caps and tracked their frequency and emergence it from 2000 to 2018. Vittayakorn et al. [14] earned similarity functions on the features over the semantic parse of clothing to mimic the outfit similarity and compared fashion trends from the runway to the real world. Song et al. [15] predicted human occupation by modelling the appearances of human clothing and surrounding context based on semantic-level descriptions. Yamaguchi et al. [16] quantified the influence of fashion visual, textual, and social factors on the popularity of fashion images.

Datasets with rich data sources, specific targets and diverse attributes are the key to fashion analysis. There exists a wide variety of benchmark datasets that contributed to a comprehensive understanding and analysis of fashion, mainly coming from e-commerce like Amazon, eBay, and ModShop [17,18] and social media [19]. Among these datasets, the largest dataset is Deepfashion which comprises 800k annotated clothing images of shopping websites and Google Images, containing 50 categories and 1,000 attributes and landmarks [20]. Yamaguchi et al. [21] collected 158k photographs from a social networking website for fashion bloggers called Chictopia, which covers 56 clothing label annotations, comments, links and 685 masks estimating complete and precise regions of outfits. The database can be used for clothing recognition and retrieval. Matzen et al. [22] built a worldwide annotation dataset named STREETSTYLE-27K which retrieved more than 100 million photos with geolocation and timestamp from Instagram and 48 million geotags from Flickr 100M. However, all of these datasets mainly include clothing and there is no clean exclusive dataset for shoe images.

Although the footwear trend is generally in line with the clothing trend, it has specific characteristics due to its relatively small size and complicated colour combination. Meanwhile, consumer demands in the footwear industry are diversified, such as the prevalent demand for comfort and athleisure in line with style and performance in activewear [23].

Nevertheless, most studies have focused on the fashion trends of clothing and there has been little discussion about the trend of footwear.

Among the many image recognition algorithms such as R-CNN, Fast R-CNN, Faster R-CNN and Mask R-CNN, Mask R-CNN has the best accuracy and speed performance. It adds a branch for predicting an object mask in parallel with the existing branch for classification and bounding box regression based on Faster R-CNN, fulfilling pixel-to-pixel alignment between network inputs and outputs. Moreover, a RoIAlign layer is proposed to remove the harsh quantization of RoIPool, which properly aligns the extracted features with the input and greatly improves mask accuracy. Hence, Mask R-CNN is chosen to recognize and extract the shoes from complex backgrounds.

This study aims to decode and analyse the colour trend of sports shoes with empowered computer vision technology. To begin with, images of sports shoes from representative websites and brands in 2021 were collected to create a dataset; then Mask R-CNN was utilized to recognize the shoe style and separate them from the background; the K-means clustering algorithm was employed to detect the shoe main colour; ultimately all those attributes were summarized for fashion trend analysis. According to our study, we would like to further approve the potential application of computer vision and machine learning as a new method to decode footwear fashion trends in an efficient and time-saving way. Meanwhile, accurate trend analysis would ensure the company achieves efficient and accurate design and decision-making.

METHODOLOGY

To analyse shoe trends, this study proposed a novel fashion trend analysis system based on computer vision technology. There were two parts of models

used in this study: Mask-RCNN for segmenting the shoe from the background and recognizing basic attributes; K-means clustering for colour extraction. Algorithms were taught the attributes of the image with labelling annotation, which is called training. The Mask-RCNN was trained with 4744 images of shoes, of which there are 2846 fashion sports shoes, 806 casual sports shoes, 759 board shoes, 142 training shoes, and 190 basketball shoes. Then 100 images of each category collected were used as the validation of accuracy and robustness for the classification test.

Dataset building and labelling

11,267 sneaker images from representative online shopping websites and classic footwear brands were selected as the main trend sources in this paper, covering SSENSE, FARFETCH, SHOPBOP, NIKE, UNDER ARMOUR, ADIDAS, CONVERSE and so on for the whole year 2021. A team of design-related students were recruited and guided for manual annotation using LabelMe and Excel. LabelMe [24] is an open-access image annotation software for labelling. For each given image, students were required to label the outline of each shoe mode.

Category classification and segment

This study utilized Mask R-CNN [25] for category classification and segmentation from the background, which is a deep convolutional neural network for solving the instance segmentation problem. As the most widely used instance segmentation network in recent years, it can simultaneously perform the tasks of object detection, classification, and semantic segmentation. The Mask RCNN is a two-stage framework, where the first stage scans the image and generates proposals about the regions that are likely to contain a target; and the second stage predicts the class of objects, refines the bounding box and generates a mask of objects at the pixel level. The main network framework of the Mask RCNN consists of 6 main components: the backbone network, the Feature Pyramid network (FPN), the region proposal network (RPN), the proposal regions of interest (ROI), the rolling and the multitasking module. ResNet101-FPN was chosen as the backbone of the Mask R-CNN, which uses a top-down structure and lateral connections to extract the RoI according to the scale of the different levels of the feature pyramid and has the most balanced performance compared to other backbone networks [26].

Extract shoe colours

This study utilised the most commonly used modified version of the K-means clustering algorithm (mean-ranked K-means) clustering algorithm [27] to identify the main colours of the shoe, which avoided a large number of distance calculations when finding the nearest cluster centre for each point. K-means clustering is a specific theoretical partitioning method that randomly selects initial cluster centres and classifies pixels by performing clustering operations on the initial cluster centres [28].

EXPERIMENTS AND RESULTS

Experiments

After extracting shoes from the background, CIELAB was used to indicate the colour of a shoe instead of using RGB. Since CIELAB is considered to be perceptually uniform in terms of human colour vision, which means that the same amount of numerical alteration in these values equates to the approximately same amount of visually perceived adjustment [29]. In this study, the obtained RGB image pixels were mapped to Lab colour space and then classified into 25 clusters using the K-means clustering algorithm (figure 1).

The results of shoe categories

Table 1 demonstrates the frequency and distribution of all categories of sports shoes for various seasons and top types. In general, the numbers of fashionable sports shoes and casual sports shoes were the second highest among all types, with 4520 (40.12%) and 2705 (24%) respectively, whereas the figure for basketball shoes was the fewest at 537 (4.77%). In all categories, spring and autumn styles appeared most frequently with 10228, followed by summer style with 567, and winter style with 472, indicating that consumers mainly consider spring and autumn styles when buying fashion sports shoes or fashion sports shoes are mostly produced.

Of all the shoe categories, low-top styles had the largest proportion among all tops except basketball shoes which the high-top styles took the vast majority. The high-top styles of fashion sneakers and trainers represented the smallest among all tops, while casual sneakers and board shoes had the smallest proportion of medium tops. The vast majority of fashion sneakers were low-top types accounting for 81.42% (3680). In spring and autumn, all styles were predominantly low-top, except for basketball shoes (predominantly mid-top). Trainers and fashion sneakers constituted the least of high-top types, and casual sneakers and board shoes represented the least of mid-top types in spring and autumn. In winter, all shoe styles were dominated by high-top styles to keep warm. In contrast, there were primarily low-tops in summer, when the high-tops were the fewest type except for board shoes.

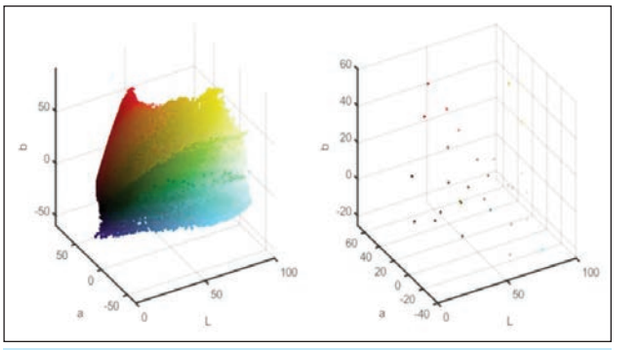

Fig. 1. Clustering process in lab colour space

Table 1

THE FREQUENCY OF ALL TYPES OF SPORTS SHOES FOR VARIOUS SEASONS AND TOP TYPE

Style	Top	Season			
		Spring/autumn	Winter	Summer	Total
Fashion sports shoes	**Total**	**4386**	**78**	**56**	**4520(40.12%)**
	low top	3601	29	50	3680(81.42%)
	mid top	447	15	4	466(10.31%)
	high top	338	34	2	374(8.27%)
Casual sports shoes	**Total**	**2461**	**178**	**66**	**2705(24%)**
	low top	1761	37	57	1855(68.58%)
	mid top	313	30	7	350(12.94%)
	high top	387	111	2	500(18.48%)
Board shoes	**Total**	**2209**	**93**	**394**	**2696(23.93%)**
	low top	1779	14	338	2131(79.04%)
	mid top	112	3	2	117(4.34%)
	high top	318	76	16	410(19.24%)
Training shoes	**Total**	**713**	**58**	**38**	**809(7.18%)**
	low top	471	5	35	511(63.16%)
	mid top	164	8	3	175(21.63%)
	high top	78	45		123(15.20%)
Basketball shoes	**Total**	**459**	**65**	**13**	**537(4.77%)**
	low top	82	2	6	90(16.76%)
	mid top	204	3	4	211(39.29%)
	high top	173	60	3	236(43.95%)
Total	-	10228	472	567	11267

The results of colour detection

Figure 2 demonstrates the percentage of 10 colours of all sports shoes according to different seasons and categories. In general, the main colour palette was black, white and grey in different shades of light. Light grey accounted for the largest colour proportion (60% in fashion sports shoes and 52% in all categories) except trainers and board shoes where black took up the largest percentage (approximately 30%). On the contrary, fashion sports shoes and basketball shoes represented small proportions of black (only 5%). The colour that constituted the second largest proportion was medium grey among casual sports shoes, board shoes, fashion sports shoes and basketball shoes, ranging from 10% to 20%. The overall colour scheme of casual sports shoes was a simple warm grey and the smallest percentage of all colours was rufous. The distribution of different grey colours in casual sports shoes was also in keeping with the colour style of casual wearing. It can be seen that several vibrant colours such as blue, fruit green, orange and red are in board shoes, trainers and basketball shoes. And it was not uncommon to apply these sporty, energetic and fashionable bright colours to those types of sneakers. On the other hand, one of the few bright and vibrant colours in fashion sports shoes was red, only occupying 0.5%, while the major colour was light grey. This was mainly because most people considered the matching of shoes and clothes when choosing fashionable sports shoes.

The lightness of the colours of sneakers varied from season to season. In winter, there were around half of the sneakers with dark colour, comprising 28% dark grey and 18% black. The general hue was warm in winter shoes while the hue was fresh and cool in spring, autumn and summer. The shoe colours conformed to the laws of the seasons just like clothes. Among the three seasons, black ranked the smallest percentage in summer and was more taken place by cool light grey compared to winter.

Figure 3 depicts the ten primary bright and spritely colour distributions of different seasons and categories. In addition to blue dominating board shoes and trainers, warm colours such as red and brown occupied the most position and cold colours such as green accounted for the least colour among casual sports shoes, fashion sports shoes and basketball shoes generally.

Concerning casual sports shoes, orange and red ranked as the largest two positions, while green and modena ranked the smallest relatively. Red ochre and reddish orange became the colour trend of fashion in sports shoes and basketball shoes respectively. It makes sense to see a vibrant colour like reddish-orange in basketball shoes and casual yellow in casual sports shoes. In terms of seasonal trendy colours, cold colours like blue and modena were the

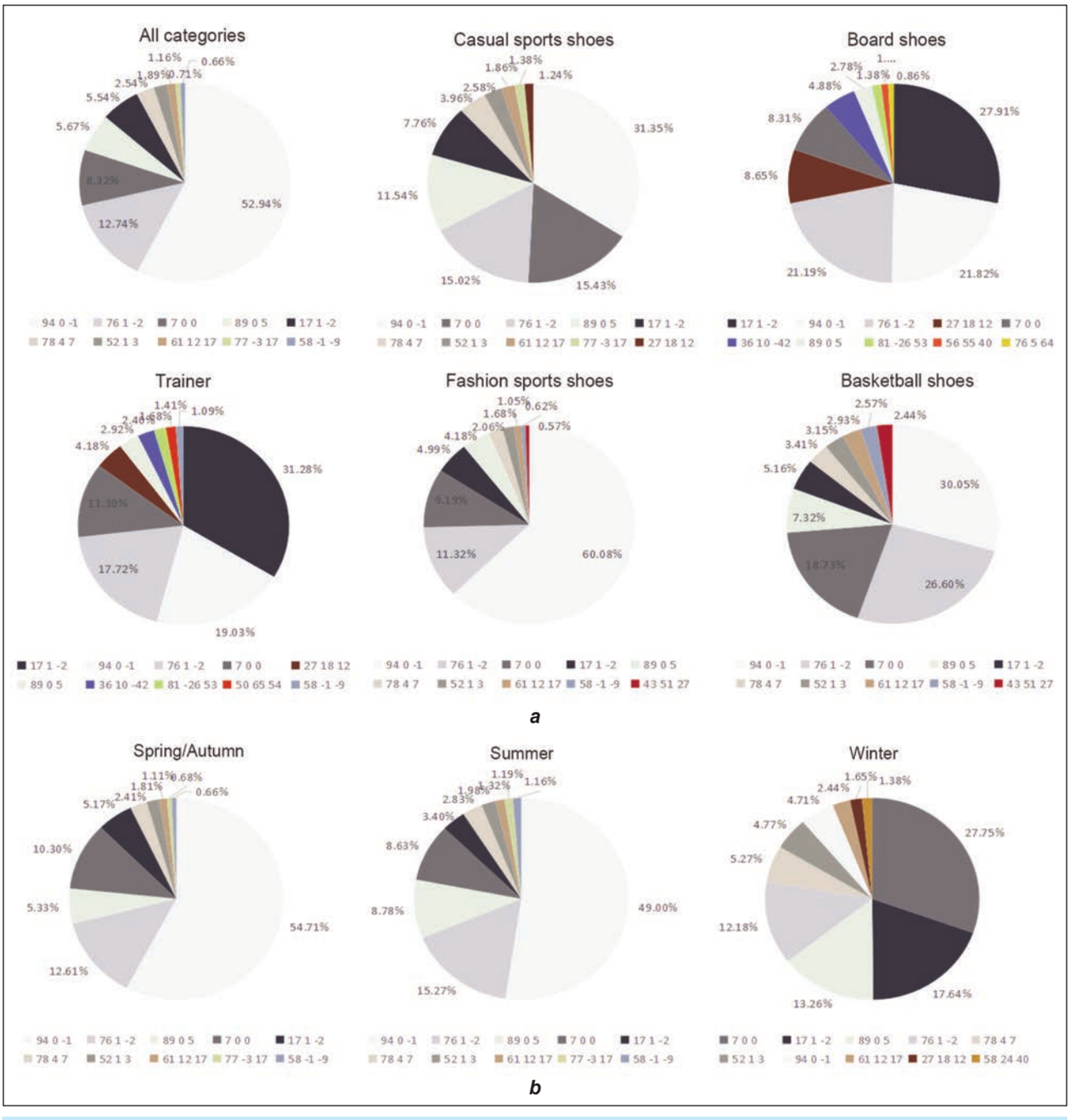

Fig. 2. 10 main colour distribution of different: *a* – categories; *b* – seasons

trend in summer while dark colours like red ochre for winter and warm colours such as reddish orange were the trend in spring and autumn in 2021.

DISCUSSION

The proposed AI method based on computer vision can accurately recognize the fashion attributes of sports shoes, including category and colour. In this study, the backbone network ResNet101-FPN has been used to recognize board shoes, sneakers and boots with intersection over union (IOU) of 79.12, 74.59, and 71.19 respectively. The reason for the difference may be that there is not enough training and the number of each category is not evenly distributed. Moreover, there exist some exaggerated and unconventional design appearances that might affect this. The average similarity of recognition of Mask-RCNN was above 85.5% and the inference time was 0.1s for each image, which exceeded the precision in the previous research and enabled the algorithm to analyse images more effectively and accurately compared to the traditional manual trend analysis method [9, 30]. In addition, 25 types of lab colours were extracted and analysed in this research, including the most used, compatible and basic colours and some trendy colours.

The datasets established in this research contain 11,269 collected e-commerce images with 4754 clean mask annotation, which is inclusively focused on sports shoes. Nevertheless, most of the fashion datasets are primarily clothing-relevant and some researchers train the models with a weakly supervised

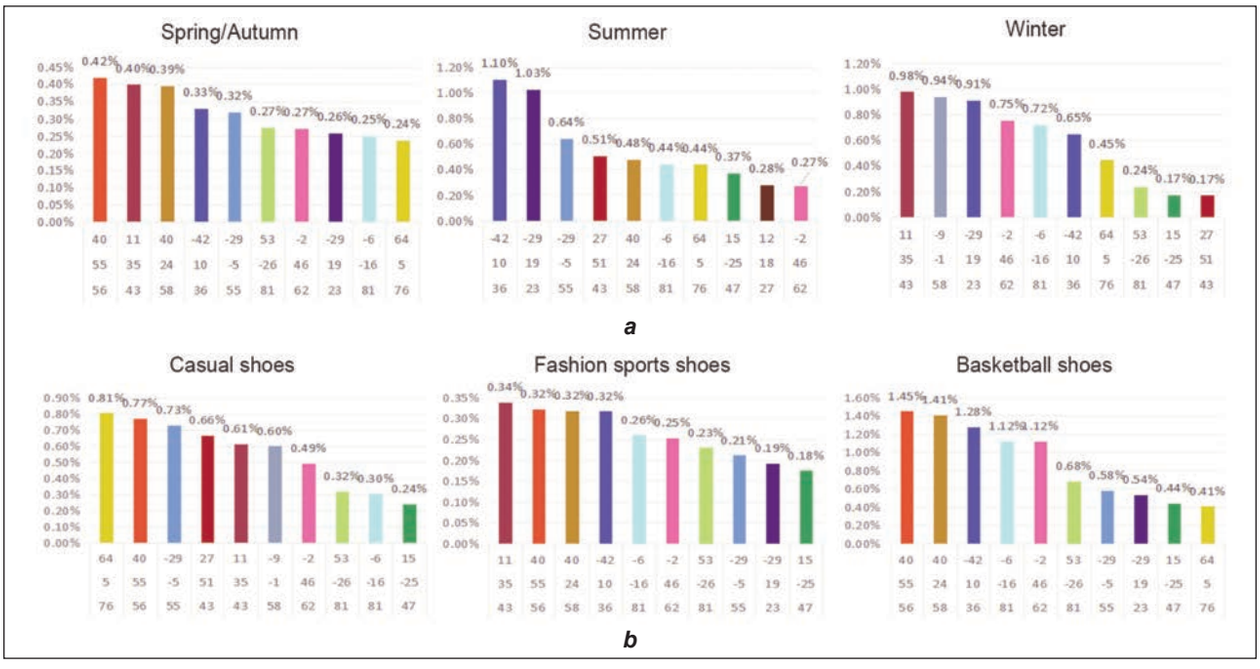

Fig. 3. 10 primary bright colours distribution over different: *a* – seasons; *b* – categories

approach that learns through noisy text labels, which may lead to inferior performance [31, 32]. With the development of online media, social media has become an important medium for fashion trend dissemination and fashion trend analysis combined with social media images from the temporal-space dynamics perspective can be the next direction. Future enlarged datasets sourcing from street photographs, runways and social media from different places and times are therefore recommended.

The exaction results indicated that the numbers of fashionable sports shoes and casual sports shoes are the highest two types, which was consistent with the current consumer attitude of focusing more on both comfort and fashion in consumption and life. It is also likely that the dataset mainly comes from fashion e-commerce, therefore fashion sneakers take up the most percentage. As for top styles, low-top styles represented the largest proportion among all tops except basketball shoes which the high-top styles took the vast majority. Although the design of the low-top is convenient for taking on and off movement, the high-top of the basketball shoe is designed to offer protection to the ankle and Achilles tendon when playing basketball.

The most frequent colours were neutral tones and were seen in the trend analysis by WGSN. About bright colours, blue dominated board shoes and trainers, which was also in line with Atlantic Blue in the sneakers trend report in 2021 by WGSN [31]. Warm colours occupied the most position and cold colours accounted for the least colour among the other 3 types of shoes generally. In summary, the primary sneakers' colours were grey, white and black, which are clean and simple. The trendy colours varied from season to season, predominantly cool colours in summer, and warm colours in spring, autumn and winter. As for trendy colours in different categories, yellow, red ochre and reddish orange represented the most popular colours in casual sports shoes, fashion sports shoes and basketball shoes respectively and Atlantic Blue represented the most popular in board shoes and trainers.

The interpretation of methods proposed in this study would be as follows: (1) by combining the Mask-RCNN with k-means, we could quantify the fashion element of shoes to automatically classify and extract; (2) subsequently, we could explore their correlations within various fashion elements, and then further establish the mathematical forecast model of the fashion trend; (3) this whole process would be independent to the viewpoints of the traditional experts. It sources from the massive data existing in the public and reflects the real-world acceptance of fashion trends. Therefore, this approach will have a wide range of applications in reality.

CONCLUSION

This study explored the potential of computer vision and deep learning as a new method to analyse footwear fashion trends efficiently and accurately compared to quantitatively conventional manual methods, according to the analysis of a dataset containing 11,269 images of sports shoes established from representative websites and brands. This study has identified yellow, red ochre and reddish orange as the most popular colours in casual sports shoes, fashion sports shoes and basketball shoes respectively and Atlantic Blue represented the most popular in board shoes and trainers in addition to neutral tones. It appears to be a pioneering study to build a dataset within the domain of sports shoes and with fine-grained attribute annotations, which will facilitate

subsequent research into shoe fashion trends analysis. This time-saving and economical method of trend analysis enables fashion companies to the fast respond quickly to trends and market information quickly, thus introducing products that meet the trend efficiently and economically.

Considering the relatively limited amounts of data, training time and technical support for the training of the project, students were asked to label only the category of the shoes. In the future, more shoe images covering wider categories can be labelled and fed into the dataset to refine the instance segmentation algorithm and fashion attributes such as patterns and materials can be considered for recognition. The fashion dataset should be expanded, containing not only online shopping images but also images from runway, street and social media and other text information like brand, year, location comments, etc. A further study focused on the multi-dimensional analysis of fashion trends such as fashion propagation and the influence factors is therefore suggested.

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An eco-friendly approach: effect of fixation time on colour and comfort properties of digital printed fabric

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ABSTRACT – REZUMAT

An eco-friendly approach: effect of fixation time on colour and comfort properties of digital printed fabric

This study will examine how digital printing affects clothing comfort on knitted fabrics from different raw materials. Garments significantly affect the heat exchange between the human body and the environment. Therefore, consumers prefer thermally balanced and effective moisture-controlled products in the selection of clothing. Air permeability is also important in explaining the comfort performance of the product in the textile industry. On the other hand, digital printing machines have become the centre of attention of consumers as a print type on which the desired pattern can be printed on the chosen fabric and more ecological, faster, and economical. However different printing processes can change the comfort characteristics of the garments.

In this study, single jersey knitted fabrics 100% Ne 12/1 cotton, 100% Ne 30/1 cotton, and Ne 12/1 70% cotton + 30% Hemp were produced. Raw materials were bleached and singed, then coloured with digital printing. After that, air permeability, bursting strength, stiffness, ironing fastness, and SEM analyses were applied to samples when the results were determined, it was seen that heavier fabric will have higher stiffness. Also, thicker yarns have higher bursting strength. It follows that the cotton-hemp blended fibres (PK) have high unevenness, and the bursting strength of the fabrics produced from this raw material is lower than cotton fabrics (P12). Similarly, since the thin-thick place values of cotton-hemp blended yarns are high, porosity is one of the most important factors affecting air permeability in fabrics. This porous structure also increased the air permeability of the fabric.

Keywords: *inkjet printing, air permeability, hemp, thickener, knitted fabrics, fixation time, ironing fastness*

O abordare ecologică: influența timpului de fixare asupra proprietăților de culoare și confort ale materialului textil imprimat digital

Acest studiu va analiza modul în care imprimarea digitală afectează confortul îmbrăcămintei realizată din tricoturi din diferite materii prime. Îmbrăcămintea influențează semnificativ schimbul de căldură dintre corpul uman și mediu. Prin urmare, consumatorii preferă produse echilibrate termic și eficiente cu umiditate controlată, în selecția îmbrăcămintei. Permeabilitatea la aer este, de asemenea, importantă în explicarea performanței de confort a produsului în industria textilă. Pe de altă parte, mașinile de imprimat digital au intrat în centrul atenției consumatorilor ca tip de imprimare pe care poate fi imprimat mai ecologic, mai rapid și mai economic modelul dorit pe materialul textil ales. Cu toate acestea, diferitele procese de imprimare pot modifica caracteristicile de confort ale articolelor de îmbrăcăminte.

În acest studiu, au fost produse tricoturi glat 100% Ne 12/1 bumbac, 100% Ne 30/1 bumbac și Ne 12/1 70% bumbac + 30% cânepă. Tricoturile brute au fost albite și pârlite, apoi imprimate digital. După aceea, permeabilitatea la aer, rezistența la plesnire, rigiditatea, rezistența culorii la călcare și analizele SEM au fost determinate pentru probele studiate şi s-a demonstrat că materialul textil cu masa mai mare va avea o rigiditate mai mare. De asemenea, firele mai groase au o rezistență mai mare la rupere. Rezultă că fibrele în amestec din bumbac și cânepă (PK) au neregularităţi mari, iar rezistența la plesire a tricoturilor produse din această materie primă este mai mică decât cea a tricoturilor din bumbac (P12). În mod similar, deoarece valorile de subţiere-îngroşare ale firelor în amestec din bumbac și cânepă sunt ridicate, porozitatea este unul dintre cei mai importanți factori care afectează permeabilitatea la aer a tricoturilor. De asemenea, această structură poroasă a influențat pozitiv permeabilitatea la aer a tricotului.

Cuvinte-cheie: *imprimare cu jet de cerneală, permeabilitate la aer, cânepă, agent de îngroșare, tricoturi, timp de fixare, rezistența culorii la călcare*

INTRODUCTION

Sustainability means ensuring diversity and productivity in a system. As mentioned in the green agreement published by the Ministry of Commerce, sustainability has become a concept that covers all production stages today. In this context, with the increase in environmentally friendly approaches, the production of organic, ecological and ethical textiles has started to become widespread. New ways are being explored to find ways to stop the environmental pollution caused by textile production, to produce fabrics that do not need toxins and large amounts of water, and that minimize local damage to the ecology [1].

Within this scope, hemp fibres are defined as one of the fibres that contribute to sustainability. Hemp fibre is used in products with high added value due to its superior properties such as high strength properties, high moisture absorption and breathability, no pilling, organic products, antibacterial properties, UV

protection, and good electrostatic properties. There is a wide variety of products made from hemp fibres [2]. Textile materials are often coloured to give the fabric a more attractive appearance or effect. Printing in textiles means painting limited spaces, allowing one or multi-colour patterning or regional colouring. In addition to various conventional methods such as rotation, film ruck, transfer, and roll printing, the digital (ink-jet) printing method, which has started to be the centre of attention of machine manufacturers in recent years, also finds wide use. Digital printing technology eliminates the mechanical steps in the conventional printing method. It saves time as it does not require many steps such as preparation. It also allows the necessary revisions and corrections to be made at the lowest cost.

When conventional textile printing and digital textile printing are compared, it is seen that there are big differences between them in terms of cost and the fulfilment of customer demands. In classical textile printing, pre-printing processes are required for the desired patterns and colours such as screen preparation costs. On the other hand, high-resolution and quality printing is possible without colour limitations in digital printing. In addition, the energy and water consumption consumed by conventional printing methods is largely avoided. It is known that 95% less water and 30% less electricity are used in digital printing [3–6]. In the literature on ink-jet printing, there is a lack of studies on the subject of pretreatment and steaming time. Thus, this study aims to investigate the effect of different fixation times on fabric properties using different raw materials for digital ink-jet printing and the possibilities of achieving higher colour yields, and better fastness properties. Yang et al. printed on 100% cotton fabric and a traditional setting machine and a newly designed setting machine were used for the fixation of the fabrics.

2–4 minutes at 110°C gave the best results in the conventional method. In atmospheric fixation, 15–25 minutes at 100°C were indicated as the most appropriate parameters [7]. In 2007, Yuen conducted a study on the pretreatment of 100% cotton fabrics with chitosan biopolymer. It was neutralized by passing through 2 baths, the first being acidic and the second acidic. As a result; it was observed that fabrics treated with the 2-bath method had a better colour than untreated fabrics and fabrics pre-treated with chitosan. The bacteria were destroyed after 48 hours in the 2-bath method and chitosan [8]. In Selçuk's master's thesis, the effect of pre-treatments applied to fabric in digital printing on print quality was investigated. When the results were evaluated, it was seen that the use of alkaline at the rate of 20 g/l gave the best colour and fastness results. However, the optimum value is given as 100 g/l for urea. The optimum value for the thickener chemical varies between 100 g/l and 125 g/l [5]. In Kaimouz's study, the effect of the fabrics and processes on ink penetration was examined. Tencel fabrics both have higher dye uptake than cotton. Standard Tencel has the best colour fastness. It has been determined that the dye uptake of the fabrics produced from Tencel A100 raw material is good, but the colour resistance is low [9]. In 2012, Gorgani et al. performed a one-step digital printing pre-treatment by applying 4 different organic salts at different concentrations and different pH values. It has been observed that the use of organic salts improves light fastness in all types and concentrations and increases the fixation rate. Regardless of the type, it has been stated that the pretreatment pH value of 8 gives the best results [10]. In a study conducted in 2016, the effect of pretreatment on the ink droplet spread was measured. In summary, 4 g of saturated fatty acid derivative (PT) added to sodium alginate controls the spread of the droplet. Thus, savings can be achieved in terms of ink cost [11]. Golam Kibria et al. aimed to investigate the effects of printing. Finally, after comparing the test results, it was found that the properties of the fabrics printed with thickeners in combination with sodium alginate were better than those printed with a single thickener [12].In another study, interlock knitted fabrics were coloured with digital printing. When the test results were evaluated; it was concluded that the fixing temperature had an effect on air permeability, but it did not lead to a significant change in bursting strength [13]. In experimental research, cotton and Tencel fabrics are coloured by a digital printing method. It was observed that the time-dependent rate of drying- thus the mass loss- and transfer capillary wetting ability were consistent with the results found in the literature [14]. In their study, Muhsin et al. investigated the performance of the digitally printed cotton fabric using three sustainable and formaldehyde-free cross-linkers, three different softeners, C8-free oil and water repellent, and halogen-free flame-retardant. The results show that the proposed sustainable finishes have significantly improved the performance of the digitally printed fabric as compared to the reference non-finished digitally printed sample [15]. The study which was published in 2021, aimed to optimize the process parameters. The bulk-scale experiments carried out at optimum levels have shown that an average of ca. 52% of reactive ink, 37.5% of urea and 50% of alkali can be saved by digital printing of cationized cotton along with the generation of nearly colourless effluent [16]. In a study, single jersey knitted fabrics obtained from raw materials of Cotton, Viscose, Cotton-Hemp, Cotton-Modal, and Cotton-Viscose mixed raw materials were used. All fabrics treated with a 6-minute fixation time have lower bursting strength than 10 minutes. For cotton-hemp and cotton fabrics, as the yarn number increases bursting strength increases too. The use of 150 g/l thickener for all cotton, viscose, cotton-modal and cotton-viscose fabrics reduced bursting strength for both fixation times [17]. This study aims to investigate the use of different types of thickeners as a replacement for sodium alginate in the pretreatment paste in digital ink-jet printing of cotton fabrics The results showed that sodium carboxymethyl cellulose can be used properly in the pretreatment paste for reactive ink-jet printing [18].

MATERIALS AND METHODS

Fabric production properties

The yarns used in the study were produced in a ring-spinning machine. Yarn properties are given in table 1. The samples were coded as follows: P30; Ne 30/1 100 % cotton, PK; Ne 12/1 70 % cotton+ 30 % Hemp and P12; Ne 12/1 100 % cotton.

The fabrics were produced in a single jersey knit structure at a speed of 20 rpm. The knitting process is explained in table 2.

Table 1

YARN PROPERTIES			
Yarn Properties	**P30/1**	**P12/1**	**PK**
Uniformity (%)	9.33	10.25	19.61
CV- %	11.78	13	25.37
Thin –40%	16.5	40.5	3987
Thin –50%	0	0	70
Thick +35%	187	618	5076
Thick +50%	14	86	2652
Neps +200%	15	46.5	3912
Neps +280%	3	6.5	1296
Hairiness H	4.67	7.44	9.35
B-Force (gF)	408.6	8.04	595.5
Elongation (%)	5.63	6.94	6.53
Rkm	20.76	16.11	11.61
B-Work (N.cm)	6.137	13.802	9.44

Table 2

FABRIC CONSTRUCTIONS				
Sample properties	**Yarn count (Ne)**	**Machine fineness (needle/ inch)**	**Machine diameter (inch)**	**Total number of Needles**
P30/1	30/1	28	30	2640
P12/1	12/1	12	30	1128
PK	12/1	12	30	1128

After fabrics are produced, the singeing process is applied to the fabrics. The purpose of the singeing process is to make the fabric surface smoother by removing the fibre ends from the yarns. Singeing process was carried out on one side, at a speed of 80 m/min, at 10 bar pressure, and a distance of 8–10 mm. The back position is vertical. Reactive pretreatment paste recipes were padded onto the singeing and bleaching knitted fabrics. The pretreatment pastes were prepared according to the recipe in table 3. Immediately afterwards, the fabrics were dried. Reactive pretreatment paste recipes were padded onto the singed and bleached knitted fabrics. The pretreatment pastes were prepared with thickener, sodium bicarbonate, urea, and water. After padding the paste, the fabrics were dried. A pattern was designed to evaluate the colour yield and printed

Table 3

PRETREATMENT RECIPES		
Chemicals	**Rate**	**Amount**
Beam Bender	1.25 g/l	627.5 g
Wetting Agent	2 g/l	1004 g
Caustic(48-49 Be)	4ml/l	3220 ml
Stabilized Peroxide	4% /fabric weight	2440 g
Acidic Acid	1 ml/l	805 ml
Anti-peroxide	0.7 ml/l	563.5 ml

onto the pre-treated fabrics with cyan, magenta, yellow and black reactive inks, at 540 × 360 dpi, using a Nassenger PRO60 ink-jet printer with a piezoelectric drop-on-demand print head. After the patterns dried, the printed fabrics were steamed for 6 and 10 minutes at 110°C with a steamer for the fixation of dyes. Finally, the fabrics were washed off to remove unfixed dyes and residual materials on the surface and dried. All the tests were performed under standard atmospheric conditions (temperature: 20±2°C and relative humidity: 65±2%). Physical properties of used fabrics such as yarn count, thickness and mass per unit area were determined according to TS EN 14971:2006 [19], TS 7128 EN ISO 5084 [20] and TS 251 [21] respectively. The air permeability tests were conducted according to the TS 391 EN ISO 9237 by using the Air Permeability Tester at a test pressure drop of 100 Pa (20 cm^2 test area) [22]. Characterization of digital printing on samples was using means of scanning electron microscope (SEM, FEI Quanta 650 Field EmiColour). Colour measurements of the samples were carried out by using a spectrophotometer (Minolta CM 3600) wavelength of 400–700 nm, under D65 daylight with an observer 10° angle. The colour fastness to ironing of the printed fabrics was assessed by the ISO 105-X11. This method was supposed to assess the resistance of the colour of textiles to ironing. The test was carried out for dry, damp and wet fabrics [23]. The fabric bursting strength was tested using a JH Truburst tester machine according to the BS EN 13938-2 testing method [24].

RESULTS AND DISCUSSION

The printing pattern chosen while producing the samples has been specially created in CMYK (Cyan-Magenta-Yellow-Key=black) colours to facilitate colour measurements.

The abbreviations used while coding the samples are specified as P30 Ne 30/1 cotton, PK cotton/hemp blend and P12 Ne 12/1 cotton. While analysing, the samples were evaluated separately for 4 different colours in the fabric. In the production of fabrics, the fixation process after the digital printing process was carried out at two different times, 6 minutes and 10 minutes. Some physical tests were performed on the samples in accordance with the standards. The results of these tests are given in table 4. In the

Table 4

Samples		Mass per unit area (g/m^2)		Wale per cm		Course per cm		Thickness (cm)		Loop length (cm)		Loop density (cm^2)
		Avg.	S.D.	Avg.	S.D.	Avg.	S.D.	Avg.	S.D.	Avg.	S.D.	
P30/1	6 min.	132.46	1	14.75	0.47	18.9175	0.8225	0.35675	0.0085	0.4605	0.00625	278.845
	10 min.	130.80	0.3925	14.4975	0.3525	18.0825	0.675	0.39075	0.0105	0.529	0.0105	262.25
P12/1	6 min.	197.53	0.5875	10	0.205	17.4175	0.1175	0.55925	0.0095	1.10925	0.03075	177.5
	10 min.	182.09	0.875	9.5	0.41	18.5	0.41	0.5815	0.0065	0.9855	0.031	174
PK	6 min.	141.05	0.5875	10.0825	0.5275	17.7925	0.39	0.53075	0.01575	0.88525	0.042	180
	10 min.	166.60	0.9925	10.165	0.44	17.835	0.235	0.5815	0.0215	1.133	0.0365	180

tables, the mean is expressed as Avg., and the standard deviation is expressed as S.D. When the physical test results were evaluated, it was seen that the fabric thickness and weight of the samples increased as the yarn thickness increased.

In addition, the samples were subjected to the ironing fastness (color fastness to ironing with the hot press) test, which is one of the fastness-to-use tests. Ironing fastness test results are also given in table 5. While evaluating the ironing fastness, both the results immediately after the test and the results after 4 hours were analysed in the same way. According to the results, although the values of the damp and wet measurements were low immediately after analyses, the ironing fastness values of all samples were high after 4 hours. It was concluded that these results were obtained because of the high fastness of the reactive dyestuffs. Table 6 shows the spectrophotometric colour analyses of the samples. With this Minolta brand CM 3600 model device, measurements

Table 5

IRONING FASTNESS OF FABRICS

Samples			PK		P12/1		P30/1	
			6 min.	10 min.	6 min.	10 min.	6 min.	10 min.
C	Dry	Immediately	4	4/5	4/5	4/5	4/5	4/5
		After 4 hours	5	5	5	5	5	5
	Damp	Immediately	4/5	4/5	4/5	4/5	4/5	4/5
		After 4 hours	5	5	5	5	5	5
	Wet	Immediately	3	3	3/4	3/4	3/4	3/4
		After 4 hours	4/5	4/5	4/5	5	4/5	5
M	Dry	Immediately	4/5	4/5	5	4/5	5	4/5
		After 4 hours	5	5	5	5	5	5
	Damp	Immediately	4/5	4/5	4/5	4/5	4/5	4/5
		After 4 hours	5	5	5	5	5	5
	Wet	Immediately	3	2/3	2/3	3/4	3/4	3/4
		After 4 hours	4/5	5	4/5	4/5	4/5	5
Y	Dry	Immediately	4/5	4/5	4/5	4/5	4/5	5
		After 4 hours	5	5	5	5	5	5
	Damp	Immediately	5	4/5	4/5	4/5	4/5	4/5
		After 4 hours	5	5	5	5	5	5
	Wet	Immediately	3	3	2/3	3/4	3/4	3/4
		After 4 hours	4/5	4/5	5	5	5	5
K	Dry	Immediately	4/5	4/5	4/5	5	4/5	5
		After 4 hours	4/5	5	5	5	5	5
	Damp	Immediately	4/5	4	4/5	4/5	4/5	4/5
		After 4 hours	4/5	4/5	5	5	5	5
	Wet	Immediately	2/3	2	3	3/4	3	3
		After 4 hours	4/5	4/5	5	5	5	5

Table 6

COLOR DIFFERENCES OF FABRICS				
Samples	**Colour**	**ΔE**	**Greyscale value**	**Kasikovic et al. in 2011**
PK	C	3.64	3	*ΔE < 0.4 → 5 *0.4 < ΔE < 1.25 → 4/5 *1.25 ≤ ΔE < 2.1 → 4 *2.1 ≤ ΔE < 2.95 → 3/4 *2.95 ≤ ΔE < 4.1 → 3 *4.10 ≤ ΔE < 5.8 → 2/3 *5.8 ≤ ΔE < 8.2 → 2 *8.2 ≤ ΔE < 11.6 → 1/2 *ΔE ≥ 11.6 → 1
	M	2.79	3/4	
	Y	1.81	4	
	K	2.48	3/4	
P12/1	C	2.51	3/4	
	M	2.86	3	
	Y	3.09	3	
	K	0.38	5	
P30/1	C	1.73	4	
	M	0.72	4/5	
	Y	1.35	4	
	K	0.48	4/5	

Table 7

PERFORMANCE PROPERTIES OF FABRICS							
Samples	**Fixation time (minutes)**	**Burst pressure (kPa)**		**Air permeability (mm/s)**		**Stiffness (kg-F)**	
		Avg.	**S.D.**	**Avg.**	**S.D.**	**Avg.**	**S.D.**
P30/1	6	170.9	2.826	1282.53	41.94	52.25	9.575
	10	169.12	2.839	968.83	111.686	53	4.636
P12/1	6	252,5	14.377	1784.813	34.617	118.75	17.398
	10	259.27	5.461	1455.178	48.788	150.75	18.29
PK	6	162.7	8.815	2218.71	0	114.75	32.04
	10	179.17	1.738	1921.993	49.071	116.75	10.568

were made under D65 daylight with an observer angle of 10°. The color difference ΔE value was measured for 10 minutes vs. 6 minutes' fixation times. In the study of Kasikovic et al. in 2011, the grey scale equivalent of ΔE colour difference limit values was given [25]. These values are indicated on the grey scale in the table.

The performance properties of fabrics are shown in table 7. While testing the performance properties of fabrics, measurements were made to include all CMYK colours in fabrics.

Also, it follows that the cotton-hemp blended fibres(PK) have high unevenness, and the bursting strength of the fabrics produced from this raw material is lower than cotton fabrics (P12) [26]. The results of the experimental study were evaluated statistically by Man Whitney U analysis and significant values given in table 8. Images obtained from SEM analysis are given in table 9. The magnification ratios were kept constant for each sample and images were taken at 500, 1000 and 5000 magnifications. When the images of the samples are examined; it can be seen that non-absorbed paste and dyestuff are found on the surface of the samples fixed for 6 minutes. However, sample surfaces fixed for 10 minutes appear smoother. The reason for this was interpreted as more binding to the fibre.

Table 8

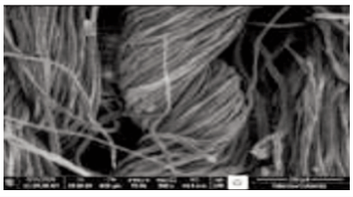
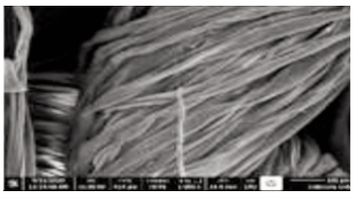
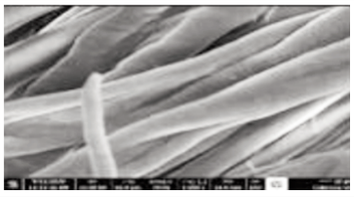
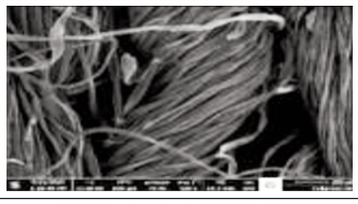
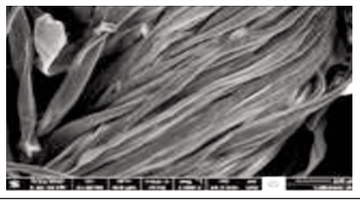
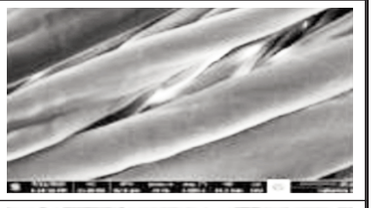
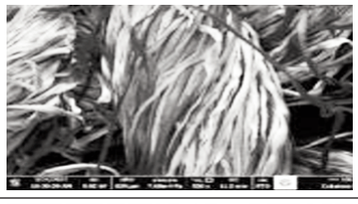
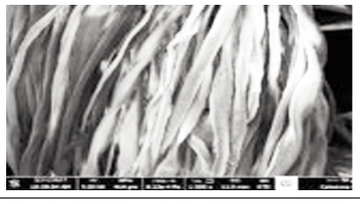
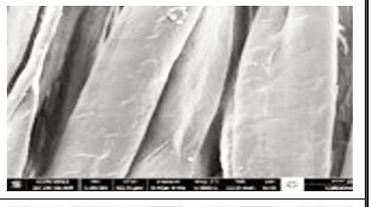
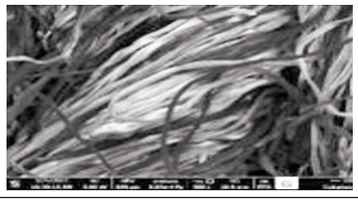
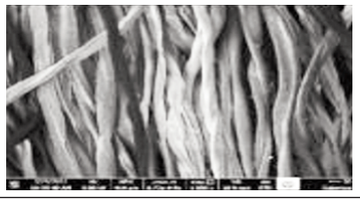
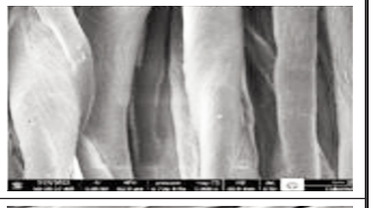
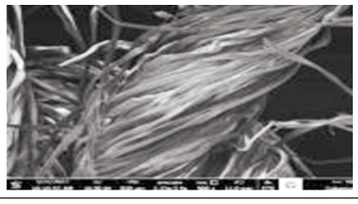
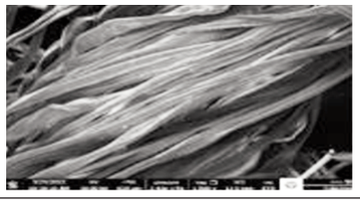
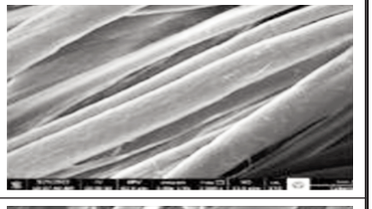
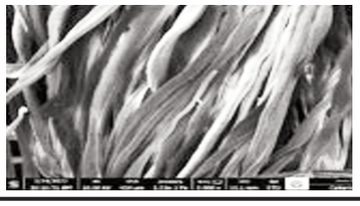
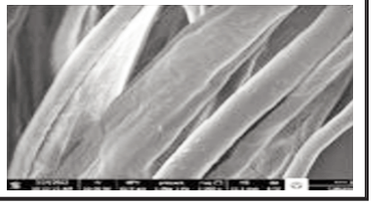
For PK-P12	**Air permeability**	**Bursting Strength**	**Stiffness**
Material	0.000	0.794	0.000
Fixing Time	0.000	0.664	0.149
P30	**Air permeability**	**Bursting Strength**	**Stiffness**
Fixing Time	0.000	0.003	0.873

CONCLUSIONS

In today's world, where sensitivity to the environment touches all production and consumption stages, many studies are carried out within the scope of sustainability. In the study, a digital printing application, which is an environmentally friendly colouring method, was carried out by using hemp, which is one of the sustainable fibres.

According to the research, it was seen that the fabric thickness and weight of the samples increased as the yarn thickness increased. It is seen that heavier fabric will have higher stiffness. Also, thicker yarns have higher bursting strength. It follows that because of

Table 9

SEM ANALYSES				
		500×	1000×	5000×
P30/1	6 min.			
	10 min.			
P12/1	6 min.			
	10 min.			
PK	6 min.			
	10 min.			

the cotton-hemp blended fibres (PK) have high unevenness, the bursting strength of the fabrics produced from this raw material is lower than cotton fabrics (P12). Similarly, since the thin-thick place values of cotton-hemp blended yarns are high, this porous structure also increases the air permeability of the fabrics.

When the results are evaluated, the effects of these parameters can be analysed by conducting more comprehensive studies on the fixation time and raw material.

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Application of Kansei Engineering in aircraft design

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ABSTRACT – REZUMAT

Application of Kansei Engineering in aircraft design

Kansei Engineering can develop a new product by translating a customer's requirements into design, which is an ergonomic technology for product development oriented towards customer emotion. Using Kansei Engineering in aircraft design is one of the most effective means to enhance flight experience. We rely on Vosviewer software to capture the research hotspots and trends of Kansei Engineering in aircraft design, which are categorized and overviewed by a visualization network. On the one hand, the importance and methods of human sensory elements, including auditory, visual, tactile, olfactory and taste, as well as human action elements in aircraft design, are studied. It is concluded that the design of aircraft layout, materials and colour schemes has an impact on human senses and behaviour. On the other hand, not only the materials and layouts for seats, cockpits and panels are discussed, but also an argument is put forward on the materials' effective application based on Kansei Engineering. Herein, we conclude with the current application of Kansei Engineering in aircraft design and advise on future design.

Keywords: *Kansei Engineering, aircraft design, ergonomics, visualization network*

Aplicarea Ingineriei Kansei în proiectarea aeronavei

Ingineria Kansei poate dezvolta un nou produs prin transpunerea cerințelor clienților în design, ce reprezintă o tehnologie ergonomică pentru dezvoltarea de produse orientată către emoția clientului. Utilizarea Ingineriei Kansei în proiectarea aeronavelor este unul dintre cele mai eficiente mijloace de îmbunătățire a experienței de zbor. Ne bazăm pe software-ul Vosviewer pentru a capta punctele importante ale cercetării și tendințele Ingineriei Kansei în proiectarea aeronavelor, care sunt clasificate și analizate de rețeaua de vizualizare. Pe de o parte, sunt studiate importanța și metodele elementelor senzoriale umane, inclusiv cele auditive, vizuale, tactile, olfactive și gustative, precum și elementele de acțiune umană în proiectarea aeronavelor. S-a ajuns la concluzia că proiectarea aspectului aeronavei, a materialelor și a schemelor de culori are un impact asupra simțurilor și comportamentului uman. Pe de altă parte, nu sunt discutate doar materialele și amenajările pentru scaune, cabine de pilotaj și panouri, dar este prezentat și un argument privind aplicarea efectivă a materialelor bazată pe Ingineria Kansei. În final, încheiem cu aplicarea actuală a Ingineriei Kansei în proiectarea aeronavelor și oferim sfaturi privind proiectarea viitoare.

Cuvinte-cheie*: Inginerie Kansei, proiectarea aeronavelor, ergonomie, rețea de vizualizare*

INTRODUCTION

Aircraft design is a complex multi-disciplinary integration process. In practice, the design of aircraft will directly influence passengers' perceived emotions and even play a role in safety. Regarding customers' perceived emotional needs, it was estimated that passengers had a relatively poor evaluation of aircraft cabin design, including spaciousness, seat comfort and aesthetics [1]. This is due to differences between the perceptions of designers and consumers [2]. Regarding the security aspect, it was discovered that defects in the design and layout of cockpit instruments led to accidents after World War II in the USA [3]. Because traditional design relied strongly on the subjective opinions and experiences of designers [4], human factors were not taken into account. Thus, the application of Kansei Engineering in aircraft design is extremely important.

Customer experience and comfort arise from perception which is an aspect of customer demand. Perception is a process that comes from human sensory awareness (e.g. touch, sight, smell, etc.), along with the generation of emotions [5]. Meanwhile, perception is highly dependent on the state of human behaviour and the environment. There are differences in emotional perceptions stimulated by the same environment, owing to cognitive, behavioural and physiological variations in humans [6]. Furthermore, Kansei is the emotional perception associated with sensory elements, i.e. perceptions that tend to be aesthetic or emotional. Kansei Engineering can transform customers' psychological needs and feelings into designs, taking human factors in design as central to meeting customer needs and increasing product satisfaction. It is a tool to develop products and can effectively reduce the perception gap between users and designers.

Kansei Engineering was successfully applied to product design by Mazda Miata in 1995 [7]. Many companies subsequently adopted Kansei Engineering to develop their products. Several disciplines such as automotive, textile, food, electronics, medical, and construction [8] are now exploiting Kansei Engineering to create new markets for themselves. Applying Kansei Engineering to emotional studies has obtained recognition in many fields, at the same time, the link between Kansei Engineering and aircraft design is being called for [9]. Ergonomics is the study of human actions and states in different environments to suit a variety of physical and psychological characteristics [10]. Kansei Engineering overcomes the shortcomings of ergonomics from an emotional perspective [11]. Therefore, ergonomics is a part of the Kansei Engineering study, while the study of ergonomics is involved in human action elements. In conclusion, both human sensory and action elements are relevant to Kansei through perception, which is an essential branch of Kansei Engineering study. Considering aircraft design based on human sensory and action elements will reduce differences in customer emotions, increase customer comfort, meet customer needs, save manufacturers testing costs and contribute to the development of aviation.

At present, Kansei Engineering is already being used to design aircraft cockpits and seats, the design core with human factors offers direction to designers. Chen et al. [12] assessed the colour scheme of aircraft cockpits by using the Kansei Engineering model and gave designers a cabin colour scheme to improve consumer comfort. Holden et al. [13] noted that the involvement of human factors in NASA's design and evaluation played a key role in the Orion Multi-Purpose Crew Vehicle development. Cao et al. [14] found that basing the principles of aircraft cockpit layout based on ergonomics could effectively reduce the pilot's perceived burden. The design elements of Kansei Engineering are of great significance for aircraft design. Nevertheless, to our best knowledge, there are no relevant systematic reviews concentrated on Kansei Engineering applications in aircraft design to date.

This review attempts to gather the methods and current status of Kansei Engineering applied to aircraft design. Due to the multi-faceted nature and complexity of Kansei Engineering research, this review selects keywords commonly used in research papers on ergonomics, perception and emotion, which are related to Kansei Engineering to retrieve and filter articles from the Web of Science (WOS) database. Publications related to these terms include journal articles, book chapters and conference papers forming a literature database. A visual network of bibliometric data is produced by VOSviewer version 1.6.16, as shown in figure 1.

Figure 1 presents the relationship between Kansei Engineering design elements and aircraft design-related topics and articles. There are a total of 38 items presented in 5 clusters: (1) perception (purple), (2) ergonomics (blue), (3) sensory perception (green), (4) Kansei Engineering (orange) and (5) emotion (red), which can be classified into 2 clusters. Among them, “Aircraft Design” (occurrences: 112 times) is a research direction derived through the crossover point (“design” (occurrences: 309 times) from Kansei Engineering and ergonomics. The first group contains categories (1) (11 items), (3) (6 items)

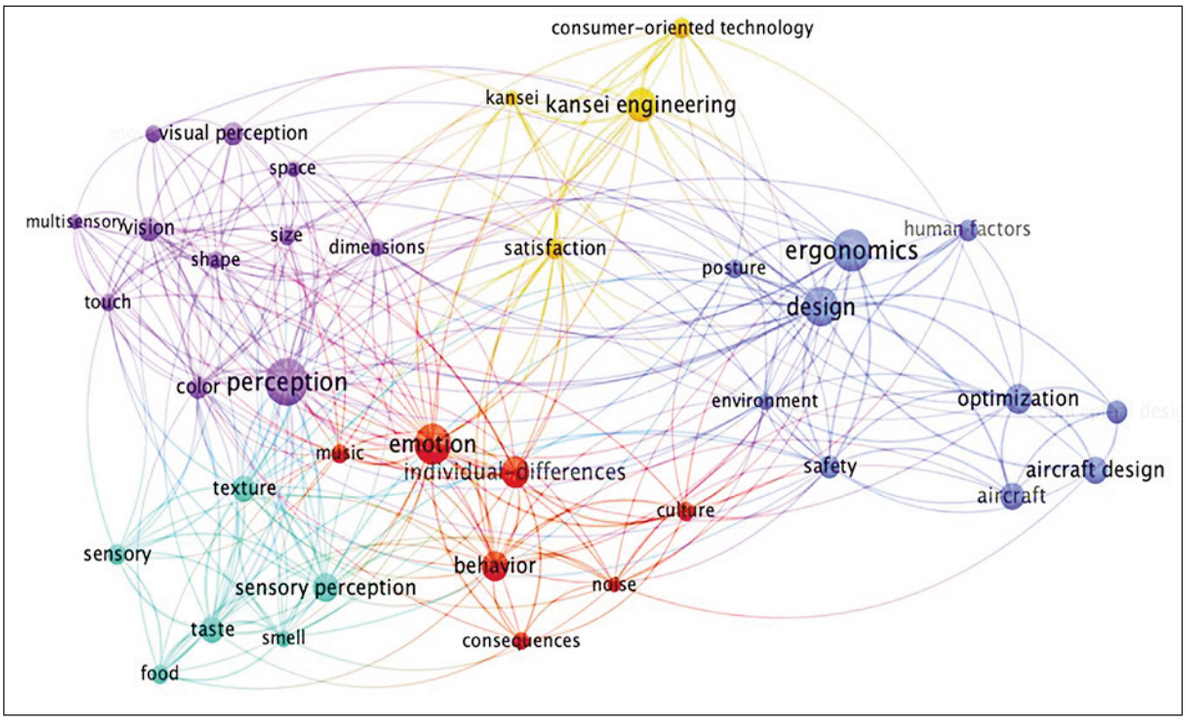

Fig. 1. Cluster analysis of keywords related to Kansei Engineering and aircraft design

and (5) (7 items), involving the classification of perception. Perception is closely related to the fields of sensory perception (occurrences: 129 times), emotion (occurrences: 328 times) and behaviour (occurrences: 150 times), and has been extended to other related disciplines. Thus, This paper analyzes the present situation and significance of aircraft design from two perspectives: human sensory perception elements of auditory, visual, tactile, olfactory and taste, alongside human action elements. The second group contains categories (2) (10 items) and (4) (4 items) involving design elements related to Kansei Engineering and ergonomics, e.g. human factors (occurrences: 60 times). Therefore, this review summarises the material selection and layout design of the cabin seats, cockpit and panels, based on Kansei's requirements and ergonomics.

This paper reviews the application of Kansei Engineering in aircraft design. The construction of the paper is as follows: 1st section analyzes the context of Kansei Engineering in aircraft design and utilizes Vosviewer software to reflect the relevant research topics. 2nd section refines the design elements of Kansei Engineering to human auditory, visual, tactile, olfactory and taste, as well as human action elements, addressing proposals and necessities for combining each design element with aircraft design. 3rd section focuses on the key points of material selection or layout of seats, cockpits, and panels in aircraft cabins, based on human Kansei needs and ergonomics. 4th section draws some conclusions. It is expected that our work will benefit the investigation of Kansei Engineering application in aircraft design and broaden its application.

RESEARCH STATUS OF KANSEI ENGINEERING IN AIRCRAFT DESIGN

Unconscious perception stimulated by the senses plays a major role in aircraft design [15]. As shown in figure 2, the first section of this chapter categorizes and outlines human sensory elements in aircraft design from a perception standpoint. Human action elements are associated with Kansei Engineering and ergonomics contained therein. The second part of this chapter deals with human action elements in aircraft design based on ergonomics and Kansei.

Aircraft design combined with human sensory elements

Human auditory, visual, tactile, olfactory, and taste sensations are complex outcomes that depend on personal history, environmental factors, object characteristics, and subjective influences [16]. It is vital to be aware of perception needs in the design process, and they are the result of multisensory integration [17]. As illustrated in figure 3, this section assesses the importance of perception in aircraft design from five sensory elements, together with a summary of ways to enhance customer sensory comfort.

Auditory sensation

As is well known, noise pollution is an increasingly serious problem arising from the expansion of the modern industry. Research has proven that aircraft noise can cause insomnia, high blood pressure, irritability and fear [18]. Pieren et al. [19] demonstrated the possibility of a perception-based evaluation on future low-noise aircraft, where a low-noise aircraft could considerably reduce one's auditory annoyance. Reducing aircraft noise using human auditory perception will not only optimize residential living conditions in the vicinity of airports but will also improve passengers' comfort in flight.

Auditory comfort evaluations are receiving increasing attention in the context of air transport [20]. Reducing noise annoyance is one of the valid ways to control noise [21], which is greatly dependent on listeners' status, life circumstances, etc. Playing a lighter sound in the headset will allow some passengers to immerse themselves in pleasant sounds so that they can ignore the cabin noise. However, this approach does not address the fundamental issue of aircraft noise. More efficient ways to promote passenger comfort are to analyze how noise is generated and how to reduce noise from the source. By adding specific noise-cancelling devices and materials, the acoustic comfort of passengers can be optimized. Examples include using tilted blades and acoustic

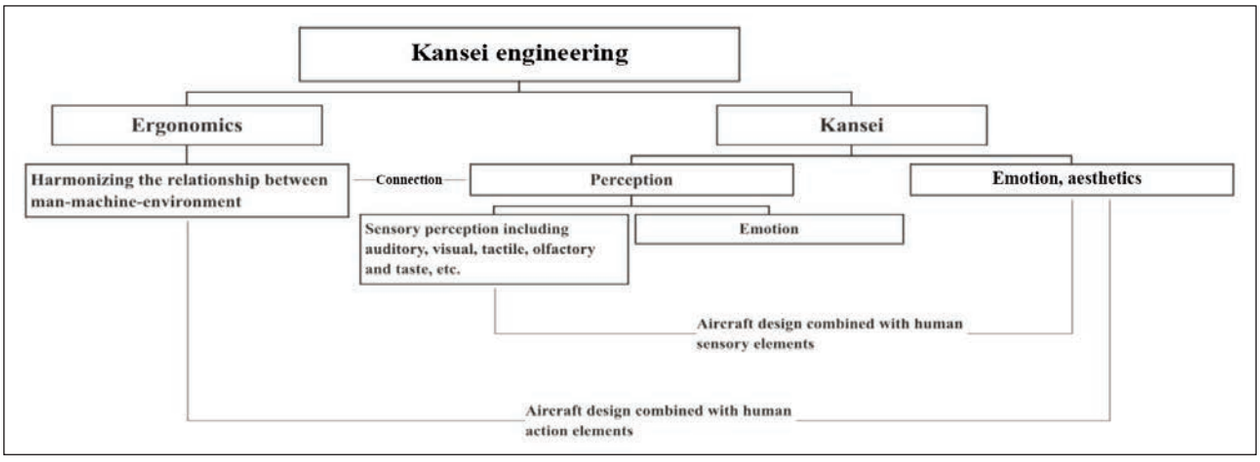

Fig. 2. A summary of the current study on Kansei Engineering in aircraft design

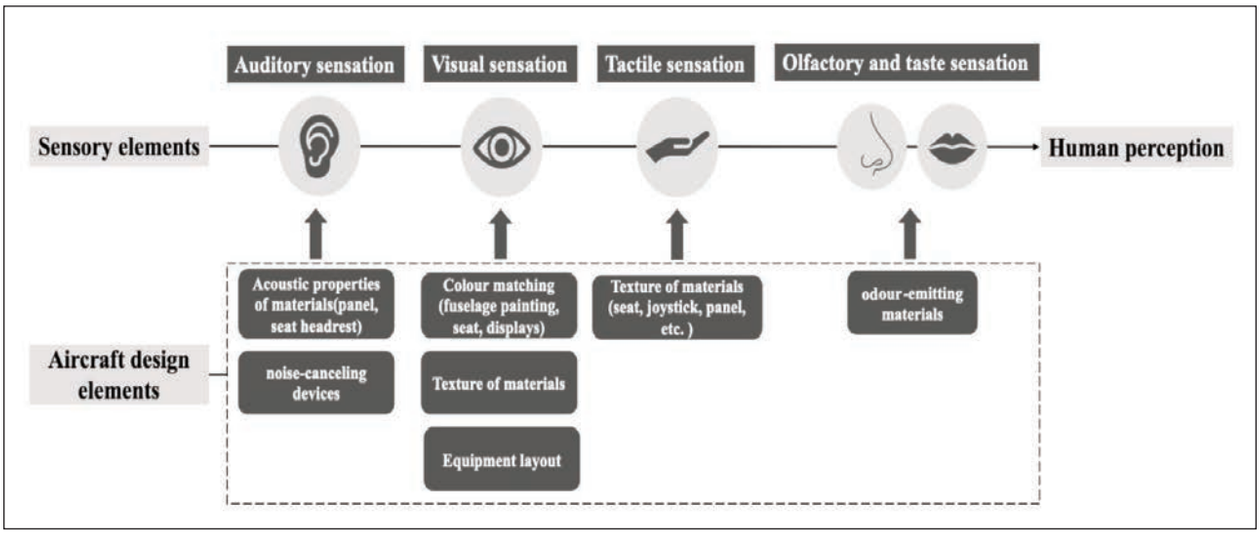

Fig. 3. Aircraft design elements associated with sensory elements

liner tubes to reduce turbofan noise [22], distributing sensor actuators on aircraft panels to reduce noise transmission [23], and using sound insulation materials such as fibreglass and honeycomb to increase sound transmission loss.

Visual sensation

One major way to create an attractive aircraft fuselage is to paint it, as shown in figure 4, *a*. Aircraft painting design can relieve visual fatigue or highlight a particular culture that will resonate with passengers. In addition, the painting design is an excellent protection for aircraft hulls by reducing corrosion in harsh environments [24], increasing ultraviolet radiation on aircraft surfaces [25], and even conferring stealth capabilities to aircraft [26].

Figure 4, *b* presents the design of cabin seats in colour scheme. Colour schemes and material choices in the cabin affect human visualization. A system to assess colour emotion using Kansei Engineering is effective in avoiding defects in colour emotion design [12]. Studies on the link between visual senses and consumers are now most commonly conducted by eye-tracking to explain consumer response to various visual stimuli [27]. One example is that data recorded by eye-tracking could be used to select Kansei words applied to user evaluations [28], thus reflecting an aircraft's visual effects.

Tactile sensation

Tactile sensation is the result of stimuli transmitted by human skin to the brain and can be applied to explore the condition of objects [29]. Currently, there is a preference for functional studies in aerospace materials. The tactile sensation of aerospace materials is often overlooked. However, the tactile properties of the material are a key characteristic that influences consumer preferences and decision-making processes [30].

Similarly, tactile adjectives allow for a systematic assessment of tactile sensations on the object's surface, to optimize the device. In addition, tactile sensations can be combined with other sensory perceptions. Tactile receptors can be applied to transform visual signals into tactile signals from the power rod in the cockpit, simplifying the complexity of the device and reducing the burden on the pilot [31]. In short, taking human tactile perception into account is a valid means to optimize aviation equipment, and will enrich the customer experience further and meet their requirements.

Olfactory and taste sensations

Studies have proven that olfactory and taste sensations are interconnected, where the sensation of taste is influenced by smell, texture, temperature, etc [32]. The unique and enclosed atmosphere of an aircraft, similar to a car, may influence passengers' sense of olfactory and taste. Aircraft internal odours are partly caused by cabin materials, components, etc., and another part by passengers, food, etc. Olfactory and taste discomfort in enclosed spaces can even result in vomiting. Fewer applications of odour-emitting materials in aircraft design can improve the odour environment in the cabin and greatly increase consumer comfort. Moreover, flight altitude can also affect human taste sensation and food flavour release [33]. Meanwhile, Yao et al. [34] pointed out that individual design requirements for odour in aircraft cabins were emphasized because of passenger odour preference diversity.

Aircraft design combined with human action elements

Kansei Engineering is an ergonomic product development technique [35]. Ergonomics is aimed at achieving the unification of human efficiency, comfort, safety and feasibility [36], closely associated with human action elements. Major parts of cabin design relevant to human action elements are things such as seats, pitch, layout, etc. Aircraft seat design covers comprehensive fields such as human seating characteristics, and movement range and limits dimensions regarding comfort, as shown in figure 4, *c*. Vink et al. [37] noted that there was a clear relationship between comfort legroom, and seat/personal space in aircraft interiors. Furthermore, improper seat

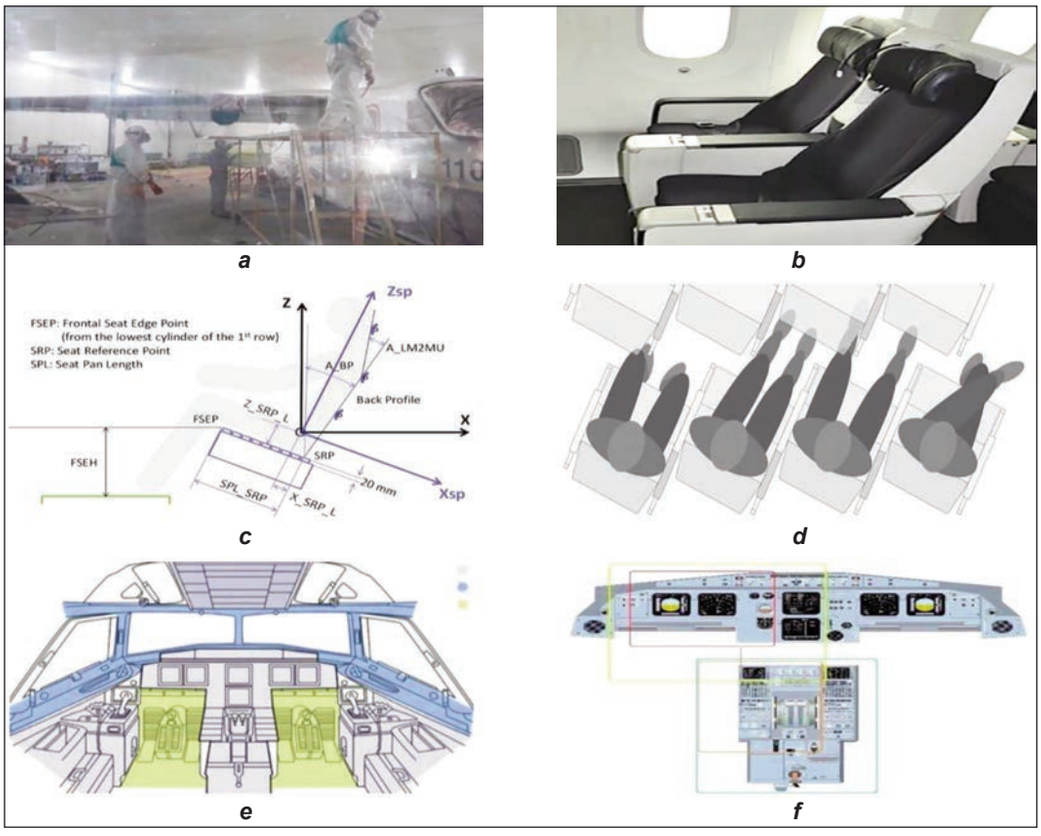

Fig. 4. Application of Kansei Engineering in aircraft design: *a* – aircraft painting work; *b* – cabin seat colour design (premium economy seats in a Boeing 787); *c* – seat profile parameters; *d* – the comfort of the seat configuration; *e* – colour distribution in an aircraft cockpit; *f* – the evaluation of the cockpit layout [12, 14, 24, 42–44]

design will increase flight personnel's discomfort in the back, neck, and lumbar areas. Sharafkhani et al. [38] invited 29 participants to sit in a simulated aircraft cabin for 180 minutes and found that from largest to smallest, were: the back of the neck, left rear shoulder, right rear shoulder, left rear hip and lower back. As is seen in figure 4, *d*, seat pitch is one of the main factors affecting aircraft seat comfort in the passenger cabin. Discomfort increases when low seat pitch disturbs passengers' necessary activities [39]. Liu et al. [40] established an evaluation model for comfort in an aircraft cabin system, which could be applied to improve comfort in the aircraft cabin. In the cockpit, to resolve inefficiencies and reduce pilots' work stress, an ergonomically constructed cockpit man-machine layout evaluation system can successfully optimize cockpit layout design [41].

CABIN EQUIPMENT DESIGN BASED ON KANSEI NEEDS AND ERGONOMICS

This chapter focuses on material selection based on Kansei's needs for aircraft cabin seating, cockpit equipment, and panels. Meanwhile, the present situation and approach to designing cabin seats and cockpit layout from an ergonomic viewpoint are discussed.

Cabin seats

Properties of seat materials

Cabin seat is usually made up of lightweight, high-specific stiffness synthetic and composite materials. Seat materials should be selected to meet not only the configuration of the aircraft but also the safety and comfort requirements of passengers. An example is using fire retardant materials to prevent fires from threatening human life [45]. Since COVID-19, passengers' demand for antimicrobial properties in materials such as seat covers and armrests has steadily increased [46]. A reasonable allocation of seats can decrease the risks of virus transmission on aircraft [47]. At the same time, lightweight materials ought to be applied to seats as much as possible to save aircraft fuel consumption and increase space utilization. Dangal et al. [48] employed spring foam technology to lighten aircraft seats while increasing consumer comfort.

Seat comfort

Studies of seat comfort involve shape and layout comfort, seat cover comfort and headrest acoustic comfort. To achieve a better coincidence in contact between human hips and the cushion, Kumar et al. [49] carried out an anthropometric data curve fitting to investigate seat comfort for pilot cushions. The insulation and breathability of seat cover materials across the seasons will affect human thermal comfort. In addition, improvements in the acoustic properties of seat headrests will enable passengers to have a more comfortable rest during the flight. Based on experimental and data results, Giannella et al. [50] proposed passive noise control improvements for seat headrests, one was based on the optimization of

the headrest shape, and the other was using a new material as a headrest cover material to improve passenger acoustic comfort.

Cockpit

The cockpit interior mainly consists of a flight display, joystick, etc. Cockpit materials are chosen on the premise of ensuring the safety of passenger life without affecting pilots' ability to drive during daytime or nighttime. Given that the cockpit is characterized by a small space, high functional integration and complex controls, the pilot's emotional perception is especially essential. Improper cockpit layout and design may lead to pilot spatial disorientation, that is, the illusion of flight [51]. Aircraft cockpit display systems are the critical interface between aircraft and pilots in human-machine interaction, which must deliver situation perception for pilots to ensure flight safety. As is shown in figure 4, *e* and *f*, the appropriate colour, language and display location of information can improve pilot efficiency. Zhang et al. [52] combined pilot performance during flight with eye movement data, and found that the red-green-yellow colour located in the centre of the aircraft display interface was more conducive to recognition. Kamine et al. [53] discovered that almost all aircraft displays, located in both vertical and horizontal visual display angles, were within the “cone of easy eye movement”. Aiming to boost the situational awareness of pilots, head-mounted virtual reality displays are one possibility for future cockpits [54].

Psychologists proved that contours contain most of the information relevant to object perception [55]. Symmetry and repetition have a major role in visual and tactile perception [56]. Hence, the shape contour design of the joystick has an impact on human sensory perception. Also, the layout of the joystick has to take into account the pilot's operational feasibility and comfort. Yang et al. [57] measured Chinese pilots' posture data while pushing the joystick that was used to assess pilots' comfort in operating posture.

Aircraft cabin panels

Aircraft cabin panels are mainly used for floors, ceilings, cabinets, etc., which are usually made up of composite materials with a certain degree of impact resistance, corrosion resistance, fire resistance and long-term cycling properties [58]. Additionally, sound insulation properties on aircraft panels were necessary to decrease aircraft interior noise [59]. Honeycomb structures have been widely applied to aerospace and automotive fields due to their excellent mechanical properties, high energy absorption capacity and low density [60]. At a certain level, honeycomb sandwich structures reduce the transmission of acoustic and optimize user acoustic comfort. Material multiple superiorities are sought after. So, improved acoustic comfort of materials can be combined with several sensory elements' design, making it possible to apply Kansei Engineering more efficaciously on the same material. For instance, a further design of honeycomb sandwich sound insulation materials to achieve aesthetic interiors and performance on a safe basis.

CONCLUSIONS

Compared with traditional design, aircraft Kansei design has the advantage of being more attuned to human demands. In this review, we gather hot topics and trends regarding the development of Kansei Engineering applied in aircraft design through VOSviewer, and then we categorize and overview them. Two perspectives of human sensory and action elements are analyzed to demonstrate the importance of Kansei Engineering in aircraft design. Moreover, the design of aircraft seats, cockpits and panel materials are discussed in conjunction with ergonomics.

It is found that Kansei Engineering has been relatively less explored in aircraft design, to improve the effective application of Kansei Engineering in aircraft design, we put forward several recommendations. Firstly, human sensory and action elements are directly related to human emotional perceptions which cannot be ignored in aircraft design processes. Secondly, human requirements are essential to developing material properties and equipment layouts. Last but not least, the application of Kansei Engineering makes it possible to achieve an efficient material application in which the same material can meet a variety of human perceptual needs. These suggestions will further promote the development of aircraft and enhance their practical application.

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Thermal performance of protective clothing (firefighter) under extreme ambient conditions

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ABSTRACT – REZUMAT

Thermal performance of protective clothing (firefighter) under extreme ambient conditions

Protective clothing is made up of multiple layers of textile, which include thermal barrier, moisture barrier, chemical protection and heat radiation protection layers etc. This clothing is commonly used by workers working in the chemical industry, blast furnaces, glass industry, industrial boilers and many more. The ambient conditions for these workplaces are humid and hot in which the clothing is designed for the external protection of heat and fluids but the neglected issue is the internal heat and moisture accumulation. This makes the clothing extremely uncomfortable and significantly reduces the workability of the wearer. The multi-layered structure of this clothing causes the body moisture and heat to trap in between layers, which in extreme ambient conditions like working near the furnace or flash fire causes body burns, these "steam burns" are common and considered to be caused by the condensed moisture trapped in the layers of protective garment. This research aims to firstly investigate the moisture flow through hybrid textile layers and its effect on heat transfer and then secondly to see the impact of extreme radiation flux on the moisture flow inside the textile layers and improvement by using Aerogels.

Keywords: *firefighter, comfort, radiation, textile*

Performanța termică a îmbrăcămintei de protecție (pentru pompieri) în condiții ambientale extreme

Îmbrăcămintea de protecție este alcătuită din mai multe straturi de material textil, care includ bariera termică, bariera de umiditate, protecția chimică și straturile de protecție împotriva radiațiilor termice etc. Acest tip de îmbrăcăminte este folosit în mod obișnuit de lucrătorii din industria chimică, furnal, industria sticlei, cazane industriale și multe altele. Condițiile ambientale pentru aceste locuri de muncă sunt umede și fierbinți, iar îmbrăcămintea este concepută pentru protecția externă la căldură și fluide, dar problema neglijată este acumularea de căldură și umiditate internă. Acest lucru face ca îmbrăcămintea să fie extrem de inconfortabilă și reduce semnificativ capacitatea de lucru a purtătorului. Structura multistratificată a acestui tip de îmbrăcăminte face ca umezeala și căldura corpului să rămână între straturi, ceea ce, în condiții ambientale extreme, cum ar fi lucrul în apropierea cuptorului sau combustia spontană, provoacă arsuri corporale, aceste „arsuri cu abur" sunt frecvente și considerate a fi cauzate de umiditatea provenită din condens în straturile de îmbrăcăminte de protecție. Scopul acestei cercetări este de a investiga în primul rând fluxul de umiditate care trece prin straturile textile hibride și efectul acestuia asupra transferului de căldură și apoi, în al doilea rând, de a vedea impactul fluxului de radiații extreme asupra fluxului de umiditate din interiorul straturilor textile și îmbunătățirea acestora prin utilizarea aerogelurilor.

Cuvinte-cheie: *pompier, confort, radiații, textile*

INTRODUCTION

When the body of the wearer of protective clothing is exposed to heat stress, the body reacts by activation of perspiration [1, 2]. The firefighter often works in extreme ambient conditions, which makes the work highly non-comfortable. The perspiration created cannot leave the clothing and often turns to the liquid inside the clothing layers, sometimes this liquid sweat gets the heat from the surrounding can turn to steam, which causes the dangerous phenomena of steam burns to the firefighters [3].

For firefighters, the main concern is heat radiation from the heated body, fire, hot air convection, and direct connection from high-temperature objects [4, 5]. Heat transmission modes including Conduction, convection and radiation have a significant impact on the thermal show of the wearer of protective garments and can cause burn damage. In the case of protection against heat or radiation, the overall structure, material and construction of the garment are very important [6].

Most of the firefighter clothing is made from Aramid fibres like Nomex and Kevlar due to higher melting temperatures and strong mechanical properties.

Human skin can get a different category of skin damage as listed below [6–8]:

I. **First-degree burn**

This is a mild kind of burn that causes damage or rashes to the top layer of the skin, these burns can often lead to scalds. These burns usually do not require medical treatment.

II. **Second-degree burn**

Second-degree burns damage the skin layer called the dermis. The burns need medical treatment; the wounds can swallow and irritate.

III. **Third-degree burn**
This is deeper skin damage and causes inner tissues to be impacted by the heat. Usually, the skin gets charred due to extreme heat.
All this protective clothing is made with packed hybrid layers to protect the wearer against the external hazardous fluid or heat, these multilayers are impermeable and non-breathable which causes great discomfort and even body burns. There are contradictory results, which state the increase and decrease in heat protection due to the presence of moisture in the textile layers [9–12]. The radiation heat protection is the most important factor for this clothing and it will tested with Aerogels can provide better protection with a delay in the time for heat to reach the wearer.

AEROGELS (HISTORY TO ITS APPLICATION IN FIREFIGHTER CLOTHING)

In 1930 Kistler discovered the Silica-based Aerogels in which he substituted the liquid phase with the gaseous phase as a 3D structure. Aerogels are commonly cloud-like materials having a similar projection instead of solid material. Aerogels are commonly prepared by the Sol-Gel process [13] which is shown in figure 1.
These Silca-based Aerogels are 90–96% air and the rest is Silica dioxide. This gives them unique characteristics of solid with extreme thermal protection due to their pore structure and presence of trapped air. The interlocked pores range from 5–90 nm with an average diameter of less than 40 nm. This structure provided ideal conditions for thermal protection and normally the thermal conductivity is less than that of air under some conditions [15]. The use of this material in garments, boilers and home insulations is new and demands further investigations.

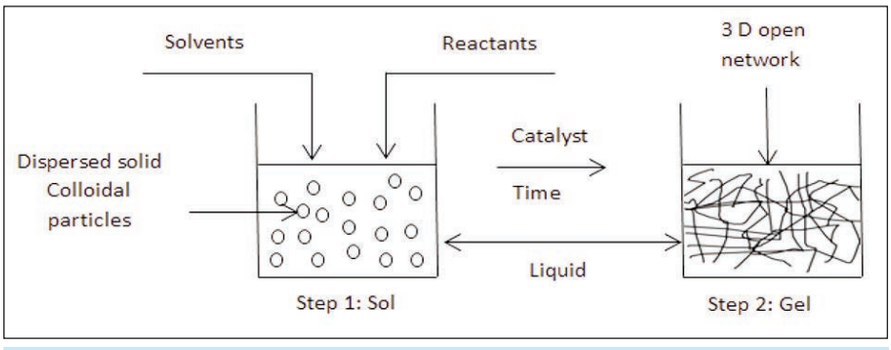

Fig. 1. Preparation of Sol-Gel [14]

OBJECTIVES OF THE RESEARCH

The objectives of the research project are:
- To understand moisture management of sweat for multilayer protective clothing like firefighter clothing.
- To improve thermal protection using different thermal and moisture barrier combinations.
- To analyse the effect of radiation heat protectors on the outer layer.
- Using the experimental and theoretical results to propose a better combination of textile layers for the protective clothing.

METHODOLOGY

To analyse the performance of firefighter clothing, the most common sandwich structure of the garment is selected and each layer of it is also purchased from the company Vochoc (Czech Republic). Another addition is the Aerogel layer which is famous for its high thermal resistance is also selected for the experiment to see the effect of the different combinations of layers on the overall protection of the firefighter clothing.
Table 1 shows the properties of each layer of the firefighter clothing. Two top layers, and one layer of Moisture protector, thermal barrier and the Aerogel layer are selected for the experiment. Each layer will be further combined to see the overall performance of moisture transport and radiation protection.
The samples are then tested under the Radiant heat flux equipment X637 B working according to ISO 6942 standard. In this experiment, the radiation heat flux of different intensities is directed to the sample. This can be from 10 kW/m^2 to 40 kW/m^2. This

Table 1

SAMPLE DESCRIPTION				
Fabric layers	**Serial**	**Composition**	**Weight (g/m^2)**	**Thickness (mm)**
Top layer 1	T1	% 75 Metaaramid-23 Para aramid-%2 Antistatic	220	0.83 (±0.11)
Top layer 2	T2	Proban (100 % cotton)	305	0.97 (±0.2)
Moisture protector	MB	Nonwoven web laminated with polyurethane	115	0.94 (±0.18)
Thermal protector	H	50/50 Meta Aramid /FR Viscose fibres	360	3.40 (±0.14)
Aerogel layer	A	Polymer with Silica aerogel	356	2.82 (±0.2)

radiation is further received by the calorimeter, which shows the heat flux that passes through the samples. The device is first calibrated according to standard and later at different energy powers (10–40 kW/m^2), the samples are tested. The longer time the samples transfer the heat to the receiver the better insulator or thermal resistant it is considered.

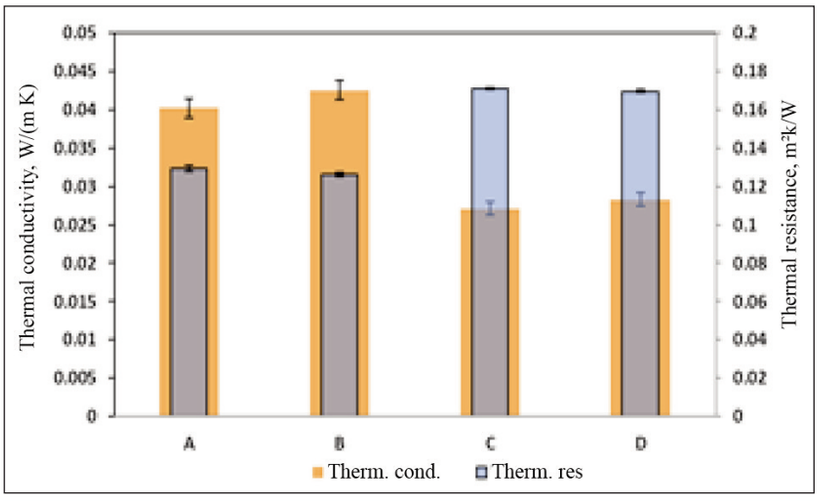

Fig. 3. Thermal conductivity and thermal resistance of layers

RESULTS

All these layers with two top layers will be tested for moisture permeability overall thermal protection and different radiation levels. The combinations made for the testing are shown in table 2.

Table 2

DESIGN OF EXPERIMENT			
Samples	**Assembly layers of fabrics**	**Thickness (mm)**	**Weight (g/m^2)**
A	T1 + Moisture barrier + Thermal protector	5.15 (±0.18)	735
B	T2 + Moisture barrier + Thermal protector	5.29 (±0.2)	801
C	T1 + Moisture barrier + Aerogel layer	4.59 (±0.19)	759
D	T2 + Moisture barrier + Aerogel layer	4.75 (±0.15)	829

Thermal conductivity and connected parameters including thickness were evaluated by Alambeta for single-layer and sandwich fabric assemblies and their corresponding values were mentioned in the figure below respectively. Thermal resistance R_{th}, depends on the thermal conductivity and the thickness of the textile layers. In general greater thickness of textiles brings better thermal protection. Also, the closed pores of air inside the sample make it more resistant to thermal change.

It can be seen in the figure 3 that the thermal resistance of the samples with Aerogel is significantly higher as compared to the classical thermal barrier. Overall thermal performance of the combined layers is suitable for high thermal protection against heat. The samples are further analysed for the water vapour resistance.

Evaluation of water vapour resistance

Sweating guarded hot plate was used according to the standards ISO 11092 to determine the overall moisture transport through textile layers. Higher resistance means that less moisture cannot pass through the fabric, so either it is impermeable or limited channels of water vapour path exist in the textile layers. Commonly the firefighter's clothing is not permeable to moisture or water vapour which makes them uncomfortable to wear during firefighting missions.

The figure 4 shows the overall non-permeable behaviour of the sandwich structure, the minor moisture exchange might be due to the absorption and then release of moisture to the sideways or a few channels of vapour paths through seams etc.

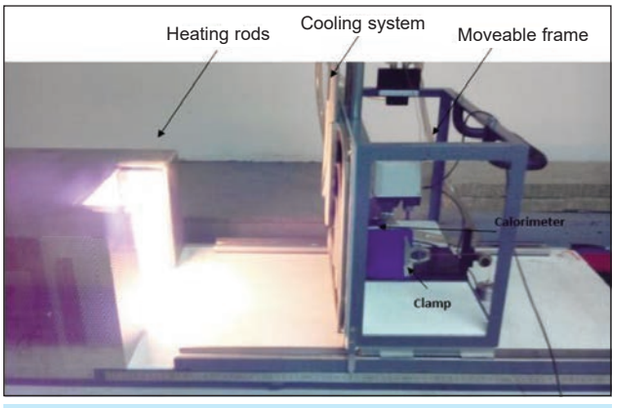

Fig. 2. Radiation heat testing equipment

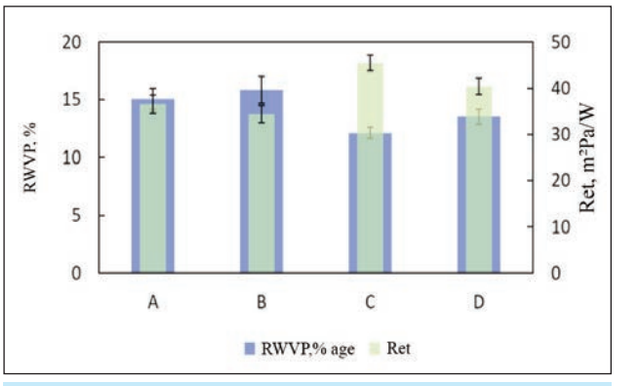

Fig. 4. Water vapour resistance of samples

Table 3

INCIDENT TEMPERATURE ON THE SURFACE OF THE SPECIMEN WHEN EXPOSED TO DIFFERENT HEAT FLUX DENSITY				
Heat flux density (kW/m^2)	**10**	**20**	**30**	**40**
Surface temperature of the samples (°C)	205	292	390	495
Sample distance from the source (cm)	37.1	25.1	19.7	16.5

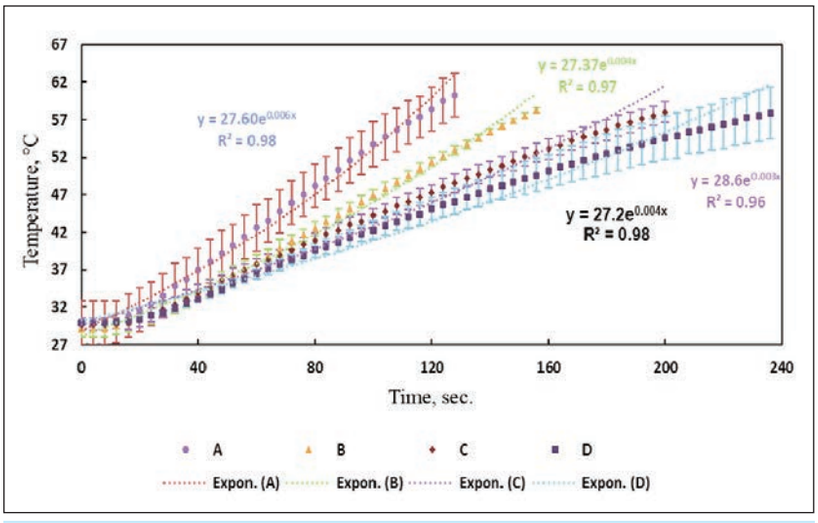

Fig. 5. Heat transmission at 10 kW/m^2

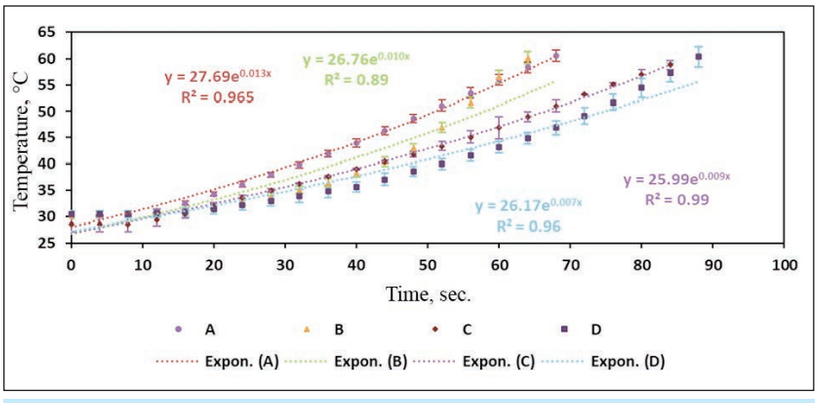

Fig. 6. Heat transmission at 20 kW/m^2

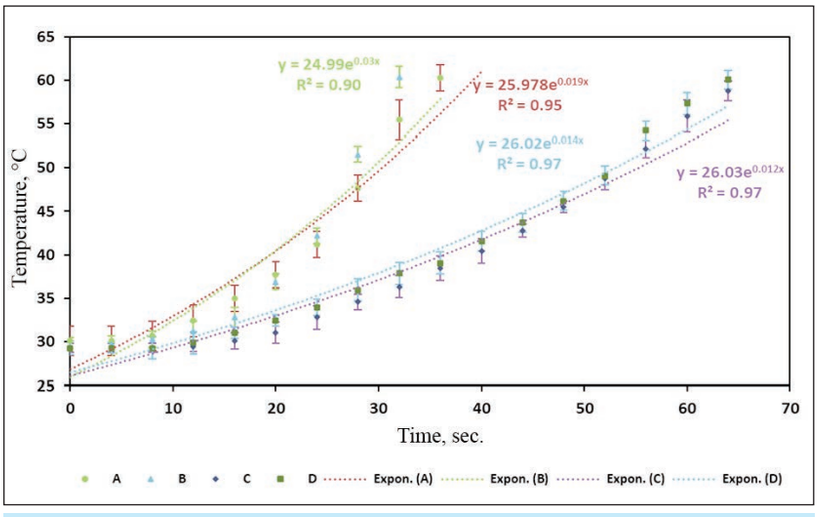

Fig. 7. Heat transmission at 40 kW/m^2

Transmission of radiant heat flux

The most important factor for the protection of firefighter clothing is radiation heat transmission. In this experiment the samples are exposed to different energy levels of radiant heat and the overall transferability of the material is tested concerning time.

The graph shows the radiant heat protection of the samples exposed to different energy levels (10–40 kW/m^2). The lower the curve the better the heat protection, which shows that it takes longer time for the heat to transfer to the other side of the sample. The machine works on the phenomenon of reaching 12 degrees rise and 24 degrees rise of temperature concerning time, so the longer it takes the better the protections. The results show that the C and D samples with Aerogels provide the best protection, the lines are more slowly rising and the difference from the classical samples is quite significant as well. This is mainly due to the better thermal protection of the Aerogels layers, as all other layers are identical in the other samples as well.

The rise is exponential which is common for heat exchange through textile materials. The results show significant improvement in the firefighter clothing with Aerogels in it.

CONCLUSION

It can be concluded from the research that the thermal radiation protection of firefighter clothing is very important and with extreme ambient heat, it is necessary to have proper sandwiched layers to provide the firefighter with maximum time and minimum damage.

The firefighter's clothing performance is mainly judged by the thermal protection from the radiant heat. The results show that firefighter clothing is almost impermeable to moisture or water vapour due to multiple layers sandwiched together with the focus on better thermal performance and comfort not considered. Whereas the samples show quite good radiant

thermal protection and the results are very promising when using the Aerogels instead of the thermal barrier. The Aerogel layer provides significant extra protection from the radiation heat and also the time delay makes more time for the firefighter during the extinguishing process. The research needs more work related to ergonomics, durability and the functional behaviour of Aerogels for the thermal protection of firefighters.

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Strategic SWOT – factor analysis of a textile company – a case study

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ABSTRACT – REZUMAT

Strategic SWOT – factor analysis of a textile company – a case study

SWOT-Factor Analysis of a Textile Company is used to recognize and solve the problem of the constantly changing fashion market and to search for opportunities for the realization of textile products. To analyse the problem of the unresolved economic environment in the textile industry, it needs to follow the policies for sustainable development while developing and showing higher productivity and strengthening its market position. We used a survey and a SWOT-factor matrix. A survey related to the production of textiles and clothing was conducted, and the degree of importance of the respondents' answers and the position they hold in their work organization was determined. A SWOT-factor matrix has been compiled, eliminating the shortcomings of existing solutions in this field. Issues are analysed to describe the strengths and weaknesses of the company. A strategic intensity at level ρ 0.5 means that the company must adopt a conservative development strategy. A diagram of strategic quadrilateral and a diagram of specific strategies have been drawn up, and recommendations have been made for the company's work in the direction of its effective development. The company must adopt a conservative development strategy. For future work of study, it will be possible to control the actions taken and to give an accurate assessment of the performed analysis over a certain period.

Keywords: *firm performance, strategic planning, management, development, sustainability.*

SWOT strategic – analiza factorială a unei companii textile – studiu de caz

Analiza factorială SWOT a unei companii textile este folosită pentru a recunoaște și rezolva problema pieței modei în continuă schimbare și pentru a căuta oportunități de realizare a produselor textile. Pentru a analiza problema mediului economic încă nerezolvată din industria textilă, aceasta trebuie să urmeze politicile de dezvoltare durabilă, dezvoltând și manifestând o productivitate mai mare și consolidându-și poziția pe piață. Am folosit un sondaj și o matrice factorială SWOT. A fost realizat un sondaj legat de producția de produse textile și de îmbrăcăminte și a fost determinat gradul de importanță a răspunsurilor respondenților și poziția pe care o dețin în organizarea muncii. A fost alcătuită o matrice factorială SWOT, eliminând dezavantajele soluțiilor existente în acest domeniu. Problemele sunt analizate pentru a descrie punctele forte și punctele slabe ale companiei. O intensitate strategică la nivelul ρ 0,5 înseamnă că firma trebuie să adopte o strategie de dezvoltare conservatoare. Au fost întocmite o diagramă a patrulaterului strategic și o diagramă a strategiilor specifice și s-au făcut recomandări pentru activitatea companiei în direcția dezvoltării eficiente a acesteia. Compania trebuie să adopte o strategie de dezvoltare conservatoare. Pentru studiile viitoare, va fi posibil să se controleze acțiunile întreprinse și să se ofere o evaluare precisă a analizei efectuate pe o anumită perioadă.

Cuvinte-cheie*: performanta firmei, planificare strategică, management, dezvoltare, durabilitate*

INTRODUCTION

This study aims to draw up specific strategies and recommendations for the chosen company's work in the direction of its effective development. The strategic plan helps reorganize the company's activities [1] and products to achieve satisfactory profitability and growth [2]. Given the incremental changes in today's business environment, the strategic plan of textile and clothing companies must be created so that strategic activities are in line with trends of the external environment [3]. The strategic analysis describes the internal and external factors of the business environment [4]. The result is a SWOT analysis that can be used for further successful development. Effective management of the textile and clothing business means choosing the right strategy and implementing it effectively [5].

The development of textile enterprises in southeastern Serbia has been studied to a lesser extent [6]. However, factors influencing manufacturing companies in other regions of the country may have also influenced this region [7]. Therefore, it is necessary to conduct additional research to establish the state of companies producing textiles and clothing in the southeastern region. Of course, this is only one stage of the business planning process, so it is necessary to conduct more in-depth research and analysis to make decisions [8].

The contribution of this paper is to perform a situational analysis of a company related to the production of textiles and clothing from the region of southeastern Serbia using SWOT. Before the methodology

implementation on the concrete case, the theoretical base and general environmental overview are given [9].

OVERVIEW OF THE TEXTILE AND CLOTHING INDUSTRY BUSINESS ENVIRONMENT IN SERBIA

Textile and clothing manufacturing companies are essential in Serbia's economy, employing hundreds of citizens. Moreover, adapting regional economies to the changing competitive environment and introducing new technologies and innovations in textile production lead to the sustainable development of companies. Hence, the strategy needs to create a conceptual model which illustrates the connections among various value chain segments in the clothing and textile sector that lead to the direction of its effective development [10].

The production of textiles and clothing is one of the essential industries in Serbia in terms of production efficiency. However, the textile industry in Serbia faces many problems. For example, leading indicators that precisely show an unresolved economic environment are as follows: economic conflicts, lack of professional staff imposed by the constant “outflow” of experts [11], deindustrialization [13], intense competition from other countries [12], high prices of process equipment [14], a general lack of financial resources [15], insufficient support from banks [16], inadequate supply of modern equipment [17], insufficient commitment and influence of the state in solving its problems [18], a small percentage SMEs with automated production [19].

Besides the high level of expert outflow, this sector encounters the problem of “employee turnover” [20]. The term “employee turnover” is a crucial metric usually central to organizations' workforce planning and strategy [21]. The impact of turnover has received substantial attention from senior management, human resources professionals, and textile engineers in the textile and clothing industry [22]. The issue of employee turnover in organizations in Serbia is an essential element that influences their overall business success [23].

According to [24], there are five productions of textiles and clothing regions in Serbia. Table 1 summarizes the regions in Serbia and what types of textiles or clothing are mainly produced there.

MATERIAL AND METHOD

Material

The companies under study are located in south-eastern Serbia and western Bulgaria. The subject of production is cotton and synthetic fabrics and clothes from them. The company that is analysed annually produces and markets fabrics of different weights and compositions and ready-made knitted garments. The company's main products are sold in the Republic of Serbia, some of them abroad. The total number of employees in the company is 120. The company produces unique work clothes, as clients are government institutions, public and commercial companies, and health centres. The general structure of the company is a Plant for preparations; a Spinning mill; a Weaving factory; Factory finishing fabric. The procedure for conducting a SWOT analysis includes a survey to identify TO-WS factors. The survey must be anonymous. The percentage of employees who participated in the survey is 70%. The company's strategic documents derive the factors used in the TOWS matrix, mass production analysis, sales sector, and human resources policy [25]. TOWS matrix provides a framework to create, compare, decide and access business strategies. It examines a business from an approach that references marketing and administration [26].

Each threat, opportunity, weakness, and strength develops appropriate questions and complete definitions. Threats and opportunities are uncontrollable factors outside the company and often represent trends in the company's level of development. Each list can be reduced to the first four to six factors if necessary. The created groups of questions must be clearly and carefully defined. Weaknesses and strengths are controlled internally by the company from the point of view of competitors and outsiders [27]. Finally, the potential measurements (weighting factors) for each TO-WS combination are determined.

Method

This work follows a methodology that uses the hybrid SWOT-AHP method and the SWOT strategy matrix. Thus, the analysis of strengths, weaknesses, opportunities, and threats (SWOT) will be addressed, with which the Analytic Hierarchy Process, known by its acronym AHP, uses. Ultimately, the SWOT matrix identifies optimal strategies [28].

PCA (Principal Component Analysis) is then used to aggregate the judgments for AHP calculation. AHP

Table 1

TO-WS MATRIX [24]

External/Internal	Strength (S)	Weakness (W)
Opportunity (O)	SO growth strategies. Use their strengths and use external possibilities.	WO reversed strategy. It takes advantage of external capabilities to overcome its shortcomings.
Threats (T)	ST diversification strategy. It uses its advantages to avoid external threats.	WT's defensive strategy. Overcomes its shortcomings and avoids external threats.

analysis determines the prioritization of progress development [29]. The SWOT method uses two types of analysis: external, which identifies opportunities and threats in the operational environment of the organization, and internal, which seeks to overcome weaknesses through the strengths of the organization. The survey using Google Forms (Google Inc.) collected data on the company's state. This free Google application creates an online form or test. The results are obtained online in real time (figure 1) [30]. In real life, respondents would prefer to answer only a few questions but are willing to fill out a short questionnaire with a small number of questions after being kindly asked to do so. For this reason, the survey was developed, contains a small number of honest, easy, and straightforward questions to respondents, and is suitable for surveying a small number of people. The survey was conducted with employees in the company in two main groups – those in management positions and employees. A total of 83 respondents were interviewed. They are chosen at random, regardless of education and gender. Therefore, all respondents are familiar with the purpose of the survey and the purpose of using the data obtained.

The questions included in the survey are shown in table 2. Detailed literature study defines sources and consultations with the representatives of the analysed enterprise. The weighting factors are calculated based on a five-point scale with possible answers to each question: 1-I strongly disagree; 2-I do not agree; 3-I have no opinion; 4-I agree; 5-I agree.

The t-test method verifies statistically significant differences between the groups of respondents. The hypotheses are H0 – no statistically significant differences between the groups; H1 – there is a statistically significant difference between the groups. Reject the null hypothesis if the calculated t is less than $-t$ (critical) or the t-calculated is greater than $+t$ (critical). If $p < \alpha$, the null hypothesis is accepted.

All data were processed at a significance level of $\alpha = 0.05$.

Depending on the respondent's answers, the “Factor analysis” method calculated the weighting factors [40]. In this method, the maximum similarity of the factor weights is calculated in the matrix Λ of the factor analysis model:

$$x = \mu + \Lambda f + e \quad (1)$$

where x is the observation vector, μ – vector of average values, Λ – matrix of the dimensions of the weighting coefficients, f – vector of independent, standardized common factors, and e – vector of independent specific factors. X, μ, and e have size d, and f has size m.

Table 2

QUESTIONNAIRES FOR COMPILING A SWOT MATRIX	
Strength (S-questions)	**Weakness (W-questions)**
S1 Mass production capacity	**W1** Work environment-teamwork, pollution, low temperatures, high humidity
S2 Cost-conscious business	**W2** Textile engineering skills
S3 Low labour cost	**W3** Operative fatigue
S4 Capital investment availability	**W4** Effluent treatment capacities
S5 Raw material supply	**W5** Availability of water
S6 Supportive management	**W6** Fragmented company
S7 High-performance machineries	**W7** Slow speed of sample development
S8 Fully managed sales network	**W8** High maintenance and service costs
S9 On-time delivery	**W9** Lack of accurate forecasting of future trends
S10 Short lead time for product development	**W10** Lack of good negotiating skills
Opportunity (O-questions)	**Threat (T-questions)**
O1 Market orders exports/locals	**T1** Ecological product requirement
O2 Common effluent discharge facility	**T2** Product lead time
O3 Technical textile	**T3** Market competition
O4 New development in dyes, pigments and chemicals	**T4** Social ignorance
O5 Low-cost dyes and chemicals	**T5** Availability of electrical power
O6 Mass production capacity	**T6** High water consumption/effluent generation
O7 Collaboration between industrial and academic organizations	**T7** Disposal of solid waste generated from effluent
O8 Technology transfer by company reorganization	**T8** High inventory cost
O9 Environmental policy	**T9** Global quality standards of the textiles
O10 Production methods that have been successful in the past	**T10** Introduction of e-commerce

Data source: Matlab 2017b (The MathWorks Inc., Natick, MA, USA) and Statistica 12 (TIBCO Software Inc., Palo Alto, CA, USA) software products processed the experimental data.

Weighting factors create the SWOT matrix. First of all, the weights of each question are determined. Then, they calculate the relationships between the different groups of questions in the SWOT matrix.

The company's market orientation can be obtained based on the quadrant of the centre of gravity in the quadrangle. If the centre is in the first quadrant, the market position is called the zone of aggression, which means that factors *S* and *O* are higher than the others. Therefore, the company's work must use advantages and opportunities. Factors *O* and *W* are dominant if the centre is in the second quadrant. The market position is called the Development Region. The third quadrant is the regulatory area, which means neutralizing threats and minimizing weaknesses. The transformation zone is in the fourth quadrant, which means using force to neutralize threats. Table 3 describes the possible positions of the surveyed company.

Figure 1 shows the strategic quadrangle and the strategy diagram in general. In addition, the direction of change of the angle θ is indicated.

In the strategic quadrilateral, *D* denotes the area of the resulting quadrilateral. *S* and *W* have expressed through $S(x1,0)$, $W(-x2,0)$, and *O* and *T* have expressed through $O(0,x3)$, $T(0,-x4)$. The coefficients *x*1, *x*2, *x*3, and *x*4 represent generalized weights for whole groups of questions *S, W, O*, and *T*. The sum of the weights of the four components of the strategic quadrilateral of the graph must be equal to 1. According to this analysis, the following formulas obtain the centre of gravity (x, y):

$$x = \frac{x_1 - x_2}{3};\ y = \frac{x_2 - x_4}{3} \tag{2}$$

The centre of gravity shows the market position of the company. From here, recommendations can be given for its development.

The areas of the quadrilateral can be calculated as follows:

$$OSA = \frac{x_2 x_1}{2};\ STA = \frac{x_1 x_4}{2};$$
$$TWA = \frac{x_4 x_2}{2};\ WOA = \frac{x_2 x_3}{2}; \tag{3}$$

When defining specific strategies, a proactive or stable and conservative position can be adopted. Therefore, the strategic intensity must be determined from the same strategy.

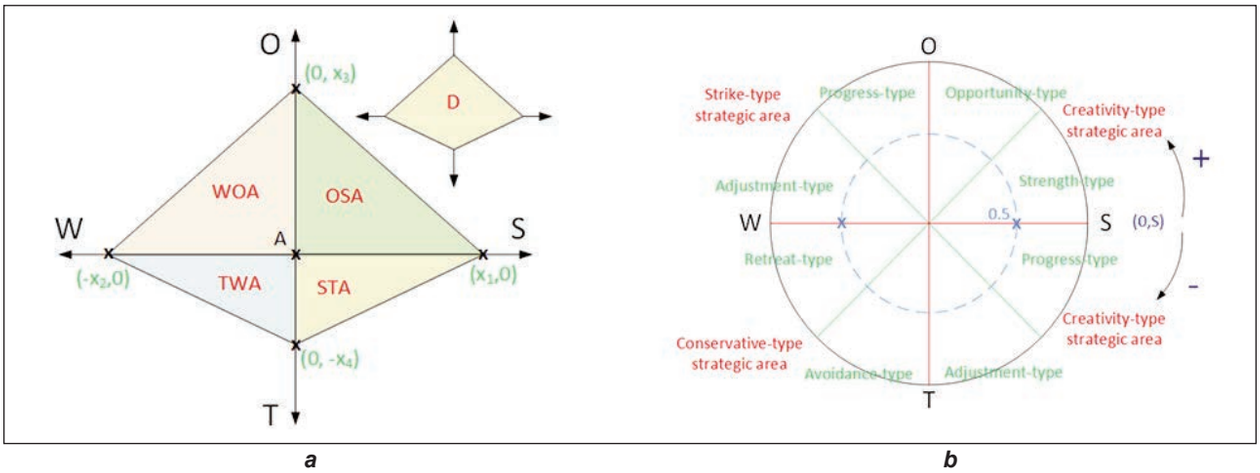
A schematic diagram of strategic type and intensity is drawn up. According to the barycentre coordinates, the parameters θ, *U*, *V*, and ρ are calculated, respectively. The polar diagram parameters are calculated as follows:

$$\theta = atan\left(\frac{y}{x}\right);\ U = x_1 x_3;\ V = x_2 x_4;$$
$$\rho = \frac{U}{U+V};\ A(\theta, \rho) \tag{4}$$

Positive strategic intensity (*U*) results from the interaction of external circumstances and internal factors.

Table 3

POSSIBLE MARKET POSITION OF THE COMPANY		
Quadrant	**Market position**	**Meaning**
O-S	Zone of aggression	The factors S and O are more important than others. Therefore, the company should focus on taking advantage of its strengths and exploiting its capabilities.
O-W	Development zone	The factors O and W are dominant.
T-W	Regulatory area	It was referring to a zone of adjustment. However, first, the company must neutralize threats and minimize its weakness.
T-S	Transformation zone	The company must use forces to neutralize threats.



a *b*

Fig. 1. Strategic diagrams: *a* – Strategic quadrilateral; *b* – Diagram to identify specific strategies

Conversely, negative strategic intensity (*V*) results from the interaction of external threats and internal weaknesses.

What intensity should be adopted depends on the overall positive and negative strategic intensity. We can estimate this by calculating the coefficient of strategic intensity. The strategic intensity factor (ρ) reflects the implementation intensity of the strategic type, $\rho \in (0,1)$.

As the value of *U* increases, the strategic intensity coefficient increases, indicating that the strategic intensity increases.

When the value of *V* increases, the strategic intensity coefficient decreases, indicating that the strategic intensity decreases.

Usually, 0.5 is used as a critical point. The operational strategy is adopted at $\rho > 0.5$. At ρ 0.5, a conservative strategy is adopted. In the analysis of the SWOT model, the strategic azimuth θ identifies the strategic type and the strategic force coefficient ρ estimates the strategic intensity.

RESULTS AND DISCUSSION

As mentioned above, grouping the results in terms of respondents' responses is the basis for formulating appropriate strategies for the textile company. There was a statistically significant difference in the respondents. A positive analysis of these questions was made, in which there is a statistically significant difference. The SWOT matrix is composed. They analyse the questions in which there is a strong connection that describes the strengths and weaknesses of the company. A diagram of a strategic quadrilateral and one for a specific strategy were made. These diagrams are analysed. They are recommended for the company's advice regarding effective development.

Table 4 lists the number of respondents who depend on the survey questions' importance and their position in the organization. They are grouped according to strengths, weaknesses, challenges, and threats to the company.

Figure 2 shows a detailed analysis of the questions with a statistically significant difference between the answers of the two groups of respondents. On the S2 issue of Cost-Effective Business, the difference is that one group agrees, and the other entirely agrees that this is their company's strength. This difference shows that both groups of respondents pointed out this feature of the company as necessary, so a collaborative group followed their answers. The same trend is observed in the answers to question S6 about “Maintenance Management”. Again, the difference in the answers is that one group agrees, and the other entirely agrees that this is a strength of their company. Again, the following analyses combine the following two groups. One of the company's weaknesses, W3, related to “Operational fatigue”, observes differences in the answers of the two groups of respondents. About 40% of respondents are still determining if the company has such a weakness. 30% of the two groups observe contradiction. Respondents in a managerial position believe that

Table 4

NUMBER OF ANSWERS DEPENDİNG ON THE İMPORTANCE OF THE QUESTİONS

PK	Management position					Employee					PK	Management position					Employee				
SV / P	1	2	3	4	5	1	2	3	4	5	SV / P	1	2	3	4	5	1	2	3	4	5
S1	3	14	6	15	26	3	12	11	22	16	W1	6	0	6	49	3	5	4	9	43	3
S2	0	3	0	19	42	0	2	8	36	18	W2	0	3	12	43	6	2	5	12	36	9
S3	0	12	6	27	19	2	12	6	36	8	W3	3	22	29	10	0	6	4	24	28	2
S4	3	3	9	40	9	1	2	15	39	7	W4	6	6	9	37	6	3	9	11	36	5
S5	3	3	12	28	18	0	5	11	43	5	W5	3	9	0	46	6	2	8	7	41	6
S6	3	0	0	37	24	1	5	12	41	5	W6	6	3	6	43	6	1	7	12	41	3
S7	0	12	6	25	21	4	8	8	31	13	W7	0	26	9	26	3	2	13	14	31	4
S8	0	3	12	34	15	1	6	9	37	11	W8	3	3	3	16	39	4	4	11	21	24
S9	0	6	3	46	9	2	1	9	38	14	W9	0	12	15	30	7	5	11	10	32	6
S10	0	19	22	23	0	4	14	11	28	7	W10	9	27	10	18	0	5	25	6	23	5
O1	0	12	15	27	10	4	9	12	37	2	T1	3	13	6	36	6	4	7	11	34	8
O2	0	9	12	36	7	6	5	10	37	6	T2	3	7	0	48	6	0	10	9	38	7
O3	0	3	9	41	11	1	3	14	22	24	T3	0	16	6	35	7	3	5	10	42	4
O4	0	9	9	29	17	2	2	12	16	32	T4	3	10	0	45	6	2	7	8	42	5
O5	0	6	6	29	23	1	3	14	15	31	T5	6	4	3	42	9	1	6	6	47	4
O6	3	0	9	43	9	2	4	12	26	20	T6	6	11	9	25	13	2	10	7	40	5
O7	3	25	13	17	6	1	18	14	21	10	T7	6	0	16	36	6	2	7	8	37	10
O8	3	16	19	16	10	4	18	13	24	5	T8	3	10	16	29	6	1	15	12	27	9
O9	0	9	13	35	7	1	4	6	41	12	T9	0	6	10	42	6	2	5	13	21	23
O10	9	13	19	17	6	4	19	11	19	11	T10	3	3	13	30	15	5	5	8	17	29

Note: PK – Position in the company; SV – importance degree; P – Question

the company does not have such a weakness, while employees believe it is present. The impact of weaknesses in the company is analysed below with appropriate analysis methods.

A SWOT matrix is based on the relationship between the weights of the questions, depending on the respondents' answers. For example, four of the company's strengths are strongly related to three challenges – only one issue of strengths combined with threats to the company.

It is important to note that the most substantial ties are with the company's weaknesses, which combine with challenges and threats. Seven company weaknesses combined with six of the challenges and seven of the threats to it.

Regarding the company's strengths, according to the results obtained, the business's challenges should be focused on producing technical textiles, developing new dyes, and reducing the prices of these products. These challenges are also related to the availability of capital investment. In addition, it needs maintenance management and high-performance machines. Finally, the threats to development in this direction are related to increased costs related to the product's compliance with ecological norms.

The weaknesses observed are related to the working environment, excessive fragmentation of activities in the company, the cost of maintenance of machinery and equipment, and inaccurate forecasting of trends in the company's field of work.

Threats to overcome these weaknesses of the company are related to competition in the market, increasing the requirements for product quality, but in strict compliance with environmental standards, which in turn leads to increased costs for the company. In addition, social awareness and the introduction of e-commerce methods are threats the company has to deal with.

The coordinates and areas of the strategic quadrilateral are determined. O = [0 0.26]; S = [0.173 0]; T = [0 –0.287]; W = [–0.28 0]; OSA = 0.023; STA = 0.025; TWA = 0.04; WOA = 0.036; D = 0.124. The centre of gravity of the company's market position is (x, y) = [–0.035 –0.009]. Figure 3, *a* shows the quadrilateral obtained. The largest area it occupies is in the TWA area. It covers 33% of the total area D. This area indicates that the company has weaknesses, the elimination of which is hindered by threats. In addition, this quadrant is located in the regulatory area, meaning the company must neutralize threats and minimize weaknesses.

The coordinates of the diagram for determining specific strategies have been calculated: θ = –165.580 U = 0.045 V = 0.0129 ρ = 0.777 (figure 3, *b*). The quadrant in which the company is located shows that it must adopt a conservative development strategy and

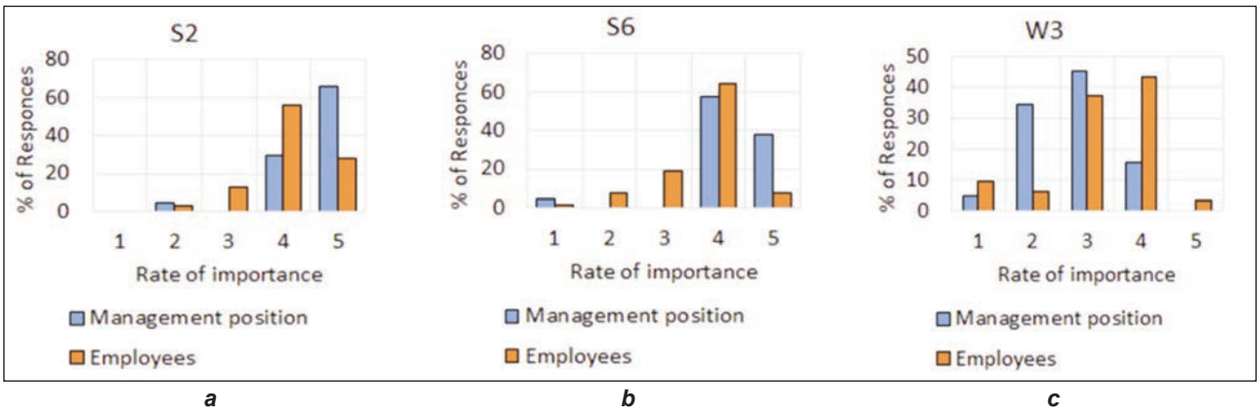


Fig. 2. Questions with a statistically significant difference between the answers of the respondents: *a* – S2; *b* – S6; *c* – W3

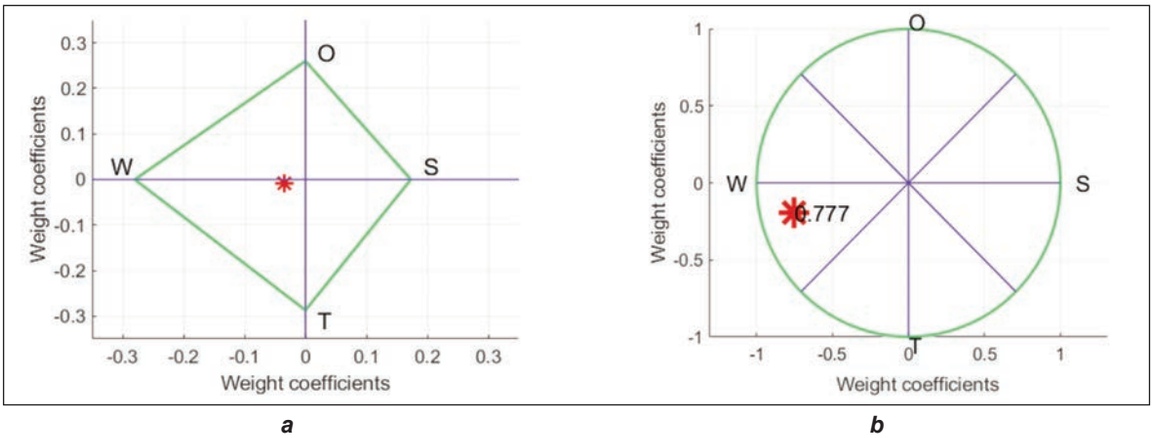


Fig. 1. Strategic diagrams of the studied company: *a* – Diagram of strategic quadrilateral for the analysed company; *b* – Diagram for defining specific strategies

protection strategy. This quadrant will ensure sustainable growth using a strategy of a defensive and conservative nature. The strategy will not lead to significant changes but will continue with a stable quota while taking the least risk in a growing market. The value of the coefficient $\rho > 0.5T$ confirms changes, which means that the company must adopt an operational strategy that will simultaneously increase both the operational potential and the market quota.

In summary of the analyses made so far, only three of the questions in the survey showed a statistically significant difference within the methods used for data processing. These questions necessitated further analysis of these three issues. Differences consist of the respondents accepting or fully accepting the questions asked. The two groups of respondents were united, and a general analysis of the market situation in which the company finds itself was made. The company highlights its strengths and weaknesses and its challenges and threats.

From the analyses made, the company has given guidelines for its development. First, it must neutralize threats and minimize its weaknesses. The company must adopt a conservative development strategy. The strategy will ensure its sustainable growth, using defensive and conservative strategies. Also, adopting this strategy would lead to a simultaneous increase in both the operational potential and the market quota of the company.

CONCLUSIONS

The general results of the research are the basis for formulating appropriate strategies for the textile company, which depends on the importance of given answers and the position employees take in the organization in which they work.

There was a statistically significant difference in some of the answers given by the respondents. Few of the company's strengths are strongly related to its challenges. However, the most substantial ties combine the company's weaknesses, challenges, and threats. Furthermore, the business's challenges have focused on producing technical textiles, developing new dyes, and reducing the prices of these products. These challenges are also related to the availability of capital investment. In addition, the company needs maintenance management and high-performance machines. The threats to development in this direction are related to increased costs related to the product's compliance with ecological norms.

This study made an additional analysis of these issues, for which there is a statistically significant difference. Results confirm a statistically significant difference between the manager positions and employees, which is essential for creating specific strategies.

A SWOT-Factor Matrix must recognize their inherent interdependence when considering strengths and weaknesses as independent attributes. Most strengths have corresponding weaknesses. If we manage or mitigate a given weakness, we might also eliminate the corresponding strength.

A diagram of a strategic quadrilateral and one for specific strategies have been drawn up. When analysing the diagrams, the company's work toward its effective development received a recommendation for improving the desired technology transfer to achieve a sustainable and competitive advantage in the textile and clothing market. It was found that the company must adopt a conservative development strategy.

The proposed methods and tools can be used to develop strategies for continuously improving companies operating in textiles and clothing.

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A review on deterioration of textile cultural heritage objects and sustainable solutions to mitigate the degradation

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ABSTRACT – REZUMAT

A review on deterioration of textile cultural heritage objects and sustainable solutions to mitigate the degradation

Heritage textiles are important evidence of human history. Folk costumes, quilts, tapestries, rugs, hangings, etc. constitute a rich collection of products that are particularly valuable but also extremely fragile. This paper presents the main causes of the deterioration of heritage textiles, followed by a summary of the main bio-treatments that are effective in their case. Essential oils and plant extracts have a strong antibacterial, antifungal and insecticidal effect and are therefore recommended to be used as sustainable alternatives to conventional treatments. At present, bio-treatments used to prevent and reduce the deterioration of heritage textiles are carried out in two ways. One of them targets bioaerosols in museum spaces and the second one targets microbial agents on the surface or in the structure of textiles. The application of bio-treatments on heritage textiles should be done taking into account the specific features given by their fibrous composition, the structure of the materials, their age, the environmental conditions in which they are, etc. At present, these treatments are not yet commonly used for heritage textiles or the spaces in which they are stored or exhibited, even though there are studies that have proven the effectiveness and safety of their use.

Keywords: *heritage textile, essential oils, plant extracts, antibacterial, antifungal, antimicrobial*

O analiză a cauzelor deteriorării produselor textile din patrimoniul cultural și soluții durabile pentru atenuarea degradării acestora

Textilele de patrimoniu constituie dovezi importante ale istoriei omenești. Costumele populare, cuverturile, tapițeriile, covoarele, ștergarele etc. constituie o colecție bogată de produse care sunt deosebit de prețioase, dar în aceeași măsură și extrem de fragile. În acest articol, sunt prezentate principalele cauze ale deteriorării textilelor de patrimoniu și o sinteza a principalelor bio-tratamente care s-au dovedit a fi eficiente în cazul acestora. Uleiurile esențiale și extractele de plante au un puternic efect antibacterian, antifungic, insecticid și de aceea ele sunt recomandate a fi utilizate ca alternative sustenabile la tratamentele convenționale. La ora actuală, bio-tratamentele folosite în scopul prevenirii și diminuării deteriorării textilelor de patrimoniu sunt realizate pe două direcții. Una dintre ele vizează bioaerosolii din spațiile muzeale și cea de-a doua vizează agenții microbieni aflați pe suprafața sau în structura materialelor textile. Aplicarea bio-tratamentelor pe textilele de patrimoniu trebuie realizată ținând cont de particularitățile specifice date de compoziția fibroasă a acestora, structura materialelor, vechimea lor, condițiile de mediu în care sunt depozitate etc. La ora actuală, aceste tratamente nu sunt încă utilizate în mod uzual în cazul textilelor de patrimoniu sau a spațiilor în care acestea sunt depozitate sau expuse, chiar dacă există studii care au dovedit eficiența și siguranța utilizării acestora.

Cuvinte cheie: *textile de patrimoniu, uleiuri esențiale, extracte de plante, antibacterial, antifungic, antimicrobian*

INTRODUCTION

Textiles are an important part of cultural heritage values, which must be preserved and passed on to future generations. Textiles are testimonies of technology, fashion, aesthetics and social life of a certain period, providing information on unpublished aspects of daily life in the past. Most heritage textiles have become part of the collections of museums or various exhibitions, having previously been worn, more or less, by different categories of wearers, on the occasion of different events or even daily. The main factors that may have left their mark on these textiles are environmental conditions (temperature, humidity, exposure to light, microbial contamination, etc.). These factors can also affect them after they have become part of the heritage of a museum, exhibition, etc. In addition to these natural factors, heritage textiles can also be affected by the interventions of restorers. Heritage textiles can undergo ageing, deterioration and decay processes that profoundly affect their beauty and their economic and ethnological value. Analysis of the causes of degradation is of paramount importance to protect heritage items and prevent their deterioration. It is also particularly important that the methods used to prevent the deterioration of heritage textiles are not only effective but also sustainable.

This paper aims to show that essential oils and plant extracts can be successfully applied to heritage textiles due to their antimicrobial effects, thus complementing the fields in which they are more commonly

used, namely: everyday clothing, protective clothing, and medical textiles.

Methods of scientific research that have been used in the paper are data collection, analysis and interpretation, and summarizing of literature. The first part of the paper there are presents and analyses the most common causes of the deterioration of heritage textiles and the second part there are presents the bio-treatments used to prevent and reduce the deterioration of heritage textiles in the two ways in which they can be applied.

FACTORS OF DETERIORATION OF TEXTILE CULTURAL HERITAGE OBJECTS

The deterioration processes of heritage textiles are caused by: the action of physical-chemical factors, microbial degradation and deterioration and mistakes in human treatment.

Physical and chemical factors contributing to the deterioration of heritage textiles

The main causes of degradation of heritage textiles are considered to be light, heat and oxygen. Light, which is so necessary for the enhancement of exhibits, can cause their degradation. This includes both natural and artificial light, the latter being less harmful because it is relatively constant in intensity and because it can be controlled and dosed in intensity, type, time and distance.

The visible effects of light on coloured textiles are fading of colour or spots, and the less visible effects are decreases in tear and tensile strength of the materials [1].

These effects depend on the raw material from which the textiles are made. For example, light exposure to wool products causes yellowing or bleaching. The critical factors that influence the yellowing of wool by light are the light's wavelength distribution (UV radiation), humidity and the type of pre-bleach applied to the wool. The photobleaching of yellow pigments is encouraged by visible blue light (maximal effect 420–540 nm) exposure of wool, therefore promoting unwanted colour changes, especially in the case of wool products that have been dyed to pastel colours [2].

Exposure of wool to UV radiation at wavelengths between 380–475 nm causes not only a change in colour but also a decrease in fibre strength [3]. Treigienė and Musnickas have shown that the tensile strength of wool fibres decreases by between 8 and 20% when exposed to UV radiation for between 40 and 120 hours [4]. Cotton fibres are sensitive to UV radiation between 200 and 300 nm. The most common photochemical damage to cotton occurs through photo-oxidation. As a result of this process cotton fibres change colour and mechanical properties – they become stiffer, more brittle and have a much lower tensile strength. Cotton fibres subjected to radiation show lower strength than wool and silk fibres [5]. Another fibre that has a long and important place in the history of textile production is silk fibres. They are strongly affected by radiation of wavelengths between 220–370 nm, radiation that causes photodegradation. "Irreversible" changes in colour and affect physical properties of fabric, such as strength and elasticity, are all causes of silk photodegradation [6].

In the case of linen fabrics, UV rays cause their colour to change and their tensile strength to decrease [7].

In the case of synthetic fibres, light sensitivity manifests itself differently, depending on chemical composition and stabilization. The most resistant are polyester fibres, followed by polyacrylonitrile and polyamide [8]. For these types of fibres, exposure to light causes different degrees of yellowing, a decrease in mechanical strength and a decrease in the degree of polymerization [1].

Temperature is another microclimate factor involved in the deterioration of heritage goods, influencing chemical reactions (oxidation reactions, hydrolysis reactions, etc.) through energy transfer, causing accelerated molecular agitation. Its variations can be determined either by the exchange of heat with the external environment or by variations in the humidity of the internal environment. Temperature is also one of the factors that can contribute to the growth of different types of microorganisms [8].

Microbial degradation and deterioration of heritage textiles

Heritage textiles serve as a substrate for microbial growth, which is frequently undetectable unless the biofilm over-agglomerates and discolours or damages the fabric's physical integrity [9].

Depending on the species of organism attacking the material and its properties, biodegradation of textiles results in various sorts of damage. The growth of micro-organisms on cultural heritage textiles often causes serious aesthetic damage due to the formation of colonies and fungal pigments. Vornicu and Bibire [10] classify the factors favouring biodeterioration into 3 groups, namely: meteo-climatic, physico-chemical and mechanical and biotic and show that the rate of deterioration and the type of degradation depends on these factors but also the simultaneity of their action. Humidity and relatively high temperatures, associated with lack of light and air, favour the growth of microorganisms. The optimum temperature for the growth of most micro-organisms is in the range 20–35°C. At low temperatures, in winter, fungal spores are very resistant due to their shape and cell envelope and their ability to remain dormant. Raising or lowering the temperature above or below the optimal value for the development of microbiodeteriogens prevents their multiplication. Oxygen also plays an essential role because most micro-organisms that grow on art objects are aerobic [10]. Microorganisms use the components of textile materials (carbon, nitrogen, sulphur, phosphorus) to grow and multiply [11].

Studies have shown that the microbial flora grown on fabrics made from plant fibres is different from that grown on fabrics made from animal fibres. The most

frequent biodeteriogens of cellulosic textiles are microfungi (*Alternaria, Aspergillus, Cladosporium, Fusarium, Memnoniella, Myrothecium, Neurospora, Paecilomyces, Penicillium, Scopulariopsis, Stachybotrys, Stemphylium, Trichoderma, Trichothecium, Verticillium*) and bacteria (*Arthrobacter, Bacillus, Cellvibrio, Cellfalcicula, Cellulomonas, Clostridium, Microspora, Sporocytophagamyxococcoide*) [10, 12–15]. Textiles made from flax and cotton plant fibres are prone to deterioration because they are rich in hemicellulose and pectin which are easily degradable by microorganisms. In the case of these textile items, microbial growth leads to changes in appearance, such as discolouration, and loss of strength and elongation [14]. The non-cellulosic components of hemp and jute textiles, such as lignin, give the fabric a greater resistance to degradation because few microorganisms possess enzymes capable of degrading them [16].
Wool and silk textiles are more resistant than vegetable textiles due to the keratin in wool and the fibroin in silk. Microorganisms such as *Trichophyton* and *Trichoderma* attack the disulfide bonds that hold the keratin chains together and are thus the main factors in wool degradation [14]. Wool is also easily attacked by insects. Silk is very sensitive to light and this favours the modification of the fibroin structure by various bacteria (*Bacillus, Pseudomonas, Serratia* and *Streptomyces*) and fungi (*Aspergillus*). Synthetic fibres are resistant to the action of bacteria and fungi. Besides these microorganisms, heritage textiles can also be attacked by some insects such as moths, beetles and ants which act destructively on all types of fibres except synthetic ones. In addition to these microorganisms, heritage textiles can be attacked by some insects such as moths, beetles and ants which act destructively on all types of fibres except synthetic ones [8].
In addition to the above-mentioned factors, known in the literature as exogenous factors, there are endogenous/internal factors that influence the biodeterioration of heritage textiles. The most relevant of these are the nature and type of raw materials; the structure of the materials; the presence and nature of biological attack; the nature and treatments carried out for conservation; the physicochemical and mechanical treatments to which they have been subjected; and the age of the material. The structural characteristics of the surface of the textile material such as type of bonding, thickness, absorbency/hydrophobicity, etc. are essential for the adhesion of microorganisms, their colonization and spread [17].

Incorrect human treatments in the conservation of heritage textiles

Heritage textiles can also be affected by the interventions of restorers [18]. Incorrect conservation can play a role in harming cultural heritage objects. In many cases, the consolidation of broken fabrics has been achieved by applying adhesives. These can be of animal origin – usually composed of collagen, obtained from bones, cartilages, tendons and skins of different mammals and fish, or vegetable origin – starch, derived from barley, corn, oat, rye, rice, potato and wheat [19, 20].
When using animal glue, factors such as temperature, light, and humidity can lead to the cross-linking of proteins and the oxidation of peptide bonds, while microbial flora invasion might encourage the appearance of undesired pigments.
When applying plant-based adhesives, it was found that the starch paste not only causes the yellowing of the material but also its strengthening/stiffening, constituting a habitat rich in nutrients for the development of bacteria and fungi, which favour the deterioration of textiles over time [20].

BIO-TREATMENTS APPLIED TO HERITAGE TEXTILES

The bio-treatments used to prevent and reduce the deterioration of heritage textiles are carried out in two ways. One targets bioaerosols and insects in museum spaces and the second targets microbial agents on the surface or in the structure of textiles.
The presence of high levels of bioaerosols in the air inside museum spaces is associated with a higher risk of biodeterioration of art object surfaces. High levels of bioaerosols are also associated with poor indoor air quality, which can reduce visitor comfort and increase health risks for visitors and those working in these spaces [21–23]. The very large number of museum visitors of different nationalities make cultural heritage objects "*important bridge nodes in the global network of pathogen spread*" [24].
Essential oils have a strong antibacterial, antifungal and insecticidal effect and are therefore recommended to be used for treating air in closed spaces [25,26]. Díaz-Alonso et al. evaluated the effectiveness of the *Melaleuca alternifolia* and *Thymus vulgaris* essential oils in reducing bacterial and fungal contamination of air in unventilated indoor spaces. The vaporization of tea tree essential oil showed the best results allowing a 77.3% reduction in air contamination for fungi and 95.0% for bacteria, respectively. They tested the efficacy of the *Melaleuca alternifolia* essential oil in the Camarín of Santos Juanes church of Valencia, Spain. The results showed improved air quality and no damage to artistic surfaces [27].
Ethanol 70%, deltamethrin (commercial pesticide, CP), *Pinus regida* essential oil (EO), and low oxygen microenvironment (LOM, 0.1%) were tested as fumigants individually and jointly by Abdelrahman et al. against *Alternaria alternata*, a fungal strain found in museums. The outcomes demonstrated the rate of mycelial growth suppression following each fumigation, the rise in the fungicidal activity of each chemical (CP or EO) when applied to LOM, and the progression of the EO's action from fungistatic to fungicidal upon combining with LOM [28].
Promising results were also obtained by WANG et al., who also tested by fumigation the efficacy of essential oils against 4 museum insect pests (*Lasioderma serricorne, Sitophilus zeamais, Tribolium confusum* and *Falsogastrallus sauteri)*. Out of the 13 essential

oils studied, 4 *(muskmelon oil, geranium oil, spikenard oil* and *patchouli oil)* have demonstrated strong insecticidal effects against the four pests [29].

Faheem and Abdurraheem tested the efficacy of botanical fumigants with the essential oils of *Ferula asafoetida, Syzygium aromaticum,* and *Mentha piperita* against larvae of *Anthrenus verbasci*. They showed that the EO of *Mentha piperita* was the most effective, followed by *Syzygium aromaticum* and *Ferula asafoetida.* Their study also revealed that although there are numerous important biodeteriogens, museums do not take proper action to control and prevent the damage they cause. They recommend integrating natural and traditional methods in the museum's Integrated Pest Management (IPM) strategies, not only for the safety of the museums' valuable collections but also for the safety of their environment, their employees and visitors [30].

Even if the bio-treatments targeting the air inside museum spaces and the insects in these spaces are not yet widely applied, we are convinced that they will in the future complement preventive conservation measures for heritage textiles (adequate ventilation of the spaces, maintaining a relative air humidity around 55%, a temperature around 20°C, and maximum room illumination levels of 50 lx and 50,000 lx-hours per year, as recommended overall exposure limits) [31, 32].

The effectiveness of bio-treatments on different types of textiles has been proven by numerous studies. The antimicrobial effects of numerous plant extracts and essential oils, applied to different types of materials, made from different raw materials, have been studied (table 1).

The application of essential oils and plant extracts on heritage textiles should be done taking into account

Table 1

ANTIMICROBIAL EFFECTS OF NUMEROUS PLANT EXTRACTS AND ESSENTIAL OILS APPLIED TO DIFFERENT TYPES OF MATERIALS

Biotreatment applied	**Material on which it was applied**	**Micro-organisms against which the applied treatments work**	**Reference**
Punica granatum L., (pomegranate) peel extract	Cotton fabric	– *Staphylococcus aureus* and *Aspergillus niger*	[33]
Punica granatum peel extracts	Hemp fabric	– *Staphylococcus aureus* and *Klebsiella pneumoniae* Effectiveness rate of 99,99%	[34]
Pomegranate, neem and turmeric extracts	Cotton fabric, used for medical purposes	High effectiveness against gram-negative bacteria	[35]
Peony, pomegranate, clove, *Coptis chinenis* and gallnut extracts	Cotton, Silk, and Wool fabrics	– *Staphylococcus aureus* – reduction rate: 96,8–99,9% – *Klebsiella pneumoniae* – reduction rate: 95,7–99,9% (exception: extraction from peony)	[36]
Rosmarinus officinalis (rosemary) EO	mix of cotton (56%) and polyester (44%)	– *Aspergillus niger* – reduction rate of maximum 22,12% – *Candida albicans* – reduction rate of 100% – *Trichoderma viride* – reduction rate of maximum 76,48% – *Aspergillus flavus* – the maximum efficiency of the treatment was 18,3% – *Epidermophyton floccosum dermatophyte* – reduction rate of maximum 56,99%	[37]
Citrus sinensis (orange) EO	mix of cotton (56%) and polyester (44%)	– *Aspergillus niger* – reduction rate of maximum 51,45% – *Candida albicans* – reduction rate of 100% – *Trichoderma viride* – reduction rate of 100% – *Aspergillus flavus* – the maximum efficiency of the treatment was 60,57% – *Epidermophyton floccosum dermatophyte* – maximum reduction rate: 92,48%	[37]
Thyme EO	Linen-cotton blended fabric (55% linen and 45% cotton)	*Corynebacterium xerosis, Bacillus licheniformis, Micrococcus luteus, Staphyloccocus haemolyticus, Staphyloccocus aureus, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa*	[38]
Aloe gel extract	Cotton fabric	– *Staphylococcus aureus*	[39, 40]
Extracted from neem plants	Cotton fabric	– *Staphylococcus aureus*	[40]

Table 1 (continuation)

Biotreatment applied	Material on which it was applied	Micro-organisms against which the applied treatments work	Reference
Hybrid combination of extracted from aloe vera and neem plants	Cotton fabric	– *Escherichia coli* and *Aspergillus niger*	[40]
Moringa stenopetala seed oil	Cotton fabric	– *Staphylococcus aureus* and *Escherichia coli*	[41]
Olive oil	Cotton fabric	– *Staphylococcus aureus* and *Escherichia coli*	[42]
Herbal extracts – chamomile, sage and green tea	Cotton fabric	– Gram negative bacteria – *Salmonella tyhimurium, Escherichia coli* – Gram positive bacteria – *Bacillus subtilis, Bacillus cereus, Staphylococcus aureus* – unicellular fungi – *Candida albicans, Candida tropical's, Candida pseudo tropical's*	[43]
Eucalyptus leaf extracts – *E.cinera* and *E.odorata*	Cotton fabric Wool fabric	– *Staphylococcus aureus* and *Escherichia coli* (*E. odorata* extract) – Higher efficiency in the case of wool textiles	[44]
Murraya Koengii (curry leave) and *Zingiber Officinale* (ginger) oil	Cotton fabric	– Gram positive bacteria – *S. aureus, B. subtilis, B. pumilus* – Gram-negative bacteria – *Pseudo, Candida, E.coli*	[45]
Propolis, beeswax and chitosan	Cotton knitted fabric	– Gram-positive bacteria – *Staphylococcus aureus* and *Streptococcus β hemolitic* – Gram negative bacteria – *Escherichia coli* and *Pseudomonas aeruginosa*	[46]
Extracts from *Galinsoga parviflora* plant leaves	Cotton fabric	98,54 % and respectively 97,96% reduction rates of *Staphylococcus aureus* and respectively *Pseudomonas aeruginosa bacteria numbers*	[47]
Peppermint EO	Cotton Fabric	*S. aureus* and *E. coli*	[48]
Melaleuca alternifolia (tea tree) EO	Viscose fabric	*E. coli* and *S. aureus*	[49]
Lime EO	Cotton fabric	inhibited *E. coli, B. cereus, S. Typhimurium* and *S. aureus,* even after washing	[50]
Cinnamon; basil; lemongrass, and mint EOs	Polyethylene non-woven fabric	*Escherichia coli* and *Staphylococcus aureus* – the best oil is cinnamon, basil oil ranks the second, the next is the mint oil, and the lowest effective is the lemongrass oil	[51]
Citrus aurantifolia (lime) EO	Cotton fabric	*S. aureus, E. coli, K. pneumoniae,* and *S. epidermidis*	[52]
Salvia officinalis L. / *Salvia lavandulaefolia Vahl.* EOs	non-woven viscose	*E. faecalis* (33 %) / *S. saprophyticus* (31%)	[53]

the specific features given by their fibrous composition, their age, the environmental conditions in which they are stored, etc. At present, essential oils are not yet commonly used for the treatment of heritage textiles, even though there are studies that have proven their effectiveness and safety as alternative methods of conservation of heritage textiles.

One such study was conducted by Matusiak et al. [54]. Their study focused on determining the antimicrobial efficacy of *Cinnamomum zeylanicum* essential oil (CEO) in the vapour phase to disinfect heritage textiles and its impact on the materials' mechanical, optical, and structural characteristics.

They showed that for the moulds *Aspergillus niger*, *Penicillium funiculosum* and *Trichoderma viride*, a minimum concentration of CEO in the vapour phase of 5.625 μg ml^{-1} is required, and for the bacteria *Streptomyces rutgersensis*, *Bacillus megaterium* and *Pseudomonas fluorescens*, a minimum concentration of 22.5 μg ml^{-1}. After being disinfected with CEO, the amount of viable microorganisms on the tested fabrics was decreased by 2 to 7 logarithmic units. Since no significant changes in optical, mechanical and structural characteristics of textiles were observed after the CEO treatment, it can be considered that this method of disinfection of heritage textiles is effective, sustainable and safe.

Another study was conducted on short coats for young men, handmade from hemp and cotton yarns and lined with sheepskin from the Mara Valley, Maramures, Romania. After testing on different delimited surfaces of the garment, it was concluded that all EOs (*Citrus limon, Lavandula angustifolia, Marjoram, Melaleuca alternifolia, Mentha piperita, Origanum vulgare*) had a strong inhibitory effect on six fungal colonies (*Alternaria sp., Aspergillus sp.,*

Botrytis sp., Cladosporium sp., Mucor sp. and *Penicillium sp.*) and a class of yeast (*Candida guilliermondii*). None of the treatments applied had visible adverse effects on the product's physical characteristics in the treated areas [55].

The effect of essential oils of lemon (*Citrus limon*), lavender (*Lavandula angustifolia*) and peppermint (*Mentha piperita*) was also tested by applying them to an "ie", a piece of clothing from the Romanian cultural heritage, stored in a museum of ethnography in Beiuş, Romania. The inhibitory effects of the three essential oils were demonstrated on *Botrytis sp., Cladosporium sp.*, respectively *Rhodotorula mucilaginosa* [56].

Fierascu et al. studied the effect of seed extracts of linden and basil (plants native to Romania), (*Allium ursinum* and *Ocimum basilicum*) on different cultural heritage artefacts. The extracts were made using the least toxic solvents possible (water, ethanol-water mixture, ethanol). The results obtained showed their efficiency in protecting the artefacts against biodeterioration, due to the antifungal effect these extracts have [57].

Other studies, carried out on different textiles from the Romanian cultural heritage, have highlighted the antimicrobial and antifungal effects of chitosan but also the fact that these treatments have contributed to the improvement of the shrinkage resistance of the materials, to the increase of the absorption degree of the dyes and the whiteness degree due to the cleaning of the stains existing on these products [58, 59].

The antifungal activity of chitosan was also tested by applying it to 3 old maps made of silk, cloth and paper. A chitosan solution (10 g/l) was used to treat the 3 types of maps and the electronic microscope was used to evaluate the results. The study highlighted the antimicrobial effect of chitosan regardless of the material on which it was applied [60].

In another study, the essential oils (EOs) from *Vitex agnus-castus* leaves and fruits, *Eriocephalus africanus* leaves, *Cymbopogon citratus* leaves, and *Rosmarinus officinalis* leaves were tested as antifungal agents against *Aspergillus flavus, Cladosporium cladosporioides*, and *Penicillium chrysogenum*. These pathogens were identified and collected from an ancient Egyptian child's mummy and then used to colonize different flax fibre samples, which were subsequently treated with the 5 types of essential oils. The highest efficacy was found to be in the case of *Vitex agnus-castus* leaf EO, which generated the most effective reduction in fungal mycelial development [61].

The use of essential oils in the conservation of heritage textiles has also been studied by a team of researchers from the University of Beira Interior in Portugal. They focused their research on the materials used to wrap heritage textiles when they are preserved. They developed a packaging material made of Polycaprolactone (PCL) which they also treated with *Lavandula luisieri* EO. The results of the study showed that both materials (PCL and PCL+EO) have good breaking strength and excellent whiteness index. They also showed that PCL+EO has a 99.33% reduction rate against *Staphylococcus aureus* bacteria and 99.29% against *Pseudomonas aeruginosa* bacteria, clearly superior to other protective materials commonly used in museums (Raw Cotton, Non-woven Polyester) [62].

Combining traditional and innovative methods of textile cleaning and preservation, Ilies et al. showed antibacterial/fungal properties of both substances obtained from boiling natural wood ash (lye) and silver nanoparticles. For this, they impregnated a very old traditional blouse from Bihor county, Romania, with 30 and 70 ppm silver nanosuspensions and washed it with lye. In both cases, the microbiological analyses showed that the reduction rate of bacterial colonies was 95%. The antibacterial effect of the silver nanoparticles present on the blouse's textile material (cotton fabric) was kept up throughout the entire study [63]. The efficiency of using silver nanoparticles for the conservation of heritage textiles and the multitude of methods that can be used for their deposition on textiles (layer-by-layer deposition, solution immersion, and sonochemical methods) are also highlighted by Lite et al. [64]. The effect of lye on heritage textiles was also analysed by Ilies et al. They showed that washing with lye a woman's blouse, made of cotton and having an age of 80–100 years, caused a decrease in the number of microorganism colonies and the amount of dust initially existing on the surface of that product [65].

Indrie et al. analysed the effects of Salvia and Thyme essential oils on the tensile strength of traditional hemp and cotton heritage textiles. They showed that the application of Salvia essential oil to cotton fabric increased tensile strength by 20% in the warp direction and 39% in the weft direction. On the other hand, the application of Thyme essential oil to the same cotton fabric resulted in a 29.9% reduction in tensile strength. The application of essential oils on the hemp fabrics determines the decrease in tensile strength in the warp direction, by up to 36% when applying Salvia essential oil and by 40% when applying Thyme oil. This study underscores the importance of consistency between the type of essential oil and the fabrics it is applied [66].

CONCLUSIONS

Heritage textiles are objects of high cultural and social value. They constitute important evidence of human history and therefore need to be protected and preserved to prevent their deterioration. However, restoration strategies are sometimes unavoidable.

Metals, metal-based chemicals, quaternary ammonium salts, phenolic compounds and other antimicrobial agents are frequently used to treat textiles, although they are hazardous and have negative environmental effects. For this reason, it is particularly important to find sustainable and effective alternatives at the same time.

The antimicrobial effects of essential oils and plant extracts have been highlighted and demonstrated by numerous researchers. A multitude of studies have shown the effectiveness of their application on different types of textiles. The most common material used in these studies was cotton fabric, but studies have also been carried out on cotton knitwear, hemp fabrics, wool, silk, rabbit hair, etc. Materials treated with different types of essential oils, plant extracts, or mixtures thereof, in different proportions and concentrations, have in all cases developed antibacterial and/or antifungal properties. It should be noted that numerous studies have focused on indigenous plants and have shown their effectiveness. Another important aspect is that these treatments did not affect the physical properties of the textiles.

The diversity of areas in which these treatments have proven useful – from textiles found in various clothing products to medical textiles or those forming part of cultural heritage – will lead to these treatments being applied on a much wider scale in the future, both because of their sustainability and because of their much lower price compared to products used in traditional treatments.

At present, biotreatments are not yet commonly used in the conservation of heritage textiles, even though numerous studies have proven the effectiveness and safety of their use. Research in this field will certainly expand in the future as well, both in the treatment of the air inside museum spaces and in the application of biotreatments on heritage objects, and these new conservation methods will become common practices in all museums.

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Personality traits and its impact on continuance intention to use social networking sites to buy branded clothing

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ABSTRACT – REZUMAT

CPersonality traits and its impact on continuance intention to use social networking sites to buy branded clothing

Personality traits are vital to study in the case of clothing buyers through social networking sites (SNS). In this study, an effort is made to bridge the gap by assessing the "big five" individual personality traits. These traits include neuroticism (extroversion), extraversion, openness to experience, conscientiousness, and agreeableness. In addition, customer value may moderate the link between personality traits and continuance intention. A survey of customers on Pakistani students was carried out. Structure equation modelling was applied to analyse the collected data from 450 respondents. Our research showed that extraversion, agreeableness, and neuroticism are all connected to the buying behaviour of students through SNS. Furthermore, this study confirms the moderating role of customer value between personality traits and purchase intention. The findings of this study have the potential to be beneficial for all stakeholders engaged in the buying and selling of clothing brands through SNS.

Keywords: *customer value, personality traits, intention to buy, social networking sites, clothing brands*

Trăsăturile de personalitate și impactul acestora asupra intenției continue de a folosi site-urile de rețele sociale pentru a cumpăra îmbrăcăminte de marcă

Trăsăturile de personalitate sunt vitale pentru studiu, în cazul cumpărătorilor de îmbrăcăminte prin intermediul site-urilor de rețele sociale (SNS). În acest studiu, se face un efort pentru a reduce decalajul prin evaluarea celor „cinci mari" trăsături individuale de personalitate. Aceste trăsături includ comportamentul nevrotic (extroversiunea), extraversiunea, deschiderea către experiență, conștiinciozitatea și amabilitatea. În plus, valoarea clientului poate modera legătura dintre trăsăturile de personalitate ale acestuia și intenția acestuia de a continua să cumpere. A fost efectuat un sondaj cu clienţi care sunt studenți pakistanezi. Modelarea ecuațiilor de structură a fost aplicată pentru a analiza datele colectate de la 450 de respondenți. Cercetarea noastră a arătat că extraversiunea, amabilitatea și comportamentul nevrotic sunt toate legate de comportamentul de cumpărare al studenților prin SNS. Mai mult, acest studiu confirmă rolul moderator al valorii clientului dintre trăsăturile de personalitate și intenția de cumpărare. Concluziile acestui studiu au potențialul de a fi benefice pentru toate părțile interesate implicate în cumpărarea și vânzarea mărcilor de îmbrăcăminte prin SNS.

Cuvinte-cheie*: valoarea clientului, trăsături de personalitate, intenție de cumpărare, site-uri de rețele sociale, mărci de îmbrăcăminte*

INTRODUCTION

Because of multinational and transnational businesses, the globe has shrunk to the size of a village in recent years. These corporations have been a driving force behind the globalization of the economy. According to Stieger et al. [1], having the goal to start a business is one of the most critical factors in the establishment, expansion, and growth of enterprises, all of which are necessary for a sustainable future. Consequently, the investigation of the aspirations of potential business owners is becoming an increasingly significant and active subject of research in the modern economy. Introducing innovative business models that contribute to all three of these areas is one way entrepreneurship may pave the way for sustainable development [2].

The utility of personality factors in predicting whether or not consumers will retain content is still in its formative stages. Previous research methods either did not consider personality factors or narrowed their attention to a specific attribute, such as ingenuity. By including assessments of personality and values, we can satisfy a demand highlighted in earlier research and better understand why Chinese customers intend to continue using SNSs. The primary objective of this study was to develop a model that would make it possible for researchers to investigate the following issues: (1) how the users' personality traits are affected by the buying intention of branded clothing; and (2) how customer value moderate between personality traits and continuance intention to use SNS's.

The following is a list of the primary contributions that this study has made. The first step in this study is to

construct and assess a model that investigates how an individual's personality traits can influence their choice to keep going. Using a sample from Pakistan to give empirical evidence for the transferability of findings from earlier studies to other nations in the dynamic Asian economic area is a second significant and crucial addition made by this research. Finally, this study is the first to comprehensively investigate users' intentions to retain their accounts across various social networking services and mobile applications. This study highlights the prevalence of users' ongoing interaction with social networking sites in Pakistan to purchase clothing with recognizable brand names.

LITERATURE REVIEW

Theoretical background

Allport theory of personality characteristics has made a substantial contribution to our understanding of the many different kinds of individuals in the world [3]. There are a significant number of various personality types, each of which is characterized by a unique set of characteristics that influence how people behave and how they engage with the world around them. Various taxonomies of personality traits at multiple levels have been built using physiological patterns as the basis. For example, a person's distinctive way of logical thinking and emotional behaviour, found to be constant over time and in different circumstances, is referred to as their personality traits. These personality traits are characterized as the following: Wang et al. [4] categorized these personality qualities by using the Big Five Model's five different categories as their guide. Generally, the model is one of the most essential in psychology for investigating a wide range of other individual behaviours. The myriad of individual behaviours may be grouped into five primary categories: agreeableness, neuroticism, extraversion, openness to experience (intelligence), and conscientiousness. Each of these categories has subcategories [5] that are further broken down into subcategories. According to the five personality traits, these characteristics have been utilized to accurately anticipate human behaviour, and the findings have made a substantial contribution to the organization of information as a result of their use. The correctness of the model's many constructs in describing each component has been verified by several research projects, and these constructs are regarded as accurate for a wide variety of presentation formats.

HYPOTHESES DEVELOPMENT

Extraverted entrepreneurs are more likely to view themselves as capable of undertaking challenging tasks, such as establishing a firm or entrepreneurship. This contributes significantly to their positive assessment and attitudes. Extraverted entrepreneurs are more likely to view themselves as capable of undertaking challenging tasks. The traits of self-assurance, vigour, activity, and optimism are related to the pursuit of entrepreneurial goals. In addition, extroverts are vocal and drawn to groups, which may help aspiring business owners looking to develop a network of external advisors. Previous research, i.e., Hartung et al. [6] has shown that the likelihood of an individual being entrepreneurial increases directly to the degree to which they are extraverted. Another study found that extraversion is positive towards the adoption e-teaching model. This study believes that the extraversion trait will lead to IT entrepreneurial intentions.

Those individuals who have the quality of conscientiousness are referred to be “global thinkers”. They have excellent organizational skills, high personal accountability, and strong internal motivation to achieve their goals, which drives them to work hard [7]. Those with a lot of self-control are more likely to make successful and well-informed decisions. In this particular instance, respectful behaviour and good adaptability go hand in hand, as seen by this skill. Because they can think things through and analyse problems before acting or formulating an opinion, they are persuasive, analytical, and laser-focused [8]. Consequently, those who possess this feature have a greater propensity to have a strong sense of civic duty and to take the initiative to deal with problems as they manifest in their day-to-day lives [9]. Those who have this trait also tend to be more outgoing. Additionally, they are interested in preserving their political and religious perspectives [10].

Another characteristic of people with the BFM personality type is agreeableness, which is associated with dependability, morality, altruism, and decency [11]. Those who possess the agreeableness trait are characterized by a lack of selfish motivation and a strong want to be of assistance to other people. This aspect of a person's character indicates a high level of humility and empathy. According to Mammadov [12], people with a high level of agreeableness are more likely than those with a low level of agreeableness to choose employment in the social sector. This is because jobs in the social sector, such as social work and teaching, typically offer opportunities to help other people. According to Lixăndroiu et al. [13], there is a correlation between agreeableness and productive entrepreneurial objectives and chances for social entrepreneurship and sustainability. Agreeableness is also associated with the satisfaction of digital students from e-learning models. Individuals with a high degree of agreeableness demonstrate concern not just for themselves but also for others who aspire to be successful marketers [14, 15].

Anxiety, rage, and a lack of self-control are the three primary traits that define neuroticism [16]. People with this personality feature find it challenging to adapt to new situations because they view everything as potentially hazardous to their health [17, 18]. As a direct consequence of this, individuals are more likely to be susceptible to feelings of worry and stress if they are exposed to new information. In the presence of symptoms of a mental disorder, there is no expectation that a person will have self-confidence or a creative inclination [19]. Those who have a high score

on the neuroticism scale typically struggle with anxiety and are plagued by worries about negative emotions such as sadness, rage, embarrassment, humiliation, and contempt. As a direct consequence of this, they are more sensitive to criticism and easily discouraged by very modest setbacks [20]. The final success or failure of a new firm started by an entrepreneur is almost entirely determined by the activities of that entrepreneur. According to Jamil et al. research [21], individuals who exhibit high levels of neurotic symptoms are not welcome in inventive environments and are forced to rely on the contributions of others [13]. It is also revealed that it negatively influences the digital students' adoption of e-learning models during Covid-19. Based on the above literature, we proposed the following hypotheses:

H1: Extraversion has a significant impact on continuance intention
H2: Agreeableness has a significant impact on continuance intention
H3: Openness has a significant impact on continuance intention
H4: Conscientiousness has a significant effect on continuance intention
H5: Neuroticism negatively affects continuance intention

THE MODERATING ROLE OF CUSTOMER VALUE

Studies in marketing have revealed several distinct categories that can be used to classify consumers' decision-making styles. Two of these categories are a perfectionist and highly quality-conscious orientation (also known as utilitarian) and a recreational and hedonistic orientation (i.e., hedonic). Users gave hedonic value the same weight as utilitarian value as a significant predictor of continuing usage [22]. This is despite numerous investigation lines revealing that utilitarian value does not significantly affect behavioural intention to use an information system (IS). Scholars have pointed out how significant it is that the simultaneous development of a user's enjoyment of mobile services and their assessment of the value of those services is substantial [23]. Empirical evidence supports the premise that Chinese users' stated enjoyment and perceived usefulness of online social networks significantly explained their willingness to continue using these platforms. Empirical data supported this finding. According to a study on the behaviour of web users' consumption, hedonism and utilitarianism are both prevalent online. As a result, the importance of our research emphasizes the significance of taking into consideration both hedonistic and utilitarian aspects when analysing the continuing intent of WeChat users [24]. According to the findings of one study, consumers who placed a higher hedonic value on their experiences were more interested in and prepared to spend money on cutting-edge technical products because of the joy and amusement they gave [25]. The level of satisfaction experienced by its users is a significant contributor to the frequency with which they access their preferred social media sites. In addition, some researchers found that hedonic use positively influences customers' intentions toward their behaviour regarding e-games. Therefore, we proposed the following hypothesis:

H6: Customer Value moderates the relationship between Personality Traits and Continuance Intention

RESEARCH METHODOLOGY

Data were collected from Pakistani students who intend to use SNSs to buy clothing brands. A comprehensive questionnaire was drafted and distributed to university students through personal visits to collect data. The total number of questionnaires allocated for data collection was 585, and 450 were returned for this study. The number of male participants was 59 percent, while the number of female participants was 41 percent. Most of the respondents were between 18 to 30 years old. Most respondents, i.e., 44 percent, were bachelor's students.

Data regarding customer value were collected using the [26] measurement scale. The scale was well-constructed through one error-free development.

Responses were recorded based on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Meanwhile, continuance intention intentions were measured using items [27].

Finally, John & Srivastava [28] items for the Big Five trait taxonomy were adopted to collect data about personality traits. The scale covers all five personality traits: extraversion, agreeableness, conscientiousness, neuroticism, and openness. This scale suits the current study well; it is frequently adopted and highly recommended by numerous researchers [29]. The scale is considered valid, reliable, and among the suitable options for the current research.

RESULTS

Model measurement

Analysis of the model for measuring latent variables illustrates how dimensions of latent variables are respected about their measurement qualities and perceived (observed) items. The outer model (measurement) is assessed by looking at the internal consistency, item reliability, discriminant validity, and convergent reliability of the measurement items [30]. This research model includes Cronbach's alpha. Table 1 shows that 11 items were deleted to increase the reliability of the items, and as can be seen, all items had strong loading and a Cronbach's alpha of more than 0.7 for all constructions. Furthermore, the composite reliability (CR) ranged from 761 to 883, above the allowed limit of 0.70 [31], indicating that all loadings utilized in this study had sufficient indicator reliability [31]. Ultimately, all items had loadings greater than or equal to the 0.6 criteria.

There are two methods for determining converging validity: CR and AVE, as well as scale reliability for each item [32]. The previous researcher said CR and

Table 1

INNER MODEL EVALUATION					
Items		**Item loading**	**A**	**CR**	**AVE**
Conscientiousness	CON1	0.720	0.798	0.855	0.696
	CON2	0.793			
	CON3	0.723			
	CON4	0.796			
	CON5	0.758			
Agreeableness	EGR1	0.801	0.765	0.842	0.520
	EGR2	0.795			
	EGR3	0.791			
	EGR4	0.776			
	EGR5	0.708			
Continuance Intention	CI1	0.782	0.774	0.841	0.570
	CI2	0.745			
	CI3	0.781			
	CI4	0.778			
	CI5	0.797			
Extraversion	EXT1	0.790	0.814	0.860	0.534
	EXT2	0.742			
	EXT3	0.778			
	EXT4	0.795			
	EXT5	0.702			
Neuroticism	NEU1	0.774	0.824	0.878	0.591
	NUR2	0.784			
	NUR3	0.803			
	NUR4	0.828			
	NUR5	0.740			

AVE should be more than 0.7 and 0.5, respectively. The convergent validity of the collected scores was assessed using composite reliability and average variance. As long as the composite reliability is not less than 0.70, it's considered a decent measure of internal consistency, according to researchers [30]. Additionally, average variance extracted scores larger than 0.50 show an appropriate convergent validity since this means a particular construct with greater than 50% variations is clarified by the needed indications [31].

Discriminant validity is determined using the Fornell–Larcker criteria. According to Fornell & Larcker [33], the upper right-hand diagonal values should be more significant than the correlation with other variables, which is the square root of AVE, which indicates the model's discriminant validity [34]. Table 2 shows which variable association with itself has the best discriminant validity.

Using R^2 values for each predicted variable, we could determine the “explanatory power” of the model. It demonstrates the extent to which independent variables depict dependent variables. R^2 is between 0

Table 2

DISCRIMINANT VALIDITY									
Item	**SD**	**Mean**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Agreeableness	0.89	3.92	0.721						
Consciousness	0.77	4.45	0.138	0.704					
Continuance intention	0.92	4.21	0.207	0.278	0.885				
Extraversion	0.72	3.98	0.380	0.283	0.758	0.659			
Neuroticism	0.88	4.11	0.228	0.329	0.516	0.324	0.769		
Openness	0.93	4.53	0.425	0.655	0.453	0.417	0.560	0.657	
Customer value	0.85	4.18	0.370	0.583	0.726	0.612	0.130	0.415	0.713

and 1, with greater values indicating better prediction accuracy. R^2 values range from 0.25 for "weak" to 0.50 for "moderate" to 0.75 for "substantial". R^2>0.5 indicates a suitable model in the main findings. Table 3 shows that all exogenous constructs have R Square values better than 0.5, which indicates a significant predictive accuracy for the model [35].
Table 3 shows the proportion of variation that has been clarified for each variable. For example, 69.9 percent of those surveyed said they had the desire to start their own business. A decent parsimonious model has R^2 values less than 80 percent but more than 50 percent, which is the case in most cases. However, the results demonstrate the model's robustness substantially. Latent variable Q2 values indicate that the model is predictive [36].

Table 3

PREDICTIVE ACCURACY AND RELEVANCE OF THE MODEL		
No.	R-Square (R^2)	(Q^2)
Continuance intention	0.699	0.326

HYPOTHESIS TESTING

The findings show that extraversion has a significant impact on Continuance Intention (β = 0.491, t-value = 18.838, p = 0.000). The findings show that Agreeableness has a significant impact on Continuance Intention (β = 0.049, t-value = 2.714, p = 0.007). The findings show that Openness has a significant impact on Continuance Intention (β = 0.301, t-value = 3.864, p = 0.000). Conscientiousness has a significant impact on Continuance Intention (β = 0.306, t-value = 2.917, p = 0.046).
The findings also show that Neuroticism has a significant impact on Continuance Intention (β = 0.082, t-value = 2.77, p = 0.008). the findings of the current investigation support the proposed hypothesis investigation support H1, H2, H3, H4, and H5 (tables 4 and 5).

DISCUSSION AND CONCLUSION

According to the findings of this study, an individual's personality qualities play a crucial part in shaping their perspectives and intents towards environmentally responsible business practices, and these attributes are essential for the advancement of a social purpose. According to our research findings, extraversion, agreement, and conscientiousness are more likely to influence continuance intention goals than neuroticism and openness. Conscientiousness is also more likely to shape continuance intention ambitions than agreement. To explain everything that was discovered, each finding will be broken down individually here. According to the results, extraversion is the essential personality attribute of all others when formulating long-term objectives. One of the most significant distinctions between sustainable and commercial entrepreneurship is that the former lays a larger emphasis on the positive effects on society and the environment than the latter. Extraverted people tend to be forward thinkers who are more involved and enthusiastic [37] to develop connections with stakeholders that are both trustworthy and mutually beneficial. According to Kerr et al. [10], a marketer's capacity to recognize a societal problem makes the first phase of opportunity identification much simpler. They have a more robust readiness to participate in activities that require social duty and are more receptive to social and cultural components. People with a higher degree of extraversion

Table 4

HYPOTHESIS TESTING				
Hypothesis		**Original sample (O)**	**T-Statistics (|O/STDEV|)**	**P Values**
H1	Extraversion → CI	0.491	18.838	0.000
H2	Agreeableness → CI	0.049	2.714	0.007
H3	Openness → CI	0.301	3.864	0.000
H4	Consciousness → CI	0.306	2.917	0.046
H5	Neuroticism → CI	–0.082	2.777	0.008

Table 5

MODERATION ANALYSIS				
Hypothesis		**Original sample (O)**	**T-Statistics (|O/STDEV|)**	**P Values**
H6	Ext*SL → CI	0.340	4.185	0.000
H6	Agr*SL → CI	0.271	2.703	0.043
H7	Opn*SL → CI	0.428	2.339	0.002
H8	Conc*SL → CI	0.049	2.160	0.031
H10	Nurti*SL → CI	–0.323	3.918	0.000

are more likely to exhibit these characteristics. A recent study conducted by Bucher et al. [38] found that customers' attitudes, social norms, and feelings of self-efficacy are strongly linked to their sense of moral obligation. In turn, this sense of moral obligation influences the customers' desire to engage in online buying.

Practical implications

According to the results of this research, the "Big Five" personality traits of extraversion, conscientiousness, agreeableness, openness to experience, and extroversion have the most significant impact on one's goals. Therefore, the most successful method to promote sustainable business practices is to educate and raise awareness through campaigns focusing on sustainability. Educational programs at places of higher learning need to be improved so that students may develop an appreciation for the idea of a sustainable orientation. We have a responsibility to help youngsters comprehend the roles they will play in the future within a system that includes the economy, society, and the natural world. As a direct result, extraversion (the desire for social inclusion), conscientiousness (the capacity for critical thought), and the willingness to work together on creative endeavours will all rise.

Theoretical implications

This study contributes to the existing body of information on leadership and entrepreneurship by investigating servant leadership's influence on the desire to participate in digital entrepreneurial endeavours. This research is quite exhaustive, beginning with the theoretical underpinnings for applying the personality model to digital entrepreneurship. Specifically, the study focuses on digital entrepreneurs. This example might provide a guide for further research in the future. According to the findings of this research, individual personality qualities have less of an impact on entrepreneurial impulses compared to the influence that servant leadership has on such tendencies. According to Liñán and Chen [39], servant leadership offers a more comprehensive corporate social responsibility and sustainability perspective. This perspective reflects the higher outcomes of economic life and the role that company leadership plays in contributing to fundamental human development. The concept of servant leadership is an effective method for achieving environmentally responsible corporate practices because it focuses on selflessness while centring attention on the greater welfare of society and the environment. Because of this, the findings of our study indicate that the servant leadership style and the sustainable business objectives of a person are compatible, given that they both express a care for the activities carried out by the community.

Limitations and future research directions

The findings of this research have a narrow scope of applicability, notwithstanding their considerable contributions. The fact that the research was carried out in Pakistan makes it highly likely that the findings cannot be extrapolated to any other countries, regardless of whether they are underdeveloped or developing. When deciding whether or not to implement the results, keep in mind the constraints imposed by the scenario. The fact that the data were collected via a cross-sectional technique adds another layer of restriction to the findings; hence, it is recommended that future research use a longitudinal strategy. Additional leadership models, such as ethical leadership, decentralized management, and transformative leadership, could be the subject of research conducted in the future. Because sustainable business is still a relatively young study area, there is a lot of space for additional exploration. It is a distinct possibility that, with some alterations, our technique may also be adapted to work by the conditions and norms of other societies.

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Promoting educational materials in digital fashion

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ABSTRACT – REZUMAT

Promoting educational materials in digital fashion

Specialized fashion software, as a technological instrument for virtual modelling, has a critical role in reducing the length of the design process and time to market, simplifying communication with other departments and improving the quality of the creative process.

This paper presents a survey of the modelling technologies used in Romanian clothing companies as a critical starting point for outlining a new methodology in teaching digital fashion. As part of the larger European survey in the framework of the Erasmus+ Digital Fashion Project, collected data from Romanian textile companies present their current needs for clothing designed with computer technologies and 3D software for virtual prototyping.

According to the sampled companies, most have high (over 42%) and medium (over 33%) levels of digital skills. The most needed occupational profile was the 3D Designer, and the age expectation was between 25–40 years. The ability to design clothing patterns using virtual prototyping was the most selected preference when asked about future development requirements. The survey results are valuable both in establishing the new methodological framework for teaching digital fashion and in identifying the needs for the other project outcomes, such as the textile database, the virtual training platform, and the new curricula.

Keywords: *virtual garment prototyping, technical drawing, garment pattern design, e-learning*

Promovarea de materiale educaționale în domeniul proiectării digitale a articolelor de îmbrăcăminte

Aplicațiile software specializate pentru proiectarea articolelor de îmbrăcăminte, ca instrumente tehnologice pentru modelarea virtuală, au un rol important în reducerea duratei procesului de proiectare și a timpului de lansare a unui produs pe piață, la simplificarea procesului de comunicare între departamente și la creșterea calității procesului creativ.

Acestă lucrare prezintă un studiu legat de tehnologiile de prototipare virtuală utilizate de către companiile producătoare de articole de îmbrăcăminte din România, ce reprezintă un punct de referință pentru elaborarea unei noi metodologii de învățare în domeniul proiectării digitale. Ca parte componentă a unui studiu mai larg pe plan european în cadrul proiectului Erasmus+ DigitalFashion, datele colectate de la companiile textile din România creionează necesitățile actuale privind proiectarea digitală și prototiparea virtuală a produselor de îmbrăcăminte prin tehnologia calculatoarelor și softuri 3D.

În conformitate cu datele primite de la companii, cele mai multe dintre acestea au deprinderi digitale ridicate (peste 42%) și medii (peste 33%). Cel mai necesar profil ocupațional a fost Proiectantul 3D, la categoria de vârstă 25–40 de ani.

Abilitatea de a proiecta tipare de îmbrăcăminte prin utilizarea prototipării virtuale a rezultat ca fiind necesitatea cea mai stringentă, când s-au chestionat companiile legat de necesitățile acestora pentru viitor. Rezultatele studiului sunt relevante atât pentru stabilirea unui nou cadru metodologic pentru învățarea proiectării digitale, cât și pentru alte elemente ale proiectului, precum baza de date pentru materiale textile, platforma de învățare online și noile materiale educaționale.

Cuvinte-cheie*: prototiparea virtuală a îmbrăcămintei, schițe tehnice, proiectarea tiparelor, e-learning*

INTRODUCTION

Interdisciplinary cooperation and development are currently supported by education and research in every domain of activity, with new opportunities for the future. The textile industry is rapidly integrating modern information technologies (IT) used in the design and development of fabrics and garments [1]. This integration is needed, given the unprecedented dynamics of the textile and clothing industry: it is one of the most varied and fast-moving industries, considering the reduction in product manufacturing time and the increased level of product complexity.

As a 21st-century concept of our life, digital fashion design is defined as overlapping the domains of fashion and information and communication technologies (ICT), in which “the virtual creation, production, and representation of one’s identity are possible via computer-generated design” [2]. Digital fashion brings together advanced digital technologies such as 3D software, 3D scanning [3], 3D body scanning [4], pattern design/making [5] and software for the design of

fabrics [6]. Joint efforts have been recently made in the field of virtual prototyping for proposed articles of clothing, which enables a reduction in labour costs by eliminating "first cutting" and "first sewing". Virtual prototyping, often known as VP, is a software-based engineering discipline that involves modelling a clothing system, simulating 2D and 3D visualization and garment behaviour under real-world operating conditions and refining its design through an iterative process [7]. The virtual construction should be identical to the specifications intended for the final product, and as such, VP is increasingly used as a substitute for rapid prototyping. The concept of Fashion 4.0 is related to the digital fitting system and provides general requirements for the development of virtual clothing systems [8].

Various 3D fashion and patternmaking software is already on the market, with commercial names such as *Browzwear, OptiTex, Lectra Modaris, SpeedStep, Gerber,* and *CLO 3D*, which use computer-aided design (CAD) and computer-aided manufacturing (CAM), bringing together design, development, marketing and a comprehensive suite of easy-to-use solutions to obtain designs to market faster than ever before. This software may be used at any step of the production chain by conducting virtual garment simulation and digital fitting, focusing on fabric modelling, and criteria for qualitative assessment of the fit and the appearance of the garment [9]. The strength of 3D software for fashion design is related to reduced time in the design process and time to market, simplified communication with other departments in real-time and improved quality of the creative process. In various situations, the benefits can become much more particular [10].

Another domain of interest for our research study is related to the benefits of e-learning. Even though the COVID-19 pandemic seems to be passing away, distance learning and e-learning instruments remain a convenient and important way to deliver educational materials through digital resources. Some benefits of e-learning include easy access and use of educational materials by the target group, accommodation of everyone's needs and personalization of educational materials, quick updates to the content and quick delivery to the target group, less impact on the environment, reduced costs, and rapid career advancement [11–12].

Online training in the field of textiles and clothing has already seen a series of contributions. The e-learning platform (www.advan2tex.eu/portal/) of the Erasmus+ projects Advan2Tex (2014–2016), TexMatrix (2016–2018), Skills4Smartex (2018–2020) and OptimTex (2020–2022) includes valuable training materials for advanced textile fields, innovation in textile companies, STEM training via multidisciplinary study of smart textiles and software solutions for fabric design [13–16]. The Erasmus+ Texstra (2017–2019) and Digitex (2021–2023) projects produced training materials in the field of e-textiles [17–18]. The T-Crepe (2019–2021) project addresses textile engineering and virtual design solutions [19]. Green textiles, sustainability and eco-friendly textile manufacturing are addressed by the projects Cleantex (2020–2022) and Factive (2020–2022) with open education materials on the web [20–21]. The Costume project (2018–2020) elaborated a new occupational profile of clothing technicians [22].

In light of the importance of software for virtual prototyping for the European textile industry, this paper aims to identify e-learning instruments that address the needs of higher education students and young professionals in this domain of activity. A survey organized at representative clothing companies in five European countries has provided supporting data for this analysis. These activities were conducted within the frame of an Erasmus+ educational project entitled "Digital Fashion – Collaborative Online International Learning in Digital Fashion" (2022–2025), which is funded by the European Commission. The first project results of Erasmus+ Digital Fashion are related to the identification of the industry requirements for education in virtual prototyping to further prepare a database and a digital platform for the training of students and young professionals. This paper presents these educational requirements as identified at the national level in Romania about other contributions in the textile field. The research was accomplished by two Romanian key players in textile education: The National R&D Institute for Textiles & Leather INCDTP – Bucharest and Technical University Iasi, Faculty of Industrial Design and Business Management.

THE SOLUTION: THE ERASMUS+ PROJECT DIGITAL FASHION

The European Erasmus+ project "Digital Fashion" has a consortium of six European partners, who will join within three years of 1 February 2022.

The activities are built around the main project results that fulfil project objectives, schematically described in figure 1. The project website includes up-to-date outcomes http://digitalfashionproject.eu.

The activities within the consortium have been allocated according to previous work experience as well as interest expressed by the partners that will be involved in all planned activities, with different tasks. The project activities are structured in four main project results (PRs) presented in table 1.

The first activity within PR1 was the identification of what partner countries would require for an educational curriculum in virtual prototyping undergirded by new digital educational methodologies. Based on these requirements, a database with fabrics, garments and styles (PR2) was conceived and implemented by the project partners to further support a digital training platform for students (PR3). New curricula using training materials for virtual prototyping (PR4) will be implemented on this training platform, and all educational resources will be validated within a joint staff training event in the last year of the project (2024).

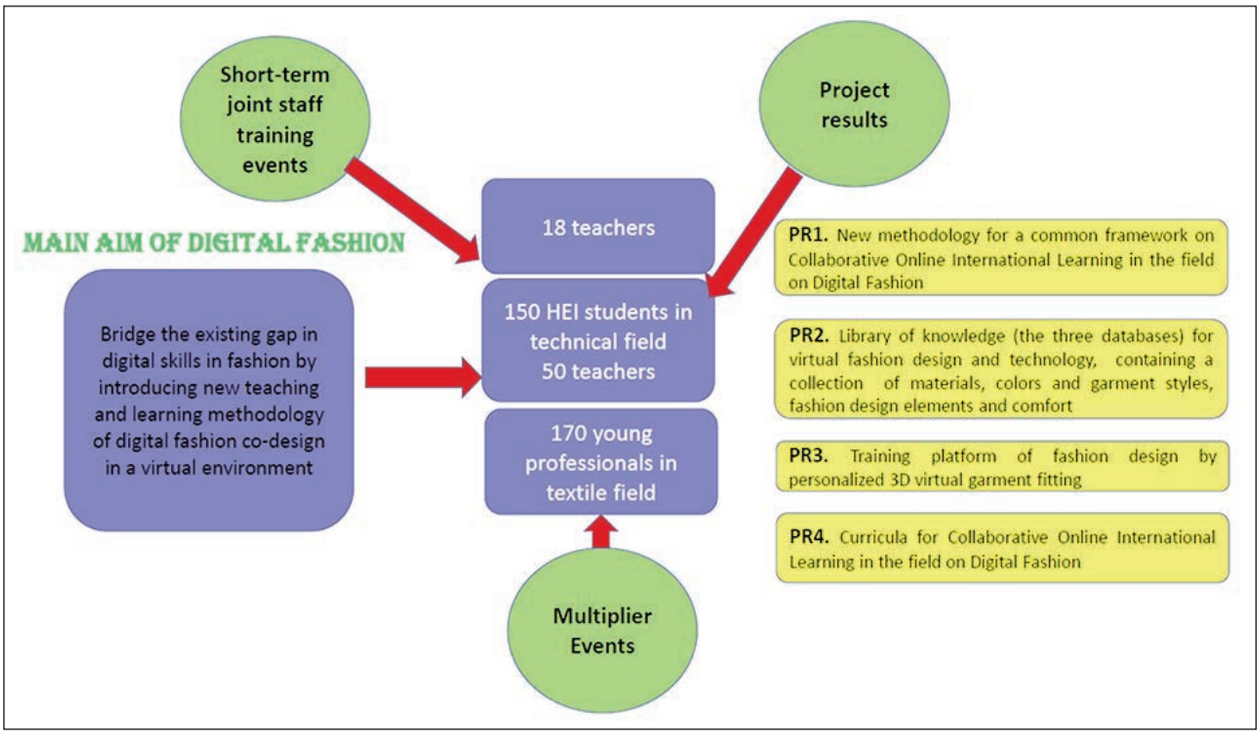

Fig. 1. Main scheme of project results, target groups, and project activities

Table 1

MAIN PROJECT RESULTS (PRS)	
Result	**Status**
PR1. New methodology on a common ground on Collaborative Online International Learning in the field of Digital Fashion.	already finished at this stage of the project (October 2022)
PR2. Library of knowledge for virtual fashion design and technology	already finished at this stage of the project (October 2023)
PR3. Training platform of fashion design by personalized 3D virtual garment fitting	already finished at this stage of the project (October 2023)
PR4. Curricula for Collaborative Online International Learning in the field of Digital Fashion	in progress (up to 2023/2024)

SURVEY OF TEXTILE ENTERPRISES TO IDENTIFY EDUCATIONAL NEEDS IN VIRTUAL PROTOTYPING

In the framework of PR1, the survey provided an up-to-date report on the need for digital skills for clothing and fashion companies and the status of the industrial application of *virtual prototyping* in European countries. Data were collected from 30 fashion and clothing companies in Romania, Belgium, Slovenia, Portugal, and France. This paper includes the outcomes of the report on the Romanian national level. The survey had as key points the assessment of digital fashion skills, applied and needed industrial software and needed occupational profiles. Eleven companies from Romania active in the field of clothing design and development participated in the survey. The companies were encoded C1–C11 to maintain confidentiality. The companies presented different sizes, turnovers and various product portfolios for the internal or external market, as presented in table 2.

Most of the sampled companies produce outerwear and underwear (over 63.6%), followed by those that produce fashion clothing (over 45.4%) and those that produce sportswear (over 27.2%). Approximately three-quarters (72.7%) of the companies produced more than one category of clothing (figure 2).

Only 27.2% of the companies indicated that they had experience in the use of *virtual fashion technology*, while the remaining companies did not (figure 3). Of the total respondents who answered positively, 66.6% had between 1 and 3 years of experience in using *virtual fashion technology*, while 33.3% had less than 1 year of experience. Of those with no experience in using *virtual fashion technology,* more than 62% intended to implement this new digital asset in their companies, while only 12.5% did not express this intention. The remaining 25% preferred not to answer (figure 3).

When asked about clothing software for industrial production, the highest use was for *computer garment*

Table 2

GENERAL DATA OF THE COMPANIES				
Code	**What types of clothing do you produce in your company?**	**How many employees are in your company?**	**Does your company export products?**	**What is your company turnover?**
C1	Knitwear	10 to 49	75% or more	1 M – 10 M Euro
C2	Sportswear	1 to 9	No	<1 M Euro
C3	Underwear, tights	10 to 49	No	<1 M Euro
C4	Fashion clothing, Women's outerwear, Men's outerwear, Sportswear	more than 249	75% or more	10 M – 50 M Euro
C5	Sportswear	1 to 9	No	<1 M Euro
C6	Fashion clothing, Women's outerwear	1 to 9	No	<1 M Euro
C7	Women's outerwear, Men's outerwear, Children's outerwear	more than 249	75% or more	10 M – 50 M Euro
C8	Fashion clothing, Women's outerwear, Men's outerwear, Children's outerwear, Knitwear, Protective work clothing	more than 249	75% or more	10 M – 50 M Euro
C9	Fashion clothing, Women's outerwear	10 to 49	75% or more	10 M – 50 M Euro
C10	Fashion clothing, Women's outerwear	10 to 49	75% or more	<1 M Euro
C11	Protective work clothing	50 to 249	75% or more	10 M – 50 M Euro

Fig. 2. Specific products of the sampled companies

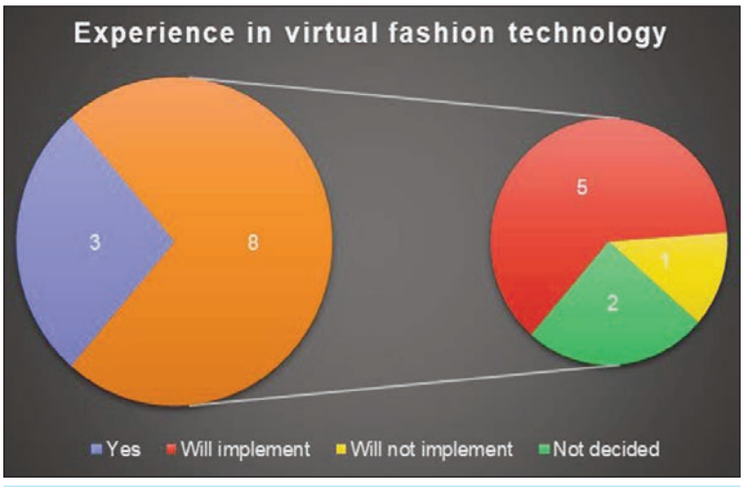

Fig. 3. Experience with virtual fashion technology among the sampled companies

pattern design (approximately 91% of all companies), while over 63.5% mentioned the use of software for *technical drawing*, 54.5% mentioned the use for *fashion drawing/illustration and* 27.2% mentioned the use for *garments virtual prototyping/fitting/visualization* (figure 4).

The most commonly used software for *fashion drawing/illustration* is Adobe Illustrator (45.5% of the sampled companies) and CorelDraw (36.3%), followed by 3D design for Illustrator and Adobe Photoshop (with 18.2% each). The least used software is Corel Photo-Paint, Graph 6+, and CLO 3D. Inkscape and Kaledo software are not used by the sampled companies (figure 5).

CorelDraw is used by most of the sampled companies (54.5%) as specific software for *technical drawings*, followed by Corel Photo-Paint, Adobe Photoshop, and 3D design for Illustrator with 18.2% each. Graph6+ and Lectra Modaris have only 9% each (figure 6).

Gemini is the most commonly used software for *2D garment pattern design*, selected by over 63.5% of the responding companies. The remaining sampled companies use each one (9%) of the following software programs for *computer 2D garment pattern design:* Lectra Modaris, Gerber, Assyst, Clo3D, and Apex3 Shima Seiki (figure 7).

The occupational profile indicated as most necessary is the *3D designer* (approximately 82% of the sampled companies). When we talk about fashion designers,

approximately 45.5% of the respondent companies replied that they need such an occupational profile, while 36.3% replied that they need a *technical designer*. Concerning the occupational profiles of *computer pattern-making designers*, approximately 92% of the sampled companies said that they do not need more specialists. These answers show the need to employ well-prepared clothing specialists for *3D design*, a task envisaged by Digital Fashion (figure 8). Age expectation was between 25–40 years.
The level of innovation varies according to the size and investment capacity of the sampled companies, with medium to high scores for approximately 72% and with 5–10% of revenue devoted to innovation. When asked about interest in 3D virtual prototyping of garments, all sampled companies answered positively. More than 72% of these companies intend to use 3D virtual prototyping instruments or software for developing clothing pattern designs; over 18% intend to use this software for virtual try-ons, and the remaining approximately 10% intend to use these for virtual presentations of collections to customers.

DISCUSSION

E-learning in the field of textiles and clothing is supported by various contributions. Existing educational materials were created to be complementary to the large domain of textile technology and were always a response to a current need [13–22]. The main aspects of e-learning materials in textiles focus on innovation, the contribution to existing curricula and validation using pilot training courses. Some online resources were created based on the structure of the learning materials [23]. Such open educational resources (OERs) highly support the mission of academia, research and industry in Europe by training higher education institution (HEI) and vocational education and training (VET) students and young professionals in textiles. In many cases, training is supported by mobility.
The outcomes of the Digital Fashion project are conceived on the innovative theme of virtual prototyping as a complementary fit with the other contributions in the textile and clothing field. The first question was related to the need to implement virtual prototyping educational materials within the industry. This need was deeply assessed by a survey conducted with 30 companies in Europe, out of which

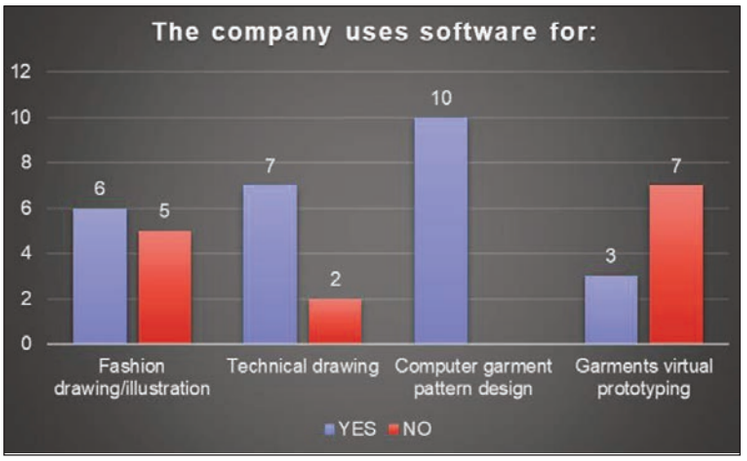

Fig. 4. Types of software used in the sampled companies

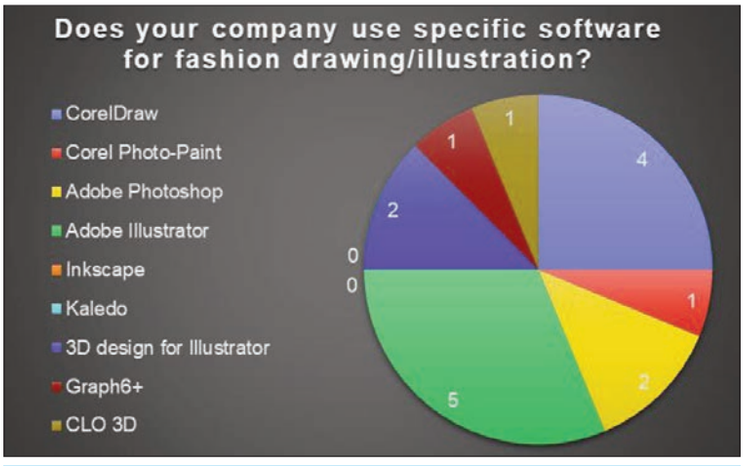

Fig. 5. Types of software used for fashion drawing/illustration in the sampled companies

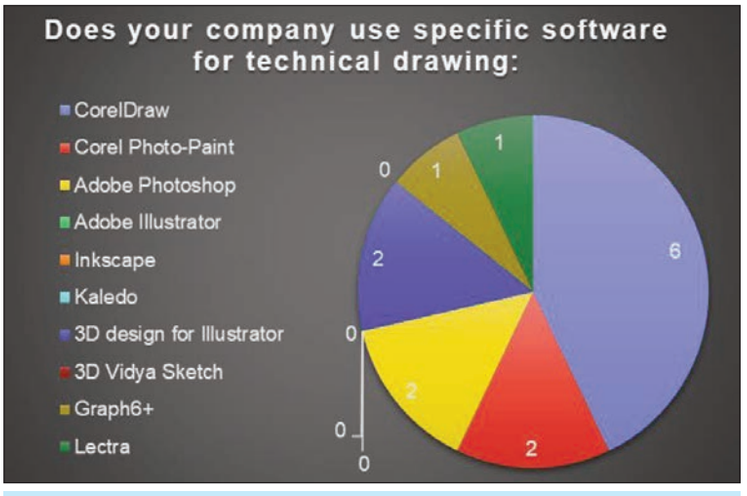

Fig. 6. Types of software used for technical drawing in the sampled companies

11 companies were at the Romanian national level. The outcomes of the survey were underlined in this paper: there is a clear future need for virtual prototyping knowledge and qualified workers for Romanian textile and clothing companies. E-learning instruments will deliver this knowledge in a fast and reliable way for HEI students and young professionals. The complete reports

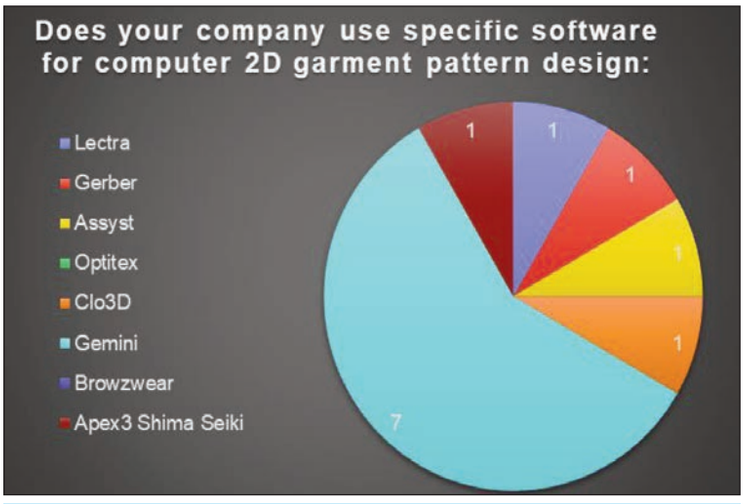

Fig. 7. Types of software used for 2D garment pattern design in the sampled companies

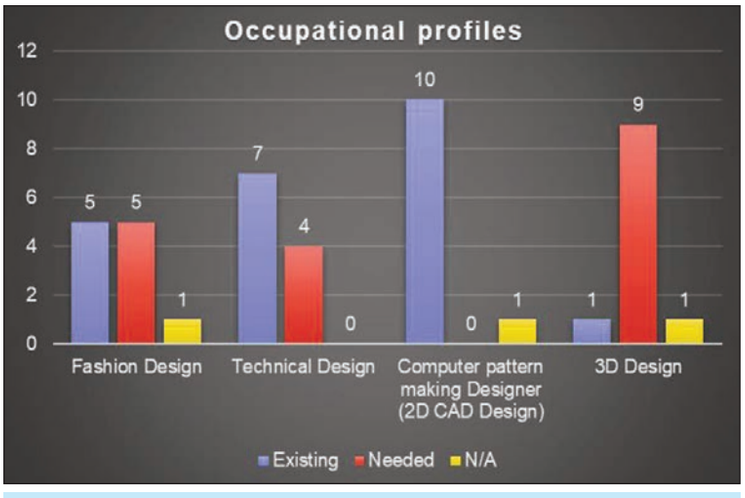

Fig. 8. Needs for the different occupational profiles in the sampled companies

from the survey and updates of project results are available at www.digitalfashionproject.eu.

CONCLUSION

This paper presents the results of a survey regarding the modelling technologies used in Romanian clothing companies as a critical starting point for outlining the need for new methodologies in teaching digital fashion. This first project result of the Erasmus+ Digital Fashion project is meant to support the other project results, namely, the database and the training platform, in understanding the existing needs. According to the survey results, there is a consistent need for virtual prototyping for textile and clothing companies, a fact that may be further exploited by developing an online training platform for digital fashion. As part of an ongoing project, the first project result yields promising support for the other three project results.

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Investigating the relationship between ownership structure, board composition, and company performance: An extensive overview of companies in the textile industry in Iran

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ABSTRACT – REZUMAT

Investigating the relationship between ownership structure, board composition, and company performance: An extensive overview of companies in the textile industry in Iran

The present study examines the relationship between the composition of the board of directors, ownership structure, and company performance in companies that are members of the Iranian capital market. This research has been investigated in a statistical sample of 113 companies from the member companies of Iran's capital market between 2011 and 2021. The results of this research have been analysed by the panel analysis method which we use two internal and external criteria to examine the company's performance. Thus the results show that there is a correlation between the proportion of foreign directors on the board of directors and the concentration of ownership with the company's internal performance criteria. Also, another result of this research is that there is a relationship between the proportion of foreign directors on the board of directors and the concentration of ownership with the external measure of the company's performance. Moreover, this research paper analyses companies in the textile industry in Iran during the sample period.

Key-words: *composition of the board of directors, ownership structure, company performance, member companies of Iran's capital market, Covid-19 pandemic, stock market, concentration of ownership, economic wealth, textile industry*

Analiza relației dintre structura proprietății, componența consiliului de administrație și performanța companiei: o privire de ansamblu extinsă asupra companiilor din industria textilă din Iran

Prezentul studiu examinează relația dintre componența consiliului de administrație, structura proprietății și performanța corporativă în cazul companiilor care sunt listate pe piața de capital din Iran. Acest studiu de cercetare a fost efectuat pe un eșantion statistic de 113 companii selectate dintre companiile membre ale pieței de capital a Iranului, pentru perioada de timp cuprinsă între anii 2011 și 2021. Rezultatele acestei cercetări empirice au fost obținute prin metoda analizei datelor de tip panel, cu ajutorul căreia utilizăm două criterii interne și externe pentru a examina performanța companiei. Astfel, rezultatele arată că există o relație de corelație între ponderea de directori străini în consiliul de administrație și concentrarea proprietății cu criteriile interne de performanță ale companiei. De asemenea, un alt rezultat al acestei cercetări este că există o relație între ponderea de directori străini în consiliul de administrație și concentrarea proprietății cu măsura externă a performanței companiei. Mai mult, această lucrare de cercetare analizează companiile din industria textilă din Iran în perioada eșantionată.

Cuvinte-cheie*: componența consiliului de administrație, structura proprietății, performanța companiei, companiile membre ale pieței de capital din Iran, pandemie Covid-19, piață bursieră, concentrarea proprietății, bunăstare economică, industria textilă*

INTRODUCTION

The outbreak of the novel Coronavirus had essential chains of economic consequences that started in China and affected almost all the economies of the world [1]. The outbreak of the Covid-19 disease has covered almost all the countries of the world (more than 210 countries and regions), and in addition to causing a wave of infections and deaths in most countries of the world, it has involved them in its economic consequences [2, 3]. In recent months, the Covid-19 virus has spread fear and anxiety among people and has severely impacted the world's economic activities [4, 5]. However, the long-term and precise effects of Covid-19 on economic wealth are still unclear [6]. Financial markets have already responded with dramatic moves; However, it makes forecasting the future cash flow of companies a highly complex problem [7]. The Covid-19 pandemic presents an interesting scenario in which an unexpected shock causes sharp changes in the performance of companies compared to managers' expectations [8, 9]. Increasing shareholders' wealth, growing profits, and creating moral duties and social responsibilities can be considered significant goals of companies [10]. One factor that influences the realization of the aforementioned factors is the proper communication of corporate governance (CG) [11]. Over the past few

years, We have seen numerous and extensive problems in the activities of companies operating in America, Europe, Southeast Asia, and other parts of the world [12, 13]. Examining examples of failed companies shows that although the problems created for them are often specific to each company, It can be said that non-compliance with the principles of CG has been the common cause of the failure of these companies [14, 15].

Differences in CG across countries appear to result from changes in corporate organizational structure, particularly ownership patterns and board composition [16, 17]. Regarding the ownership structure, a conventional classification distinguishes between two general categories of corporate ownership structure [18, 19]. The problem of CG that companies face in each of these areas is different, and the board of directors, as the highest governing body of a company, must adapt its composition and performance to solve the prevailing problem of CG in each case [20–22]. In countries where ownership is dispersed, the dominant problem is the agency problem between shareholders and managers due to the separation of ownership and control [23, 24]. In this case, the board of directors should be configured primarily as an instrument of monitoring and control to align the interests of those who manage the company with the interests of those who provide resources and bear risk [25, 26].

On the other hand, in areas where share ownership is highly concentrated, the problem of CG emphasizes the relationship between small and large shareholders [27, 28]. Therefore, the problem of lack of motivation to monitor shareholders' managers is minimized [29, 30]. However, the problems between large and small shareholders are exacerbated. Issues such as the limited legal protection afforded to investors – are generally extendable to continental European countries [31–33].

There are different aspects of ownership concentration through institutional, managerial, government, family, and foreign ownership [34, 35]. Concentrated ownership has an inverse relationship with a company's performance [36]. The principle of cost-effectiveness suggests that large shareholders will be more motivated to manage and maximize company value than small shareholders [37, 38]. Moreover, concentrated ownership motivates large shareholders to secure their interests at the expense of small shareholders [39, 40]. Concentrated ownership gives more power to a small number of shareholders, which reduces board control. This ultimately reduces the company's reliance on CG practices [41, 42]. In concentrated ownership companies, there are shareholders with high ownership and shareholders with low ownership [43]. High-ownership shareholders have power that they can use to exploit low-ownership shareholders in terms of paying them dividends or transferring profits to other units of the company. This creates a foreclosure opportunity for retail shareholders. In this way, the financial market will be damaged [44, 45]. Ownership concentration always affects performance in the same way. Major shareholders try to control management and enforce their policies, usually not to management's liking, further compromising independent decision-making.

However, it negatively affects business performance. In cases where there is diversity in ownership and the concentration of a dominant group is low, managers are independent in their decisions and shareholders are not influenced by a particular group [44, 46].

Considering the different and inhomogeneous ownership structure in other countries, which originates from different social, economic, and legal conditions in these countries, the relationship between the ownership structure, the composition of the board of directors, and the performance of the company in the financial markets of developed and developing countries is different. Is. Despite this, little research has been done on the ownership structure and the board of directors, especially its relationship with the company's performance in Iran. Considering the process of privatization and downsizing of the government, which is one of the economic topics of the day, examining the mechanisms of the ownership structure on the performance of companies in Iran's capital market is of double importance. It may even be that the influence of the board of directors on performance is different in particular business cultures. Therefore, this research aims to empirically test the characteristics of the board of directors as an effective CG tool on the company's performance in Iran's business environment.

A study conducted on Jordanian companies showed that the concentration of ownership has an inverse relationship with the performance of companies [47]. Machek& Kubíček [48], in their research on the relationship between ownership concentration and performance, state that theory suggests that low ownership concentration is associated with agency costs and that highly concentrated ownership structures force controlling owners to pursue private interests. Both situations are likely to be associated with negative effects on firm performance. The findings of the study by Chandani and Ahmed [49] showed that the size of the board of directors, the audit committee, and the director's compensation have a positive correlation with the ROA and ROE of the company's performance in the textile industry, and on the contrary, the financial leverage has a negative correlation with the company's performance in the textile industry. Al-Ahdal et al. [50] investigated the impact of CG on the financial performance of companies listed on the Indian Stock Exchange and the Persian Gulf Cooperation Council. Their results showed that board accountability (BA) and audit committee (AC) have an insignificant effect on firms' performance as measured by ROE and Tobin's Q. Similarly, transparency and disclosure (TD) have an insignificant negative impact on firm performance as measured by Tobin's Q. In addition, country dummy results show that Indian companies perform better than GCC companies in terms of CG practices and financial performance. Research findings of Dube et al. [51] support

the agency cost theory that black ownership is negatively correlated with debt ratio (long-term debt) and performance (Tobin's Q [TQ]), and also, black ownership is positively and significantly correlated with asset returns. Finally, their empirical findings indicated that the ratio of long-term debt to total debt-to-market value was lower for black ownership than total ownership, while TQ was higher for black ownership than total ownership. In their research, Asif et al. [52] investigated the financial status and performance of textile companies in the stock market and offered suggestions to improve the shortcomings. They state that the main source of cash in these companies is cash from abroad, while it was observed that the profitability ratios of these companies have an inverse relationship with their debt ratios. It was also observed that the profitability ratios of textile companies are improved with the improvement of liquidity ratios. The findings of Gulzar et al.'s research [53] show that the size of the board of directors and the performance of textile companies are statistically significant with return on assets and Tobin's Q.

Our research aims to examine the relationship between ownership structure, board composition, and company performance. We rely on a large body of research, and the central issue of this research is whether there is a positive relationship between the proportion of foreign directors on the board of directors and company performance. Is there a positive relationship between board size (BS) and company performance? Therefore, this research aims to investigate the member companies of Iran's capital market by measuring the composition of the board of directors, the ownership structure, and the performance of the company using new methods (internal and external criteria). The remainder of the paper is organized as follows. 2nd section presents an in-depth literature review and discusses the research hypotheses. 3rd section describes the data and methodology. The results and the associated discussions are presented in the 4th section. 5th section presents the Conclusion of the paper.

LITERATURE REVIEW & HYPOTHESIS DEVELOPMENT

External directors on the board with company performance measures

Corporate ownership through stock ownership significantly impacts how companies are controlled [4, 54, 55]. This way, the owners delegated the company's management to the managers, and the stock exchange was formed [56]. Therefore, any problem that arises in the mentioned market is not only an economic problem, but it turns into a social problem in which the general interests of the society will be endangered [57].To solve the mentioned problems, one of the essential concepts raised in the last two decades, the concept It is CG.

Establishing a relationship between agency theory and CG leads to methods that protect the parties' interests [58, 59]. Among the CG mechanisms that establish effective control over the representative relationship and the resulting conflict of interest are the board of directors and its composition [4]. Rufia et al. [60], in their research, analyse the relationship between board characteristics and financial performance in small and medium enterprises (SMEs). They examined a set of variables related to board characteristics such as composition, characteristics, structure, and processes, and firm-specific characteristics such as annual sales growth, asset value, sales turnover, leverage, firm size (employees), firm age, generational changes, They controlled for director and family ownership and showed a significant correlation between specific board characteristics and financial performance.

The separation of ownership from management at the level of companies has caused a conflict of interest between managers and owners [61]. The relationship between managers and owners is referred to as an agency relationship [62, 63]. The agency relationship is defined as a contract in which a person or persons (owners) hire another person (agent) to perform some services and thereby entrust him with authority to make some decisions[4]. This representation and power may train opportunistic managers who invest in projects that serve the interests of the manager instead of the interests of the shareholders [64]. In recent years, CG, which includes a set of relationships between shareholders, managers, auditors, and other stakeholders, has been proposed as a means of reducing the amount of conflict between different shareholders, as well as the separation of ownership from the control of a business entity [31, 65, 66]. The findings of Baldacchino et al. [67] indicate that, while Boards of Director evaluations are carried out in Maltese-listed companies, they lack the necessary formal structures that specify critical evaluation measures. Thus one may infer that those charged with the responsibility of conducting evaluations are not being well determined. By departing from the recommendations of the Maltese CG Code on performance evaluations, Maltese-listed companies have generally opted to resort to an inward and more restricted assessment style, doing away with external or independent parties in the process. Mishra et al. [68]in their research to study the performance of the company, use accounting-based performance measures such as return on assets (ROA) as well as market-based. Performance measures such as Tobin's Q (TQ). Their results show that, on the one hand, BS, board activity, and promoter ownership positively affect firm performance, while on the other hand, board meetings are negatively related to firm performance. However, Poni and Analcinia's [69] studies show that ownership structure is the only essential condition of CG in determining the performance of Syrian companies, as it is positively and significantly loaded on company performance proxies (ROA and EPS) and also, the analysis of ownership structure items shows that foreign ownership is the main source of this positive and significant effect. Nakhai et. al. [70] state that the structure of the board

of directors has a positive effect on the Kitobin ratio and it is not significant for other variables. CG also has a positive effect on the measures of dividends, return on assets, return on equity, and unconditional conservatism, but it is not significant for the Qotubin ratio and stock return. The research findings of Mashayikhi et al. [71] indicate that none of the independence of the board of directors and the leadership structure, as well as their combination, have any relationship with the company's performance. However, the research showed that about 76% of the surveyed companies had a non-combined management role; on average, 60% of their board members were non-executive directors. The results of Shomali and Abumsha [72] show a positive and significant relationship between managerial ownership, macro ownership, and foreign ownership and stock performance and an important negative relationship between foreign ownership and stock performance. In their research, Ammar et al. [73] investigated corporate governance and performance: empirical evidence from the textile sector of Pakistan. Their empirical findings showed a positive relationship between the board of directors and the size and performance of the company. Another result of this research is that the dichotomy between the percentage of non-executive directors and the executive director has a negative relationship with the company's performance.

According to the above contents, as well as the control of the key and important daily decisions of the business unit by professional managers and other regulatory agents, “how to control managers by shareholders” can be considered one of the main goals of CG. CG involves establishing a control system to respect the rights of the shareholders, as well as correctly implementing the resolutions of the shareholders' meetings and preventing possible abuses [73–75]. Therefore, according to the stated contents, the first hypothesis of the research is written as follows:

H1: There is a relationship between the proportion of foreign directors on the board of directors and company performance measures.

Board size (BS) and firm performance measures

Establishing a relationship between agency theory and CG leads to methods that protect the parties' interests [59, 76, 77]. Among the CG mechanisms that establish effective control over the agency relationship and the resulting conflict of interest is its board of directors [78, 79]. The board of directors is an essential element in the organizational structure of any company, which is considered the axis of communication between shareholders and managers, and because of this, it plays an essential role in CG at the company level [80, 81]. Most of the discussions in this area also deal with achieving an optimal composition of the board of directors [82, 83].

The board of directors is key in doing the best possible CG at the level of companies [84, 85]. The board of directors is the most important factor through which shareholders can control executive management [86]. In the subject literature of this topic, various empirical studies have been conducted that have investigated various aspects of the relationship between the board of directors and the company's performance [87–89]. The turning point of these studies is the board of directors' effectiveness in monitoring the process of maximizing the value of shareholders' shares [90, 91]. The size, composition, and number of independent board members of the board of directors have been among the characteristics used and tested in numerous studies as factors to evaluate the company and its performance [92, 93]. Arab Mazarizdi et al. [94] stated in their research that CG variables, including the number of board members, the number of non-executive board members, and the number of significant shareholders, do not affect the return on equity. Still, on the other hand, these variables are effective on Tobin's Q and also, on other hand, the results of this research are that the number of board members has a negative and, of course, insignificant effect on Tobin's Q. Still, the number of non-commissioned members of the board of directors and the number of significant shareholders has a positive but insignificant impact on Tobin's Q. The results of the research of Al-Mashadani et al. [95] revealed that the survey revealed some CG mechanisms such as BS, diversity in gender, ownership structure board independence, and firm performance indicators like return on assets are almost have a positive link with firm performance. The results of Pohesh Yan et al. [96] show that there is a negative correlation between the size of the board of directors and the company's performance. In Hendriani and Robianto's research [97], the company's performance is determined by the market criterion (Tobin's Q). The findings of this research indicate that institutional ownership and board independence only have a positive effect on Tobin's Q value. At the same time, BS can also increase Tobin's Q. This research also shows that BS has a non-linear relationship with investment as a proxy of IOS. At the same time, IOS variables can mediate the effect of BS on firm performance. The results of the research of Nepal and Deb [98]show a significant positive relationship between the size of the board of directors and the performance of textile companies, and another result of this research is that an important inverse relationship between the independence of the board of directors and financial performance has also been shown. This agrees with the policy implications as the inclusion of more board members is likely to increase firm performance. The study of Bashir and Asad [99] showed that BS and board meetings (BM) have a significant effect on textile company performance; in addition, the moderating effect of leverage on the relationship between board meetings and textile performance is significant. Is, but it is insignificant to the performance of the textile company. The results of Ahmed et al.'s research [100] showed that board characteristics do not significantly moderate the relationship between structural capital and business performance in textile industries.

Larmou and Vafeas [101] state that BSis positively correlated with firm value in inter-firm tests, changes in BSare associated with annual stock returns, and larger BSis positively associated with shareholder value. In her research, Guest [102] states the positive relationship between the size of the board of directors and the company's performance. According to the above, the second hypothesis of the research is as follows:

H2: there is a relationship between the size of the board of directors and the company's performance measures.

Ownership concentration with company performance measures

A CG mechanism to prevent managers from deviating from owners' interests is centralized ownership [66]. Large investors have sufficient incentive to obtain information, control managers, and exercise CG over management decisions [103, 104].

Meanwhile, large shareholders can choose their representatives on the board of directors and prevent the management from controlling the board of directors [90, 105]. Large shareholders will be more effective in exercising their voting rights than small investors [106]. Non-separation of ownership and management so that problems of representation are rarely seen, the concentration of ownership in a group with a small number of shareholders (founding members, state ownership), transfer of wealth from minority shareholders to majority shareholders, weak protection of investors in Wamkan's articles of association [107, 108]. Abuse of power by the majority shareholders is one of the characteristics of this type of ownership [109, 110]. Centralized ownership does not rely much on the legal system, and in terms of significant shareholders, it can be classified with bank ownership and control, ownership of financial institutions, family ownership, managers, government companies, and other significant natural and legal entities [111]. Therefore, it can be said that agency problem is one of the main topics in financial research these days. The emergence of agency problems is strongly influenced by the firm's high concentration and low ownership. Firms with a highly concentrated ownership structure will have greater agency conflict compared to firms with a low ownership structure [112]. Companies with high ownership concentration make the shareholders control the majority of the management and even become part of its management [42]. Majority shareholders can expropriate minority shareholders [113, 114]. There are two activities by which the majority shareholders can take advantage of the policy control they have, first through the company's operating policy, including granting high salaries and benefits, bonuses, and large compensation to the majority shareholders. The second way is through contractual policies with other parties [115].

The results of Nashir and Gupta [116] show that concentrated ownership reduces agency costs because block holders actively monitor firm management, thereby leading to better firm performance. Gupta et al. [117] state that the largest shareholder has a positive effect on performance. Horobet et al.'s study [118] deals with the relationship between ownership concentration and company performance in the manufacturing sector in the European Union in an economic environment under the pressure of global financial crises and government debt and states that there is a positive relationship between ownership concentration and company performance for western companies, but for established companies, This is not the case in the East. The research results of Iwazaki and Mizobata [119] indicate the existence of a statistically significant and positive effect of ownership concentration on company performance. The results of Afghan et al. research [120] showed that the final shareholders' voting rights clearly and negatively affect Tobin's q, while the square of voting rights affects it positively. The results of Mashaikh et al. [121] show a significant relationship between ownership concentration and EPS measure at the 95% confidence level. The greater the concentration of ownership, the more control is exerted on managers and improves the performance of companies, and the relationship between the concentration of ownership and efficiency measures depends on the type of ownership and the factors affecting efficiency. According to the stated contents, the third hypothesis of the research is stated as follows:

H3: There is a relationship between ownership concentration and company performance measures.

DATA DESCRIPTION AND METHODOLOGY

Sample selection

To test our proposed hypotheses, we consider listed companies in the Tehran Stock Exchange, markets for which all data were available. Tehran Stock Exchange was established in February 1968 based on the law approved in May 1966. The activity period of the Stock Exchange can be divided into four periods: the first period (1978–1968), the second period (1980–1989), the third period (1989–2005), and the fourth period (from 2005 to now). The stock exchange means an organized and formal capital market in which the buying and selling of company shares government bonds, or private institutions are done under specific rules and regulations. An essential characteristic of the stock exchange is the protection of the law for the owners of savings and stagnant funds and the legal requirements for capital applicants.

In terms of microeconomics, the stock market is a very close example of a perfectly competitive market. Goods are homogeneous in the stock market, and due to the presence of a large number of buyers and sellers in it, as well as the freedom of entry and exit of forces, the set prices are very close to the equilibrium prices. By creating a competitive environment as an economic tool, the stock exchange allows profitable companies to obtain financing through the sale of shares. On the contrary, loss-making companies automatically go out of business. In this way, with

such separation, the market can deal with the optimal allocation of resources.

All data were hand-collected from companies' financial reports provided on the websites: https://www.tsetmc.com, https://www.fipir.com and https://www.codal.ir.

A corporation had to meet five main criteria to be included in the study's final sample: non-financial listed firms, accessibility to a corporation's complete 10-year annual reports from 2011 to 2021 inclusive, and the accessibility to a corporation's corresponding accounting/financial data for the same period. The criteria were set for several reasons. First, banks and insurance companies were excluded because of their specific rules and regulations. Second, the criteria helped meet the requirements for a balanced panel data analysis, whose benefits have been widely articulated.

Table 1 displays the sample selection procedure over the period 2011–2021. Our initial sample comprises 349. All companies admitted to the stock exchange. We exclude 69 Companies under investigation except for investment, holding, and financial intermediation companies, 51 Companies that have been admitted to the stock market after 2011, and 26 firms During the research period, the trading of the company's shares has been stopped or cancelled in the Tehran Stock Exchange for more than six months, 32 firms Their fiscal year does not end on March 19 every year and 58 firms Their information and financial statements from 2011 to 2021 are not fully available, giving us a final sample of 113 firms with a total of 1,130 firm-year observations.

Table 1

RESEARCH SAMPLE SELECTION METHOD

Row	Terms and restrictions	Number
1	All companies admitted to the stock exchange on 2021/03/19	349
2	Companies under investigation except for investment, holding, and financial intermediation companies	(69)
3	Companies that have been admitted to the stock market after 2011	(51)
4	During the research period, trading the company's shares was stopped or cancelled in the Tehran Stock Exchange for more than six months.	(26)
5	Their fiscal year does not end on March 19 every year	(32)
6	Their information and financial statements from 2011 to 2021 are not fully available	(58)

We have a sample of companies based on the industry in table 2.

As can be seen from table 2, the highest percentage is related to Textile Industry with a company in the statistical sample and the lowest percentage is related to iron and steel with one company in the statistical sample.

Table 2

SAMPLE COMPANIES BY INDUSTRY

Industry	Number of observations	
	N	%
Iron and steel	1	0.8
Car and parts	20	17
Cement-lime-gypsum	16	14.1
Chemical	10	8.8
Basic metals	6	5.3
Tile and ceramics	5	4.4
Steel industry	4	3.5
Textile Industry	23	20.3
Rubber and plastic	3	2.6
Equipment and machinery	6	5.5
Pharmaceutical materials	16	14.1
Food – sugar	3	2.6
Total	113	100

Variables of the study and research models

Variables of the study

In this research, our dependent variable is the company performance, which is the same as Ganguli and Guha Deb's [122] research, which divides the company's performance into two internal and external criteria. Our independent variables are the concentration of ownership (P_HOLD), the size of the board of directors (BD_SIZE), and the ratio of foreign directors (BD_IND).

Where

I. **PERFORM** = firm performance is measured by:

a. Tobins Q(TQ) = (*MarketValueofequityshares* + + *bookvalueofpreferencesharesanddebt*) / *BookValueofTotalAssets*

b. Return on Assets: $ROA = \frac{EBITDA}{TotalAssets}$,

where EBIDTA is the earnings before interest, depreciation tax, and amortization and is taken as the measure for accounting profitability.

II. **P_HOLD** = Ownership concentration is the total percentage of shares of shareholders who own more than 5% of the company's shares.

III. **BD_SIZE** = A board of directors with a large number of directors may not be useful for the company and may bring a lot of costs. It seems that a larger board of directors will improve its supervisory function and thus be more effective, but on the other hand, the board of directors may become too large, and subsequently, the quality of communication in it will also be affected by this issue. Similar to the sensitive research of Hassas Yaganeh et al. (2008), the size of the board of directors is considered one of the independent variables. BS is calculated using the natural log of the total number of board members in each fiscal year [123].

IV. **BD_IND** = to measure the variable of the ratio of foreign directors, similar to the research of Dimitropoulos and Asteriou (2010) and Ghaemi and Shahriari (2009), the ratio of the number of non-commissioned directors to the total number of board members has been used to measure it [124, 125].

To avoid model misspecification, this study considers various control variables that may potentially affect the dependent variable. Previous studies [122, 126] control firm size, leverage, and dividend as key variables. The control variables are measured as follows:

V. **FM_SIZE** = Company size measured by sales report.

VI. **LEV** = the company's leverage, which is measured by the ratio of the book value to the book value of total assets at the end of the year.

VII. **DD** = dividend per share of the company i at the end of year t

Based on the literature [122, 127], we hypothesize that there can be an endogeneity between P_HOLD and performance variables, so we use OLS regression to estimate where the lag of promoter stock (P_HOLDLAG) to It is used as an instrumental variable. (iv) in models. Wooldridge (2009) suggests that the criterion for choosing IV is that it should be such a variable that is determined outside of the structural equation, uncorrelated with the error term, and correlated with the explanatory variable [128]. P_HOLDLAG meets all criteria. Typically, OLS estimation is efficient when the explanatory variables are exogenous [129]. We perform the endogeneity test [130] to determine whether OLS is necessary for our models. Based on the test results, we conclude that there is endogeneity between ROA and P_HOLD, but the latter is endogenous when Tobin's Q is used as a performance measure. We also test whether there is an endogeneity of BS and performance, but the result does not indicate the existence of such a relationship.

To understand the impact of various levels of concentration of ownership on market performance, we also carry out a 'piecewise regression'9which is a standard approach adopted in empirical research involving data non-linearity [122, 131, 132]. Here we repeat both models (1) and (2) for various ranges of ownership concentration. This is primarily to explore the possibility of the existence of a 'nonlinear' relationship between ownership concentration and firm performance, as identified in other empirical works detailed elsewhere.

Research models

Morck et al. [133] use a 'piecewise' linear regression model where they demonstrate that Tobin's Q of firms first rises as ownership concentration increases to 5%, then falls for ownership concentration levels between 5 and 25%, and finally rises as ownership concentration continues to increase. Different measures of ownership concentration have been used in previous studies. Morck et al. [133], and Loderer and Martin [134] take shareholding by the directors, while Hermalin and Weisbach [135] consider shares held by the CEO and former CEOs still on the board as a measure of ownership concentration. The models we use are as follows:

$$ROA = \alpha_0 + \alpha_1 P\_HOLD + \alpha_2 BD\_SIZE + \\ + \alpha_3 BD\_IND + \alpha_4 FM\_SIZE + \alpha_5 LEV + \alpha_6 DD \quad (1)$$

$$TobinsQ(TQ) = \alpha_0 + \alpha_1 P\_HOLD + \\ + \alpha_2 BD\_SIZE + \alpha_3 BD\_IND + \alpha_4 FM\_SIZE + \\ + \alpha_5 LEV + \alpha_6 DD + \alpha_7 ROA \quad (2)$$

RESULTS AND DISCUSSION

Descriptive statistics and univariate analysis

The statistical method used in this research is the regression method using combined data. The hypotheses were tested through the results of econometric models and multivariable F regression. Fisher's statistic was used to determine the regression model's significance. To investigate the importance of the coefficient of independent variables in each model, the Student's test was used at the 95% confidence level. The statistical analysis of the data was done with the help of E-Views statistical software. Table 3 summarizes the basic descriptive statistics of the regression variables of the sample companies Listed in the Tehran Stock Exchange from 2011 to 2021.

Table 3

DESCRIPTIVE STATISTICS

Indicators	P_HOLD	ROA	TQ	B_SIZE	BD_IND	FM_SIZE	DCS	DD	LEV
Mean	71.68452	0.144486	2.550432	5.046018	0.629001	14.27493	0.690265	905.3265	0.551909
Median	75.42500	0.113039	1.598851	5.000000	0.600000	14.10366	1.000000	300.0000	0.555155
Maximum	99.00000	0.830346	46.97168	7.000000	1.000000	20.46713	1.000000	64000.00	2.077506
Minimum	0.000000	–0.404462	0.446999	3.000000	0.000000	7.101676	0.000000	0.000000	0.012734
Std. Dev.	19.38404	0.157479	3.060620	0.354157	0.241730	1.599109	0.462589	2809.831	0.227008
Skewness	–1.262494	0.643675	6.440364	3.757125	–0.979258	0.559128	–0.822976	15.92761	0.348110
Kurtosis	4.840726	4.042104	66.06148	30.40341	3.977120	4.506279	1.677289	324.3723	5.409987
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

This part presents some concepts of descriptive statistics of variables including mean, median, minimum and maximum observations, standard deviation, skewness, and kurtosis. The essential central index is the average, which indicates the distribution's balance point and centre of gravity and is a suitable index to show the centrality of the data. The median is another central index that shows the state of society. As the results show, the average ROA variable is equal to 0.1130, which indicates that 11% of the data are less than this value and the rest are more than this value. An important point that can be inferred from the comparison of the mean and median is the issue of the normality of the data. One of the essential parameters of data dispersion is the standard deviation. An important point that can be deduced from a variable's standard deviation is entering the variable in the regression model. As can be seen in the table, the standard deviation of the variables is not zero, so the studied variables can be included in the model. The degree of asymmetry of the abundance curve is called skewness. If the coefficient of skewness is zero, the society is completely symmetrical, and if the coefficient is positive, there is a skew to the right, and if it is negative, there is a skew to the left. For example, the skewness coefficient of the variable TQ is equal to 6.4403, which means that this variable is skewed to the right and deviates from the centre of symmetry by this amount. The amount of elongation of the abundance curve compared to the standard curve is called protrusion with elongation. If the elongation is around zero, it means that the abundance curve is balanced and normal in terms of elongation. If this value is positive, the curve is prominent, and if it is negative, the curve is wide. In this research, all the variables are positive.

Examining the collinearity of explanatory and independent variables

One of the regression assumptions is the absence of collinearity between explanatory variables in the model, so before estimating the model, this problem is controlled by calculating the correlation matrix. The correlation coefficient and significance level are calculated to check the collinearity between the model's explanatory variables. The matrix of correlation coefficients is according to table 4 and table 5.

Tables 4 and 5 show the two-by-two correlation values of all variables except for the dependent variables. The first number is the degree of correlation and its significance probability. Since there is no high correlation between the variables, there is no problem of collinearity between the variables.

Analysis of final models and testing of research hypotheses

The results of the analysis of the first research model, which examines the proportion of foreign managers, the size of the board of directors, and the concentration of ownership with the internal measures of the company's performance in panel A and the results of the analysis of the second model of the research which examines the proportion of external managers, the size of the board of directors and the concentration of ownership It deals with the external measures of the company's performance in the panel B, can be seen in table 6.

The value of the F statistic and the probability value for panel A are 52.36815 and 0.000, respectively, which indicates the significance of the model in general (because the probability value of this statistic is less than 0.05). The most famous statistic of the goodness of fit is the coefficient of determination, whose value is between zero and one. If the coefficient of determination is large and close to one, the model has fitted the data well, while if R2 is low, i.e., close to zero; the model has not provided a good fit

Table 4

CORRELATION MATRIX BETWEEN EXPLANATORY VARIABLES IN THE FIRST MODEL

Correlation Probability	P_HOLD	B_SIZE	BD_IND	FM_SIZE	LEV	DD
P_HOLD	1.000000					

B_SIZE	–0.061626	1.000000				
	0.0383	-----				
BD_IND	–0.067629	–0.016194	1.000000			
	0.0230	0.0866*	-----			
FM_SIZE	0.068641	0.038951	0.029095	1.000000		
	0.0210	0.0007	0.0285	-----		
LEV	0.099871	–0.053921	–0.221078	0.109058	1.000000	
	0.0008	0.0700*	0.0000	0.0002	-----	
DD	0.104831	–0.022333	0.040084	0.157914	–0.162612	1.000000
	0.0004	0.4533***	0.1781***	0.0000	0.0000	-----

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 5

CORRELATION MATRIX BETWEEN EXPLANATORY VARIABLES IN THE SECOND MODEL							
Correlation Probability	**P_HOLD**	**B_SIZE**	**BD_IND**	**FM_SIZE**	**LEV**	**DD**	**ROA**
P_HOLD	1.000000						

B_SIZE	–0.061626	1.000000					
	0.0383	-----					
BD_IND	–0.067629	–0.016194	1.000000				
	0.0230	0.5866***	-----				
FM_SIZE	0.068641	0.038951	0.029095	1.000000			
	0.0210	0.1907***	0.3285	-----			
LEV	0.099871	–0.053921	–0.221078	0.109058	1.000000		
	0.0008	0.0700*	0.0000	0.0002	-----		
DD	0.104831	–0.022333	0.040084	0.157914	–0.162612	1.000000	
	0.0004	0.4533***	0.1781***	0.0000	0.0000	-----	
ROA	0.058331	–0.006312	0.170124	0.141908	–0.675855	0.435746	1.000000
	0.0500	0.8322***	0.0000	0.0000	0.0000	0.0000	-----

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 6

HYPOTHESIS TEST RESULTS								
	Panel A ROA				**Panel B** Tobins Q(TQ)			
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
P_HOLD	0.000144	0.000173	3.832957	0.0051***	–0.023205	0.003553	–6.530617	0.0000***
B_SIZE	–0.007016	0.005970	–1.175111	0.2402	0.054481	0.133811	0.407151	0.6840
BD_IND	–0.029853	0.007426	–4.020086	0.0001***	–0.447636	0.166389	–2.690302	0.0073***
FM_SIZE	0.040652	0.002787	14.58639	0.0000***	1.150745	0.057982	19.84653	0.0000***
LEV	–0.414175	0.016045	–25.81295	0.0000***	0.742965	0.315361	2.355918	0.0187**
DD	1.92E-05	1.48E-06	12.97977	0.0000***	–2.85E-05	1.29E-05	–2.217360	0.0268**
ROA					4.979324	0.435146	11.44289	0.0000***
C	–0.180737	0.060820	–2.971665	0.0030***	–13.30999	1.262870	–10.53948	0.0000***
R-squared	0.859397	Mean dependent var		0.180206	R-squared	0.623922	Mean dependent var	5.093545
Adjusted R-squared	0.842986	S.D. dependent var		0.188450	Adjusted R-squared	0.579611	S.D. dependent var	4.493318
S.E. of regression	0.079294	Sum squared resid		6.356741	S.E. of regression	2.547237	Sum squared resid	6553.299
F-statistic	52.36815	Durbin-Watson stat		1.891161	F-statistic	14.08075	Durbin-Watson stat	1.621049
Prob (F-statistic)	0.000000			Prob (F-statistic)	0.000000			

of the data. In panel A, the coefficient of determination is equal to 0.859397, which shows that the model has provided an acceptable fit. Also, the value of the adjusted coefficient of determination (Adjusted R-squared) is equal to 0.842986, based on which it can be said that this model is more than 84 percent of changes in the dependent variable, i.e., the company's internal performance measures that explain the return on assets (ROA). Watson's camera statistic shows the correlation between the model's residuals and is within the permissible range of 1.5 to 2.5.

As can be seen in panel A, there is a negative relationship between the proportion of external directors on the board of directors and the company's internal performance measures, which according to the research of Mishra et al. [68] and Shomali and Abumsha [72]. The results show that the lower the ratio of foreign managers on the board of directors,

the better the performance of the companies, and conversely, the higher the ratio of foreign managers on the board of directors, the worse the performance of the companies.
As seen in panel A, considering that the p-value for the coefficient of the BS variable is greater than 0.05, it indicates that there is no relationship between the size of the board of directors and the internal measures of the company's performance. Regarding the possible reasons for rejecting this hypothesis, it can be pointed out that according to Article 701 of the Trade Law in Iran, the number of board members of most of the Tehran Stock Exchange companies is five, and a low percentage of these companies is more than five. At the same time, the increase in the number of members also brings with it problems, among which we can mention the increase in costs, problems caused by the coordination of members, and as a result, the quality of communication between them decreases.
Also, according to the results listed in panel A, considering that the p-value for the variable coefficient of ownership concentration is less than 0.05, it indicates that there is a positive relationship between ownership concentration and the company's internal performance measures. Mork et al. [136] state that large shareholders have their interests, which are sometimes not compatible with the interests of other shareholders. Perhaps the reason for the performance of companies with a centralized ownership structure can be found in this factor. As seen, the ownership concentration positively affects the company's performance, and the more the ownership of the largest shareholder increases in the company's ownership structure, the more its performance will increase. Thomson and Peterson [137] also found a positive and significant relationship between concentrated ownership and economic performance as a dependent variable.
In panel B, the value of the F statistic and the probability value for the overall model are 14.08075 and 0.000, respectively, which indicates the significance of the model in general (because the probability value of this statistic is less than 0.05). The most famous goodness-of-fit statistic is the coefficient of determination, which has a value between zero and one. If the coefficient of determination is large and close to one, the model has fitted the data well, while if R2 is low, i.e., close to zero; the model has not provided a good fit of the data. In the above table, the coefficient of determination is equal to 0.623922, which shows that the fitting model is acceptable. The percentage of changes in dependent variables, i.e., external functions, has explained the company's performance (Tobin's Q ratio).
In panel B, we first examine the relationship between the proportion of foreign directors on the board of directors and the external measure of company performance. As can be seen, the p-value for the variable coefficient of the proportion of foreign directors in the board of directors is less than 0.05, which indicates a negative relationship between the proportion of foreign directors in the board of directors and the external measures of the company's performance. That is, with the increase in the proportion of foreign directors on the board of directors, the value of Tobin's Q decreases, and this decrease is statistically significant.
Considering that the p-value for the coefficient of the BS variable is greater than 0.05, it indicates that there is no relationship between the BS and Tobin's Q, which according to the search of Ganguli and Guha [122] and considering that the p-value for the variable coefficient of ownership concentration is less than 0.05, it indicates that there is a negative relationship between ownership concentration and Tobin's Q, which our results are in accordance with the research of Nashir and Gupta [116] and Horobet et al. [118].

CONCLUSION

The conflict of representation between the owners and managers of joint-stock companies has caused the shareholders to think of aligning the interests of the managers with the interests of the owners of the companies, and to achieve this, They found the best solution for examining the ownership structure and composition of the board of directors based on the performance of the companies [138–140]. The use of innovative techniques based on artificial intelligence provides certain advantages to companies, including moving towards optimization of cost advantage [141]. On the other hand, Ehsanifar et al. [142] examined relevant aspects of the Iranian companies from the construction industry based on the influence of certain factors on risk management strategies such as technological, cultural and economic factors considering the impact of uncertainties and lack of information. Moreover, there are research studies which highlight the advantages of using innovative approaches such as Building Information Modeling (BIM) for the sustainable development of companies and the achievement of increased financial performances [143].
The present research has examined the relationship between the composition of the board of directors, the ownership structure, and the company's performance in the companies that are members of the Iranian capital market. It has been investigated using a sample of 113 companies with continuous data between 2011 and 2021. Forming a limited liability company and opening the ownership of the company to the public has a significant impact on the way companies are run. The market system was organized so that the company owners delegate the company's management to the company managers. The separation of ownership from management leads to the generality of the representation problem.
The main purpose of this study is to examine the relationship between the composition of the board of directors, ownership structure, and company performance in companies that are members of the Iranian capital market. The importance of this research is

that the empirical approach to managers, investors, and other decision-makers shows that the different ownership structure of listed companies affects their performance. Economic growth and development, the increase of joint-stock companies, and the separation of management from ownership have turned agency issues into one of the essential concerns of investors today. In agency relations, the owner's goal is to maximize wealth; to achieve this goal, they monitor the agent's work and evaluate his performance. In this case, the question that can be investigated is whether the different ownership structure of companies affects their performance. According to the obtained results, it can be stated that the institutional owners cause the better performance of the companies due to effective supervision and having the necessary resources and expertise to manage the companies. Because in this research, there is a relationship between the concentration of ownership and the internal measures of the company's performance, it is better to have the ownership of the shares of the companies in the hands of several institutional institutions to improve the performance of the companies. The findings of this study for the legislators and investors of the companies that determine the maximum limit of the founders' shares and the minimum presence of foreign directors on the board of directors of companies that are members of the Iranian capital market, which may affect the company's performance in terms of liquidity, representation, and asymmetry of information. To be is of particular importance. This research provides new insight into the relationship between board composition, ownership structure, and performance of Iranian capital member companies. The findings of this study have different applications in developing countries that have a strong legal framework to protect investors.

RESEARCH LIMITATIONS

In all the research that takes place, limitations are an integral part of the research. Because these are the limitations that provide the ground for future and new research, this research is not an exception to this rule and has the following limitations:

1. Due to the multitude of models presented to measure the company's performance, using different models may lead to different results.
2. The items included in the text of the financial statements have not been adjusted due to the effects of inflation. Since the business units were established at different times and acquired their assets at different times, the quality of comparison is high. Some items can affect the results of the research and generalize the results with limitations.

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The effect of marine environment on the mechanical performance of Dacron sailcloth

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ABSTRACT – REZUMAT

The effect of marine environment on the mechanical performance of Dacron sailcloth

The usage of sails is increasing parallel to the sustainability initiatives in marine transportation not only for recreational craft but also for large vessels carrying commercial goods and passengers. In this study, the marine environmental degradation of the sailcloth which significantly shortens the lifetime of these materials was investigated experimentally. Dacrons, which are relatively cheap, easy to form, and resistant to breakdown, but problematic to keeping their original shape while subjected to wind loads, were selected as the sailcloth. The combined effect of seawater exposure, temperature, UV, wet-dry cycle, water repellent treatment on the Dacron's mechanical performance was measured by tensile tests performed for the Dacron specimens with nine different areal weights and in two different fibre directions (warp and weft) and by dynamical mechanical analysis for a representative Dacron sailcloth. The comparative results show that the marine environment has significant degradation effects on the mechanical performance of sailcloths.

Keywords: *Marine environmental degradation, Dacron sailcloth, marine textiles*

Efectul mediului marin asupra performanței mecanice a pânzei de vele Dacron

Utilizarea pânzelor se devoltă în paralel cu inițiativele de sustenabilitate în transportul maritim nu numai pentru ambarcațiunile de agrement, ci și pentru navele mari care transportă mărfuri comerciale și pasageri. În acest studiu, degradarea pânzei de vele din cauza mediului marin, care scurtează semnificativ durata de viață a acestor materiale, a fost investigată experimental. Pânza Dacron, care este relativ ieftină, ușor de manipulat, rezistentă la rupere, dar problematică în a-şi păstra forma originală în timp ce este supusă la sarcina datorată vântului, a fost selectată ca pânză de vele. Efectul combinat al expunerii la apa de mare, temperatură, UV și ciclul umed-uscat, tratamentul hidrofug asupra performanței mecanice a pânzei Dacron a fost măsurat prin teste de rezistenţă la rupere efectuate pentru mostrele de Dacron cu nouă mase diferite și în două direcții diferite (urzeală și bătătură) și prin analiză mecanică dinamică pentru o pânză de vele Dacron reprezentativă. Rezultatele comparative au arătat că mediul marin are efecte de degradare semnificative asupra performanței mecanice a pânzei de vele.

Cuvinte-cheie*: degradarea din cauza mediului marin, pânză de vele Dacron, textile marine*

INTRODUCTION

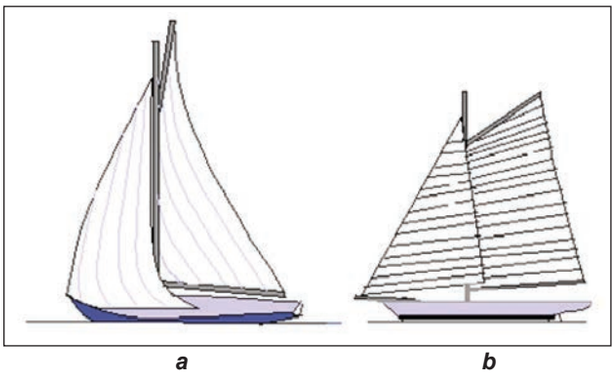
To improve the sustainability of maritime transportation by propelling ships using renewable energy sources, considerable efforts are being put forward on a global scale. Also, strict regulations on minimising GHG emissions have prompted technical experts to explore energy-saving and emission-reduction technologies in ships, including novel hull and superstructure design, new propulsion systems, advanced energy management and operational optimization. Additionally, new energy sources such as the utilization of wind energy and solar energy to replace fossil fuels in ships could be a promising way to help conventional shipping become green [1]. Using sails as a part of wind energy systems is one of the focused alternatives in these efforts. For instance, the ship whose today's biggest triangular sail is the passenger ship "Wind Star" was built in 1986 (figure 1). The ship has a rigging system consisting of 50 m masts, brackets and six polymer lateen sails covering an area of 2000 m^2. By this rigging, the energy efficiency of the ship has been increased by approximately 25% [2].

Fig. 1. Wind Star, a triangular sail-assisted ship (Windstar Cruises 2022)

A plate found in Kuwait that has been dated back to seven thousand years ago depicts a man in a boat using sail [3]. Until the recent two centuries, sails

have been the dominant mode of marine propulsion of ships. The materials used to make sail have evolved from natural materials such as animal leathers, papyrus, cotton and flax to today's composite ones with woven synthetic fibres such as Nylon, Polyester (PET), Pen (Pentex), Kevlar, Technora, Twaron, Spectra, Dyneema, Centran, Zylon (PBO), Vectran, Carbon fibre and coated with polymeric coatings. Synthetic fabrics command sixty per cent of the global fibre market [4].

The most commonly used synthetic fabric due to its cost-effectiveness is aliphatic wowen PET which is known by its commercial name. Dacron is relatively cheap, easy to form, and resistant to breakdown. However, it has the problem of keeping its original shape when subjected to load [5]. It has been produced by several producers since the 1950s. Dacron sailcloth is generally used in the crosscut configuration (figure 2) and has different mechanical performances in warp and weft directions showing a relevant weakness in the bias direction.



a *b*

Fig. 2. Sail designs: *a* – vertical seam construction; *b* – crosscut construction

Sails are improving continuously in terms of their material, weight, fibre orientations and geometry mainly under the competition in sailing races like America's Cup. It is well known that the sail performance is directly related to the materials from which the sails are made and their behaviours under the harsh marine environment. There are mainly two forms of sailcloth: woven, which consists of a weft/warp direction, and laminated. Woven sailcloth is generally made of Dacron with a resin which blocks the yarns and improves the stability of weaving [6].

There is a lack of data on the mechanical performance throughout the material's lifecycle from the sailcloth manufacturers' side. However, a sailing boat designer needs such kind of data while studying the performance of the sail on the mast of a rigging arrangement. The sailcloth is generally assumed to have a smooth surface with almost zero porosity and be seawater resistant, not to mention the effect of ultraviolet (UV) radiation on the behaviour of the fabric [5, 7]. There is almost no experimental research data regarding the sailcloth's environmental behaviour in the literature. Since Dacron is a typical type of sail due to both its popularity in usage and the surface treatment it undergoes during the manufacturing process [8], this study is focused solely on Dacron sailcloth.

Apart from the sailcloth itself, the other elements of sailing boats have also been investigated by a few numbers of researchers. For instance, the failure modes of sailing boats' masts were studied by Boote et al. [9] using the real scale measurements of accelerations induced on the masts of two sailing boats during their trip from South Africa to Italy to predict possible failure of the masts in time. The study of Blicblau et al. [10] that has investigated the effects of the forces acting on the laser boat's sailcloth experimentally may also be worth mentioning in the same sense.

Environmental ageing is an essential element in understanding the long-term performance of a material. For this purpose, accelerated ageing procedures have been applied and then the degradation has been measured in the related properties compared with the initial values measured on unaged reference specimens [11]. In the last two decades, a certain amount of degradation of mechanical properties when polymer-based composite materials are exposed to thermal and moist environments has been reported. It is also concluded that those kinds of materials have exhibited the behaviour that absorbed moisture reduces the desired properties such as its glass transition temperature and also causes plasticization of it, resulting in the reduction of the strength [12]. In the case of UV radiation exposure, the breaking of polymer chains produces free radicals and reduces the molecular weight causing severe degradation of mechanical properties [13, 14].

To improve the performance of sailcloth, manufacturing industries have defined several cloth treatments called 'finishes'. Finishing treatments can be considered as the prevention of environmental degradation related to water vapour. Water-repellent treatment is one of the important finishing processes [15]. The most important chemicals for oil and water repellence for polymer-based textiles are fluorocarbon [FC] compounds which are organic compounds which are perfluorinated carbon chains. The efficiency of FC compounds is due to the structure of the bond between the F and C atoms. Since the length of a C-F bond (1.35 Ä) is shorter than that of a C-C bond (1.54 Ä), the F atom strongly bonds with the C atom and the movement of fluorinated alkyl groups is restricted. This causes fluorocarbon compounds to have low boundary surface tension and liquids can never penetrate the related fabric after water and oil-repellent treatments [16]. According to the study of Namlıgöz et al. [17], water-repellent results obtained from the new chemicals such as polymeric dendrimers containing FC were significantly better than conventional ones. As for the conventional FC compound, a higher concentration of FC was suggested.

To understand the degradation level of mechanical performance, in addition to the tensile test, dynamic mechanical analysis (DMA) at a certain frequency over a range of temperatures has been considered a

useful analytical technique for the characterization of sailcloth as a polymeric material. By DMA, the temperature dependencies of the dynamic moduli, stress relaxation, mechanical loss, and damping phenomena, as well as locating the glass transition of the materials can be concluded [18].
In this study, the combined effect of seawater exposure, temperature, UV, wet-dry cycle and finishing (water-repellent treatment) on the Dacron's mechanical performance which influences the end use of this sailcloth in the marine environment have been investigated experimentally. Tensile tests were performed for the Dacron specimens with nine different areal weights and in two different directions (warp and weft) and dynamical mechanical analysis for a representative Dacron sailcloth is made. The comparative results were given with the conclusions.

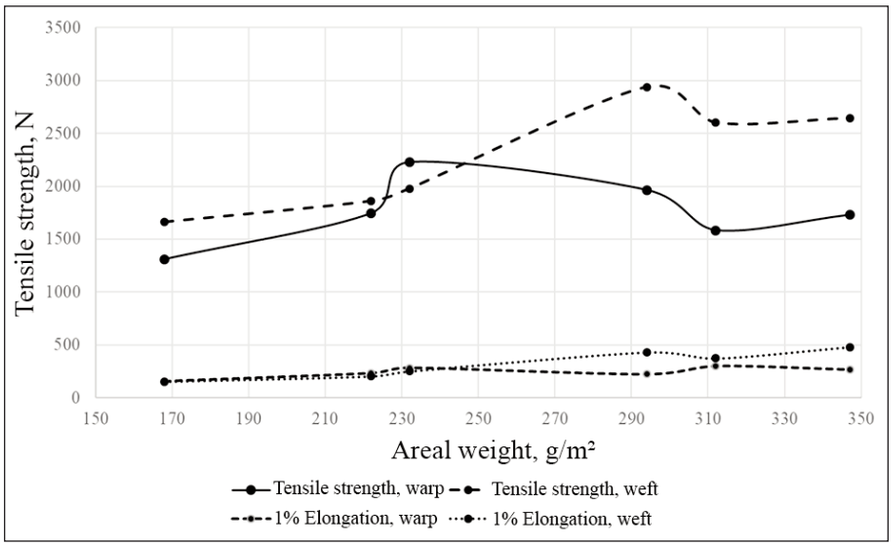


Fig. 3. The tensile strength and 1% elongation force of Dacron sailcloth with different areal weights in two fibre directions (warp and weft)

EXPERIMENTS

Materials

Dacron sailcloth is used in this study due to its common use in sailing practice.
From a face-to-face interview among the sailors of a local sailing club in Izmir (Turkey), their experiences and perceptions on the usage of Dacron sailcloth have been recorded, as can be listed below:

(1) The effective lifetime of this sailcloth in practice can be taken as 5 years-approximately. After this lifespan, the sailcloth loses its mechanical performance significantly by showing large deformations under wind loads when under sailing conditions above 25 knots of wind speed in particular.
(2) UV exposure can severely degrade this sailcloth. In other words, its resistance to UV exposure is relatively poor.
(3) To extend the lifetime of the Dacron sailcloth, it is advisable to take the following considerations into account:
– In the design stage:
• The local sailing conditions such as significant wind directions and speeds, Proper geometry and joining method of sailcloth units
– In storage:
• Maintenance and storage of sailcloth after the sailing season should be properly done, i.e. washing sailcloth with fresh water and storing it in a place at room temperature.
– In usage:
• A small proportion of UV-resistant fabrics as possible should be exposed to direct sunlight (while the rest of the sailcloth is kept in folded condition).
• Extreme loads on the rigging should be avoided.

From a Dacron sailcloth manufacturer's data of tensile tests performed using sailcloth with areal weights from 168 to 347 g/m^2 and thicknesses from 0.215 to 0.4 mm respectively, the relation between the sailcloth's areal weight and their tensile strength is depicted in the figure 3 [19].
The areal weight of Dacron sailcloth samples used in the study and their fibre alignments are given in table 1.

Table 1

DACRON SAILCLOTH USED IN THE STUDY

Type of sailcloth samples	Areal weight (g/m^2) / the direction of fibre alignment
1	177 / Warp
2	177 / Weft
3	225 / Warp
4	225 / Weft
5	186 / Warp
6	186 / Weft
7	187 / Warp
8	187 / Weft
9	262 / Warp
10	262 / Weft
11	280 / Warp
12	280 / Weft
13	310 / Warp
14	310 / Weft
15	350 / Warp
16	350 / Weft
17	415 / Warp
18	415 / Weft

Tests

Ageing

Different ageing processes were applied to test samples by exposing them to natural sunshine for 15 days in August in Izmir (38°24'45"N – 27°8'18"E) by placing them behind glass with the solar angle of 60° from the vertical plane; by applying a wetting-drying process with synthetic seawater (a 5% solution of NaCl) and by exposing them to UV on Prowhite UV Test Box under 35 watt/m^2 light intensity for 72 hours according to ASTM G 154-02 standard. A total of six ageing processes given in table 2 were studied.

Table 2

AGING PROCESSES	
Ageing status	**Ageing applied**
No-ageing	-
Aging-1	– 15 days exposed to natural sunshine
Aging-2	– 15 days exposed to natural sunshine – Wetted 3 times in daytime with 2 hours intervals daily
Aging-3	– UV for 72 hours
Aging-4	– Aging-2 + Aging-3
Aging-5	– Water repellent treatment + Aging-3
Aging-6	– Water repellent treatment + Aging-2 + Aging-3

Water-repellent treatment

For the fluorocarbon finishing of sailcloth, 50 g/l Periguard UFC was added to the padding liquid and the pH of the liquid was adjusted to 5.5 by the addition of acetic acid. After immersing of fabric into the padding liquid, the fabric is squeezed throughout rollers under 1 kg/m^2 pressure. The fabric dried at 170°C in an oven after treatment. Curing was achieved at 170°C for 1 min in the oven.

Tensile tests

Test specimens were cut from a sailcloth. The tensile properties of the samples were determined by the EN ISO 13934-1 strip method at a crosshead speed of 250 mm/min using the Zwick/Roell model Z010. The tensile strength and the modulus were determined from the stress–strain curves. Three samples were tested in each set and the average value was reported with ±1 standard deviation. Tensile properties were determined by the direction of the fibre alignment.

Dynamic Mechanical Analysis (DMA)

DMA was performed on the DMA Analyzer Q8000 at the labs of the University of Ljubljana Faculty of Natural Sciences and Engineering in Slovenia. Temperature-dependent viscoelastic properties of fabrics were measured between 0 and 200°C. During the tests, the frequency was 1 Hz while the amplitude was 10 μ. From the stress and strain amplitude and their phase angle, storage modulus (E'), loss modulus (E'') and mechanical damping parameter (Tan δ = E''/E') were calculated.

RESULTS

Tensile test

The results of the tensile test are given in figure 3 and the degradations on the tensile strength are also summarized in table 3.

From figure 4 and table 3, it was observed that the tensile strength of the sample increased while the square areal weight increased.

Each of the environmental ageing processes had significant degradation effects on the original tensile strength of the sailcloth. These degradations increase while the number of ageing effects/agents increase, i.e. the largest degradations were seen in the combined ageing conditions, in Aging-4 (15 days exposed to natural sunshine + at the same 15 days-period wetted three times in daytime with two-hour intervals + UV for 72 hours), in particular.

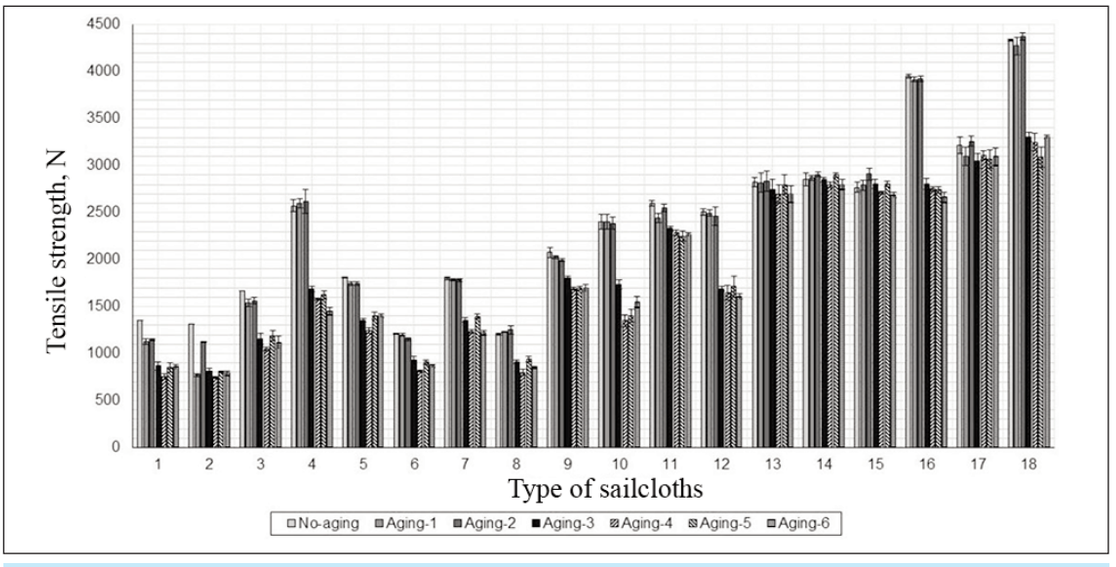


Fig. 4. Results of tensile tests

Table 3

TENSILE STRENGTHS OF THE SAMPLES AND THEIR DEGRADATION

Type of sailcloth samples	Tensile strength (±1 standard deviation), N and *Degradation, %*						
	No-ageing	**Aging-1**	**Aging-2**	**Aging-3**	**Aging-4**	**Aging-5**	**Aging-6**
1	1667 (2.16) ***0***	1542 (40.03) ***8***	1563 (37.38) ***7***	1153 (59.56) ***31***	1046 (18.06) ***39***	1189 (53.15) ***29***	1118 (68.49) ***33***
2	2572 (62.89) ***0***	2599 (48.13) ***–1***	2620 (126.70) ***–1***	1688 (28.33) ***35***	1579 (6.60) ***39***	1625 (43.64) ***37***	1451 (36.04) ***44***
3	1352 (2.94) ***0***	1127 (32.89) ***17***	1152 (9.98) ***15***	870 (45.11) ***36***	755 (2499) ***45***	854 (51.56) ***37***	858 (27.76) ***37***
4	1311 (1.70) ***0***	772 (13.14) ***42***	1124 (7.35) ***15***	816 (24.34) ***38***	743 (10.61) ***44***	804 (13.14) ***39***	793 (23.85) ***40***
5	1810 (4.08) ***0***	1749 (20.27) ***4***	1747 (22.23) ***4***	1354 (21.65) ***26***	1246 (29.22) ***32***	1406 (39.90) ***23***	1402 (20.46) ***23***
6	1215 (4.08) ***0***	1200 (11.22) ***2***	1154 (14.38) ***6***	934 (37.85) ***24***	817 (10.20) ***33***	908 (22.45) ***26***	870 (12.96) ***29***
7	1804 (14.31) ***0***	1787 (8.73) ***1***	1782 (11.90) ***2***	1355 (23.62) ***25***	1236 (21.42) ***32***	1396 (25.92) ***23***	1222 (24.39) ***33***
8	1203 (10.20) ***0***	1229 (4.19) ***–2***	1252 (41.60) ***–4***	910 (20.46) ***25***	798 (32.78) ***34***	944 (31.03) ***22***	851 (10.23) ***30***
9	2077 (55.20) ***0***	2028 (13.57) ***3***	1992 (15.52) ***5***	1807 (18.24) ***13***	1690 (17.20) ***19***	1695 (18.02) ***19***	1699 (37.97) ***18***
10	2402 (76.54) ***0***	2401 (79.63) ***0***	2387 (63.30) ***1***	1735 (49.89) ***28***	1350 (60.49) ***44***	1401 (70.32) ***42***	1549 (60.40) ***36***
11	2595 (29.33) ***0***	2444 (48.32) ***6***	2546 (39.10) ***2***	2332 (25.66) ***10***	2284 (30.23) ***12***	2250 (52.26) ***13***	2266 (21.40) ***13***
12	2507 (31.05) ***0***	2495 (36.81) ***1***	2462 (94.81) ***2***	1691 (23.54) ***33***	1646 (75.53) ***35***	1713 (110.33) ***32***	1607 (28,25) ***36***
13	2825 (52.17) ***0***	2820 (99.68) ***1***	2833 (109.60) ***1***	2373 (105.73) ***29***	(96.33) ***39***	(100.76) ***36***	(87.50) ***33***
14	2856 (66.25) ***0***	2872 (23.10) ***1***	2907 (24.56) ***2***	2000 (25.76) ***30***	1656 (34.75) ***42***	1770 (26.56) ***38***	1890 (55.46) 36
15	3217 (88.43) ***0***	3101 (94.38) ***1***	3261 (57.78) ***1***	2300 (76.89) ***28***	2025 (53.11) ***37***	2190 (99.00) ***32***	2280 (93.56) ***29***
16	4337 (12.92) ***0***	4273 (89.07) ***1***	4375 (39.94) ***1***	3079 (50.26) ***29***	2820 (93.12) ***35***	3035 (105.19) ***30***	2950 (23.79) ***32***
17	2771 (51.49) ***0***	2791 (50.86) ***4***	2910 (61.68) ***1***	2807 (49.83) ***31***	2714 (17.66) ***34***	2803 (27.90) ***30***	2688 (25.47) ***28***
18	3954 (19.07) ***0***	3916 (25.84) ***1***	3922 (30.43) ***1***	2808 (59.76) ***24***	2752 (28.33) ***25***	2743 (34.87) ***29***	2664 (52.43) ***24***

In the samples with water-repellent coating finishes, a 1–2 % difference was found between the values of warp and weft alignments. However, after the subjected to Aging-2, there was a remarkable difference (5–10%) between the values of the samples with water-repellent coating and the values of non-coated samples.

Degradations of fibres in the weft direction in the form of monofilament which are thicker than the fibres in the warp direction were found to be much more serious. Surface finishing (water-repellent treatment) also caused a significant decrease in the initial strength of the samples.

Dynamic Mechanical Analysis (DMA)

Dynamical mechanical properties including glass transition temperature (Tg) were characterized due to the supermolecular structure of the fabric, segment mobility and the energy of intermolecular activity.

From the figure 4, the results can be summarised as below:

- Storage modulus of all the samples was slightly observed to decrease starting from 100°C while for the control sample with no-aging, the decrease was noted to be much more significant (figure 4, *a*).
- For all the samples above 100°C, the decrease was more significant. In the degraded samples, at 150°C, the storage modulus of the material is higher than those of non-aged ones.
- Glass transition temperature decreases from 130°C to 124°C for all the aged samples.
- The loss modulus of the samples that were affected significantly by the environmental agents has a

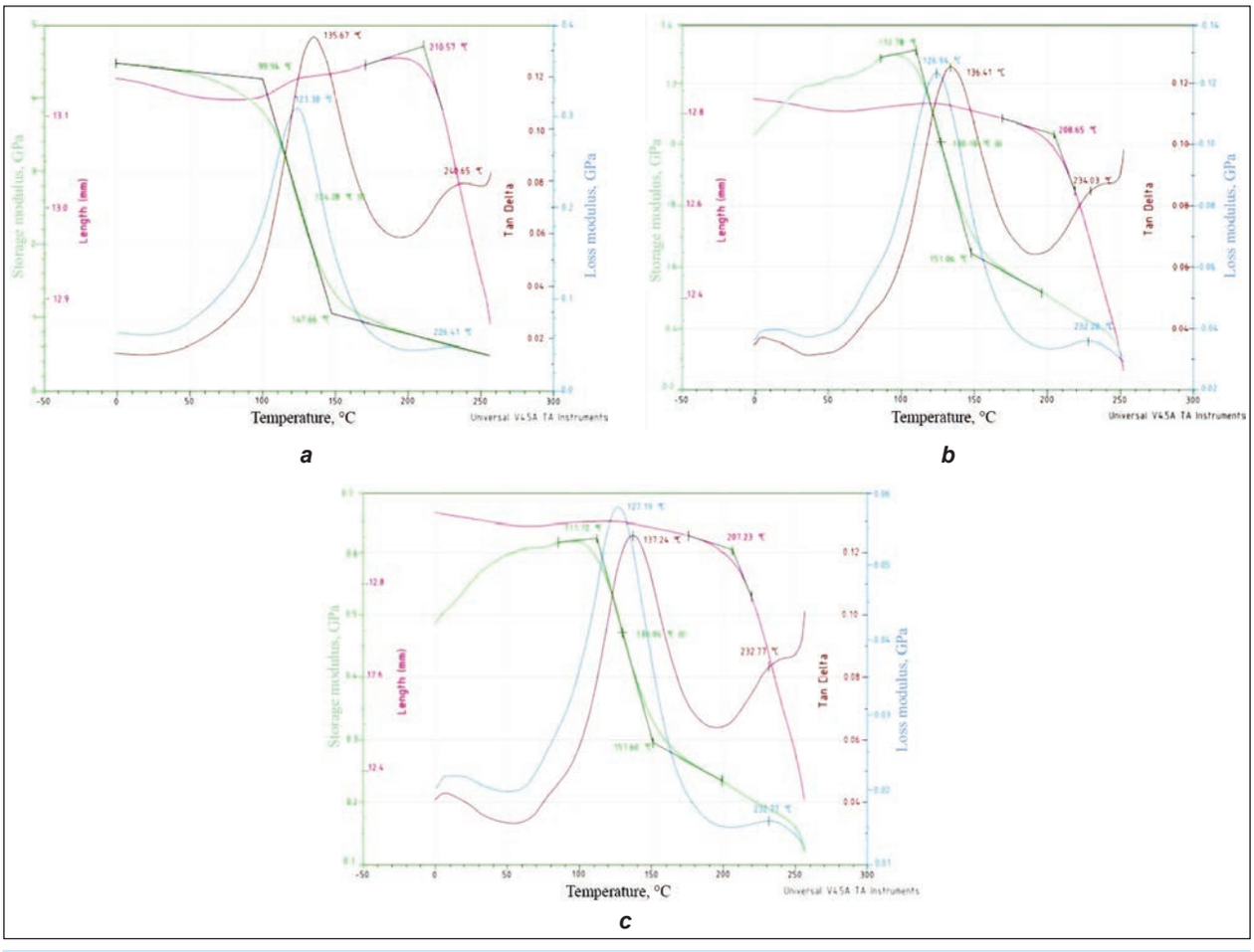


Fig. 5. DMA analysis of sailcloth-16 (350 g/m^2) in weft direction: *a* – no-aging; *b* – Aging-3; *c* – Aging-4

maximum of 127°C as a consequence of a drastic decrease of storage modulus above 100°C.

- Maximum Tan δ of the sailcloth, can be seen at 135, 136 and 137°C. These values can be a consequence of the intense segmental motion of the sailcloth.

CONCLUSIONS

Effects of marine environmental degradations on commonly used sailcloth were shown using experimental data in this study. Choosing the right sailcloth with a proper fibre alignment is crucial not only in the design stage but also in the lifecycle of a sailing boat. The assessment of such degradation effects through the lifetime of these fabrics needs further extensive research.

From this study, which considers the combined effects of seawater and UV exposures, wetting-drying cycles and finishing, it is seen that the marine environment has a significant effect on the mechanical performance of sailcloth and water-repellent treatment is a solution to prevent sailcloth from severe adverse effects of environment. With sail design optimized with this kind of experimental data, end users will not have to turn to economically and environmentally unsustainable options.

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Integrated innovation of smart materials and product design from the perspective of design intelligence

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ABSTRACT – REZUMAT

Integrated innovation of smart materials and product design from the perspective of design intelligence

Materials are the physical basis and carrier of product design, and the selection of materials is an important part of product design. With the continuous exploration of materials, smart materials have become a hot topic in science and technology innovation. This study uses the winning entries of industrial design awards in the past five years as the data source, and 54 design entries using smart materials for innovative design were obtained after retrieval. The current status of the application of smart materials in product design has been summarised through classification analysis, case analysis and comparative analysis. It is found that the integrated innovation of smart materials and product design is still relatively simple. There is still a lot of space for the development of the application of smart materials in product design. In terms of the existing ways of integration of smart materials and product design, this study proposes that the future integration of product design and smart materials can be innovated from biology, ecology, sensing and computing perspectives through methods such as bionic design, sustainable design, personalised design and parametric design. This study provides a reference for the application of smart materials and new creative expressions in future product design and proposes a new trend for the integration of smart materials and product design in the future.

Keywords: *design intelligence, smart material, product design, integrated innovation, design method*

Integrarea inovativă a materialelor inteligente și a designului de produs din perspectiva inteligenței designului

Materialele reprezintă baza fizică și purtătorul designului de produs, iar selecția materialelor este o parte importantă a designului de produs. Odată cu explorarea continuă a materialelor, materialele inteligente au devenit un subiect important în inovația din știință și tehnologie. Acest studiu folosește lucrările câștigătoare ale premiilor de design industrial din ultimii cinci ani ca sursă de date, iar 54 de elemente de design care utilizează materiale inteligente pentru design inovator au fost obținute după recuperarea datelor. Starea actuală a aplicării materialelor inteligente în designul de produs a fost sintetizată prin analiza de clasificare, analiza de caz și analiza comparativă și s-a constatat că integrarea inovativă a materialelor inteligente în designul de produs este încă relativ simplă și există încă destul loc pentru dezvoltarea aplicării materialelor inteligente în designul de produs. În ceea ce privește modalitățile existente de integrare a materialelor inteligente și a designului de produs, acest studiu propune ca viitoarea integrare a designului de produs și a materialelor inteligente să poată fi inovată din perspective biologice, ecologice, de detecție și calcul prin metode precum designul bionic, designul sustenabil, designul personalizat și designul parametric. Acest studiu oferă o referință pentru aplicarea materialelor inteligente și a noilor expresii creative în proiectarea viitorului produs și propune o nouă tendință pentru integrarea materialelor inteligente și a designului de produs în viitor.

Cuvinte-cheie*: inteligență de proiectare, material inteligent, design de produs, integrare inovativă, metodă de proiectare*

INTRODUCTION

The development history of materials is a witness to the history of human civilization. Christian Thomsen, a famous Danish archaeologist, divided the process of human civilization into the Stone Age, the Bronze Age and the Iron Age according to the changes in the materials used for production tools [1]. These epochs named after materials are important symbols of the development of the Times, showing the important position of materials in human history. From the evolution of the Stone Age, Bronze Age and Iron Age, we can see that the exploration and application of materials are constantly deepening, and the emergence and wide application of each generation of materials is greatly changing people's lives and production modes. Research into innovative materials is critical to the long-term success of any technology sector and industry in today's society, it is a fast-growing field full of challenges and opportunities and is considered to be one of the important manifestations of the development of scientific and technological strength [2]. Smart material is not only an important part of contemporary high technology, but also an important pillar and breakthrough in the development of high technology.

As materials evolve, design evolves simultaneously. The journey of design development also happens along with the history of human civilization. Material is the physical basis of product design, material not

only can greatly change the structure and function of the product but also can bring a new leap in product design and form a new design style [3]. The discovery and use of each new material have led to tremendous progress in product design, and designers have constructed the history of human creation with materials [4]. From the Neolithic small-mouthed peaked bottom bottle to the world-renowned Ming-style chairs, the design 1.0 character of the agrarian era was manifested. From the AEG electric kettle of Peter Behrens of the Deutscher Werkbund to the Model T car of Henry Ford, the design 2.0 character of the industrial era was manifested. From the mobile phone invented by Martin Cooper to the global Internet, the design 3.0 character of the knowledge and information era was manifested. But after the beginning of the first year of artificial intelligence, a new challenge began, and design entered a new stage from the information age, ushering in the 4.0 period of the intelligent age of design.

An endless stream of new materials is being continuously applied to daily life and production, people's understanding of materials is deepening, and the relationship between materials and design and production is becoming closer. But with the advent of the intelligent age, the development of design and materials is facing new challenges. The arrival of the intelligent age is prompting people to continuously expand the development space of design and materials. Combined with ubiquitous digital sensors, networks and software-based automation, intelligence is transforming our economy and defining a new era of industrialization. With the opportunities of the times, the emergence of new materials makes it possible to innovate the form, form and function of products, and the changeable characteristics of smart materials also bring changes to the design interaction form [5]. Meanwhile, the demand for product innovation also promotes the emergence of new materials and drives the development of new materials. A mutually beneficial symbiotic relationship is formed between new materials and new designs, which can help designers generate more creativity, it also promotes the application and development of materials.

In the context of the intelligent era, design practice has changed dramatically in terms of design materials, design objects and design processes [6], and intelligence has become a main feature of design. Smart material is a new functional material derived from the background of design intelligence, which is one of the important directions of the development of modern high-tech new materials [7]. The characteristics of smart materials are different from traditional materials, and the methods of material-oriented design mode are also different from the traditional design mode [8]. Therefore, this study will summarize the current situation of the application of smart materials in product design from the perspective of design intelligence, and explore the new path of the future application of smart materials in innovative product design.

RELATED WORKS

The evolution of design materials

Materials are the tangible carriers on which technological progress depends, and they are the physical basis for the development and continuation of human civilization [9]. In the Paleolithic Age, primitive people used natural materials such as stone, bone and wood to make tools, clothes and daily necessities. As processing levels increased, artificial materials such as textiles and ceramics emerged, which were used to produce more household items. From natural materials to processed materials, to the current composite materials, organic polymer materials, etc., all provide different possibilities for product innovation. At the stage of product design using traditional materials, designers pay more attention to the inherent characteristics of materials such as mechanical properties, stability and safety, as well as the functional structure, processing process, mechanical properties, morphological texture and sustainability of materials when selecting materials.

The rapid development of design has placed higher demands on materials, and smart materials have emerged as the times require. Emerging technological platforms require more complex solutions that include versatile, controllable, sustainable and reliable materials [10]. Similar to traditional materials, smart materials can serve as physical carriers for products, and combined with new processing techniques, they can achieve breakthroughs in product modelling. In addition, the versatile characteristics of smart materials can bring new experiences and interactions for users. Smart materials have become innovative self-healing products that can facilitate changes in their physical properties by altering the environmental conditions in which they normally operate [11]. At this stage, the material properties that designers focus on are also changing. For example, designers need to consider how to integrate the functions of smart materials, how to combine smart materials with parametric design and so on. From traditional materials to smart materials, design and materials are evolving together with social development, and design concepts and material properties are changing in the evolution of design and iteration of materials (figure 1).

The basic application of smart materials in design

Smart materials have special physical or chemical properties that can solve technical problems that are difficult to solve with traditional materials and have great application potential in designing next-generation sensing platforms [12]. The smart material industry is the key technology to build the commonality of modern industry and can be widely used in medical care, furniture, architecture, wearable devices, etc. Its downstream industries also include many manufacturing industries, such as energy, computer, transportation, aerospace, electronic information, automobile, etc.

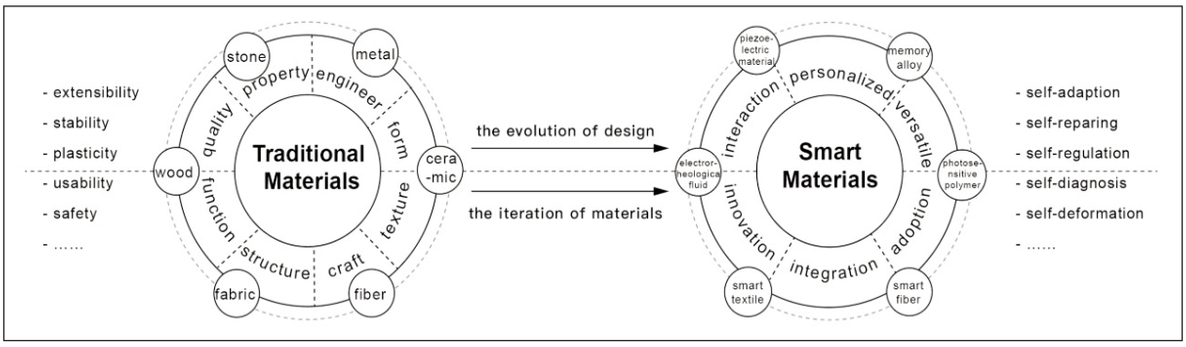


Fig. 1. Change in design concepts from traditional materials to smart materials

There are two main forms of smart materials, one is the material itself has smart functions, which can automatically change its performance with external changes [13]. The other is embedded smart materials, which means that the basic material carrier is embedded with sensing elements to detect the surrounding environment through the sensing elements. Generally speaking, smart materials have both sensing and response properties. Smart materials can detect and recognize external stimuli, such as changes in light, temperature, stress, pH, etc., and then drive themselves to respond to external changes, such as deformation, discolouration, self-adaptation, self-healing, etc. [5]. Table 1 provides a brief introduction from the variability perspective of smart materials.

METHODOLOGY

Research framework

This study obtains design entries from three industrial design awards: DIA, Red-dot, and iF. and explores the application status of smart materials in product design through design entries analysis. There have been many studies using Design Award entries for academic research [14, 15]. Design awards are open participation events that produce a large number of works each year that represent the cutting-edge design for that year and have become benchmarks for good design practice across industries. This study focuses on winners that integrate innovation in smart materials and product design for analysis. The methodological framework is illustrated in figure 2.

Table 1

BRIEF CLASSIFICATION OF SMART MATERIALS

Change	Trigger mechanism	Example of application	Representative material
Shape	(1) Electricity: Electrochromic materials change shape by applying voltage.	Aircraft, automobiles, construction, household goods, etc.	High-strength alloys, carbon fibres, polymeric materials, etc.
	(2) Stress: bend, expand or contract through mechanical stress.		
	(3) Temperature: Deformation is caused and recovered by temperature change.		
Colour	(1) Light: Photochromic materials respond to light.	Defence industry, fashion costume, etc.	Textile, rubber, plastic, coating, fibre and other polymer materials
	(2) Temperature: the colour change of thermochromic materials depends on their temperature.		
	(3) pH: change the colour or transparency by different pH values.		
Temperature	(1) Energy: Adjust the temperature according to the perceived body energy.	Sportswear, medical supplies, etc.	Textile materials, fibre materials
	(2) Humidity: adjust the temperature according to the ambient humidity.		

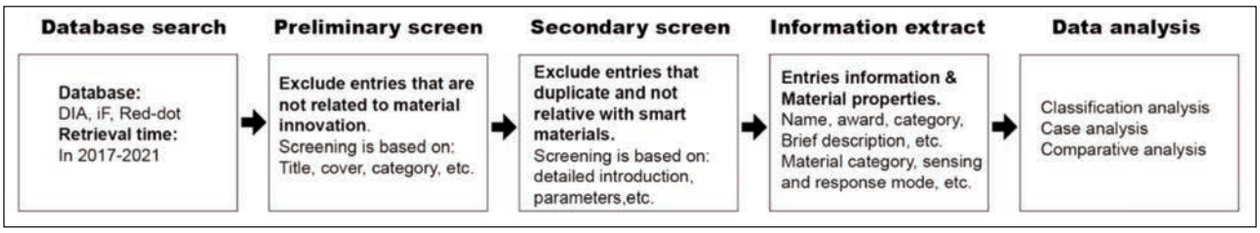


Fig. 2. Research framework

Database search

The reasons for choosing DIA, Red-dot, and iF as the database are as follows:

1) Globalization: These three awards, as internationally influential awards, attract several world's outstanding design and intelligence innovation works to participate every year.

2) Award concept: All three awards are global competitions for cross-border innovation combining art, technology and business, all focusing on intelligence and innovation.

3) Award settings: There are industry groups and concept groups, which can represent different levels of industrial design work.

Since the results of the 2022 awards have not yet been completed, to discuss the application of smart materials within a unified framework, the search period is set from 2017 to 2021, that is, to screen the winners in the past five years.

Entries select

The selection of entries was conducted in two stages. The first stage is the preliminary screening, which is mainly to quickly screen out entries related to material innovation by browsing the title, cover, and category of the entries. The second stage of screening is mainly through browsing the detailed introduction of the entries, including the parameters of the entries, graphic introduction, video introduction, as well as the query of extended materials, etc., to understand in detail the innovation point of each entry and the use of materials, and to exclude entries unrelated with the application of smart materials. Meanwhile, it is necessary to eliminate the duplicate entries between different awards in this round.

Information extraction

Extract information from the selected entries. It mainly contains two types of information, the first type is the basic information, such as the item name, the year of the award, the type of award and a brief description. The second type is the material properties information, such as the category of the material used, and the induction and response mode of the smart material. These two types of information are extracted and coded in Excel.

RESULTS

In this study, we searched a total of three design award winners for the last five years, with a total of 1,650 winning entries for DIA between 2017 and 2021, 10,535 winning entries for iF between 2017 and 2021, and 13,194 winning entries for Red-dot between 2017 and 2021. These entries constitute the original database for this study. After screening according to the established criteria, 19 DIA works, 10 iF works, and 25 Red-dot works were finally eligible, for a total of 54 works.

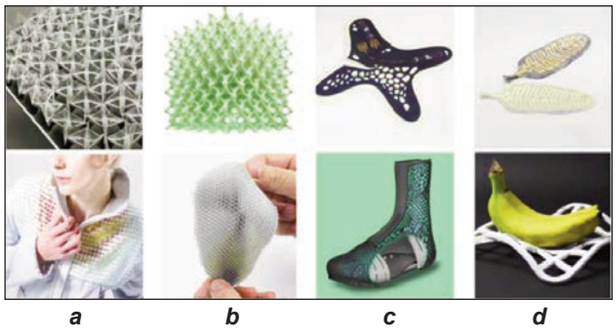
Current status of smart material application in product design

The category information of the 54 winning entries is statistically analysed, and the results are shown in table 2. We can learn the following information: In the award category, the winning entries of smart materials in the industry group are much higher than those in the concept group. In the product type, smart materials are currently the most widely used in the costume category, followed by wearable accessories, etc., and the exploration of the raw materials is also the focus of attention. In the application area, the most winning entries are currently applied in outdoor sports and healthcare, followed by costume design, furniture, fashion, food packaging and others. In terms of material used, most of the traditional materials are still used as carriers for intelligent combination, mainly textile materials, followed by organic plastics, etc. In terms of sensing and response, temperature sensing and regulation are still some of the most used functions, such as smart material deformation and discolouration, etc. Meanwhile, embedded intelligent material is also a hot spot at present.

New trends in the application of smart materials in product design

To find the joint point of integrated innovation between smart materials and product design, all the selected entries were summarized. Then, four representative linkages were summarized through sorting: biology, ecology, sensing and computing. These four types of cases are shown in figure 3.

Biology is a common link between smart materials and product design, the functional principles and behavioural characteristics of biological systems are often applied to product design. The two entries in the group (a) are Dynamic Interactive Bionic Wall and Illusional Fashion In Motion. The Dynamic Interactive Bionic Wall imitates the rhythm of deep-sea creatures when they breathe to achieve the effect of indoor sound regulation. Illusional Fashion In Motion is a clothing design inspired by the colour-changing mechanism of chameleons, which uses nanocrystal properties to adjust the refraction of light and thus change the colour of the skin. Both works use the bionic design method to construct technical systems by imitating the functional principles and behavioural characteristics of biological systems, applying the



a *b* *c* *d*

Fig. 3. Product design case

Table 2

INFORMATION ON THE CATEGORY OF WINNING ENTRIES			
Item	**Detailed information**	**N**	**Proportion**
Categories			
– industry group	Entries that have been on the market for less than 2 years.	39	72.22%
– concept group	Unlisted works that are still conceived and envisioned, are capable of presenting the complete design concept.	15	27.78%
Product type			
– costume	Mainly includes sports warm garments, fashion garments, etc., with temperature regulation function or shape change function.	33	61.11%
– wearable accessory	Mainly including motion detection wearable accessories, and medical aid accessories, such as "electronic band-aids" that can monitor body data.	8	14.81%
– raw material	Mainly refers to innovations based on the material itself, such as changing the structure of a fibre or textile material so that it can adapt to changes in its surroundings and make changes.	6	11.11%
– package	Mainly related to food packaging, capable of detecting food spoilage through food temperature and reflected in colour changes.	3	5.56%
– footwear	Mainly refers to footwear entries, including rapid-forming sole materials, and shoes adapted to the human form.	3	5.56%
– food	For example, foods that can change shape by heating	1	1.85%
Application area			
– outdoor sports	Refers to designs in the field of outdoor sports, mainly outdoor sports equipment.	24	44.44%
– healthcare	Refers to entries for healthcare purposes, including human data monitoring, diagnosis, feedback, etc.	10	18.52%
– costume design	Refers to garment-related designs, such as self-adapting women's underwear for body size.	7	12.96%
– furniture	Refers to entries in the category of household items, such as deformed furniture, wall skins that can regulate sound, etc.	5	9.26%
– fashion	Refers to entries that apply the visible changeable properties of smart materials to the field of fashion, such as colour-changeable clothing.	4	7.41%
– food packaging	Refers to food-related smart material applications that can detect and visually represent the status of food	4	7.41%
Materials used			
– textile	Mainly the combination of textile materials and smart materials, or textile materials as a carrier, and then embedded sensors	38	70.37%
– organic plastics	including pu plastics, 3D/4D printing materials, etc.	10	18.52%
– others	Including flexible composite materials, biomaterials, photosensitive resins, food materials, organic polymers, etc.	6	11.11%
Sensing			
– temperature	Monitor temperature changes in the surrounding environment or human body.	33	61.11%
– sensor	Monitoring of ambient environmental data or human data through embedded sensors.	12	22.22%
– light	Perceiving natural or artificially altered changes in ambient light.	4	7.41%
– others	Including environmental sound perception, human behaviour perception, morphological perception, energization, etc.	5	9.26%
Response			
– temperature regulation	Automatic regulate the temperature according to the conditions to keep the temperature in balance.	28	51.85%
– deformation	Morphological changes occur after induction changes	9	16.67%
– feedback control	Refers to the process where the sensor monitors the data, feeds it back and waits for the next instruction	8	14.81%
– discolouration	Change in colour after induction change	7	12.96%
– others	Includes sound modulation and intelligent display after sensing changes	2	3.70%

superior system performance of nature and society to artificial systems, and improving the form, function, structure and other design elements in product design [16]. Bionic design is an important research method in industrial design and an important means of innovation [17]. However, Smart Materials fabrication and integration into biosystems remain in their infancy [18].

Ecological characteristics are also regarded as an important link between smart materials and product design. Environmental factors in the ecosystem, such as temperature and light, are often used as sensing mechanisms to trigger smart materials to respond. The two entries in group (b) are Futurecraft 4D and Optical Textiles, in which Futurecraft 4D uses light to induce a polymerization reaction of polymeric resin to complete the curing process of the shoe sole material. Optical Textiles uses optical principles to create optical illusion materials with a prismatic refraction effect. Both of these works interact with the ecological environment in their production or use. Smart materials can change their physical and chemical features in response to external stimuli in an adaptive, interactive and self-regulating mode [19], For example, with the help of environmental temperature and humidity changes to achieve the deformation of smart materials or temperature regulation function, there are ecological environmental parameters involved.

Embedded smart materials are also a popular trend in materials development. Many functions of product design need to rely on algorithms to achieve. Smart materials can be designed in different forms, such as watches, wristbands, shirts, shoes and glasses, for health monitoring and to respond to inform users [20]. The two entries in group (c) are Electronic Band-Aid and Adaptiv. The Electronic Band-Aid is a future electronic wearable device, which integrates the network composed of all electronic components required for sensing, signal processing, and wireless communication. Adaptiv contains a series of sensors that measure foot and body movement in real-time and adjust the shoes to accommodate the body's movement. Technological progress is enabling more and more sensors to be used in product design, but how to reduce people's perception of sensors and make them naturally integrated into products still needs to be considered.

Computing is an indispensable element for smart materials and design intelligence. Many functions of product design rely on algorithms to achieve, and the mode of smart materials sense and response can be regulated by algorithms. The two entries in group (d) are ShapeTex and 4D Printed Morphing Furniture. ShapeTex is a programmable morphing fabric that contains a three-layer structure of polymer, metal and fabric that produces a morphing effect when energized. 4D Printed Morphing Furniture can transform the three-dimensional model into a flat model through the calculation of the software, and then obtain the desired shape by soaking in hot water. The use of computer-aided product design has turned out to be a popular area of research, and the use of computerized parametric interventions in smart materials can help us make more creative and controllable works.

DISCUSSION

The selection of materials affects the form, function and use of the product, and is one of the important ways of product innovation. One of the tasks of designers is to try to creatively use the available materials and explore their potential [4]. From the analysis of the current winning entries, the smart materials in the industry group are much higher than those in the concept group, and most of them are limited to sportswear and other wearable products, which shows that the application potential of smart materials can be greatly developed. Designers should base on the functionality and technicality of smart materials to inject more innovative solutions into product design. Besides, from the perspective of the application mode of smart materials, smart materials have become mature in temperature change sensing and response technology. However, the integration of smart materials and product design is still relatively simple, looking at the application of smart materials in product design in the past five years, it is easy to see that the use of smart materials is still in a state of weak intelligence, only with the basic characteristics of smart materials to achieve simple interaction, the future of smart materials still need to make breakthroughs to the level of strong intelligence.

Meanwhile, the integrated innovation of smart materials and product design in the design intelligence era should consider combining with more elements, such as biology, ecology, sensing, and computing. Smart materials and product design naturally develop different design methods when they are combined with external elements (as shown in figure 4). In the combination of smart materials and biology, a bionic design method is formed to map biological properties into product design. In the combination of smart materials and ecology, the sustainable design method is a hot spot, applying environmental ecological characteristics to the use of design materials, which improves the ecological effectiveness of the ecosystem while bringing new ideas to product design, such as temperature regulation or generating response through the temperature sensing characteristics of smart materials to achieve the purpose of recycling resources and improving ecological effectiveness. In the combination of smart materials and sensing, personalized design is the main focus, and embedded smart materials are characterized by the ability to monitor changes in human data and trigger feedback mechanisms, which can promote the emergence of more personalized design. In the combination of smart materials and computing, parametric design emerges as the times require. Parametric design can quickly complete a large number of complex operations, improve the efficiency of manufacturing, and also lay a solid foundation for some popular manufacturing

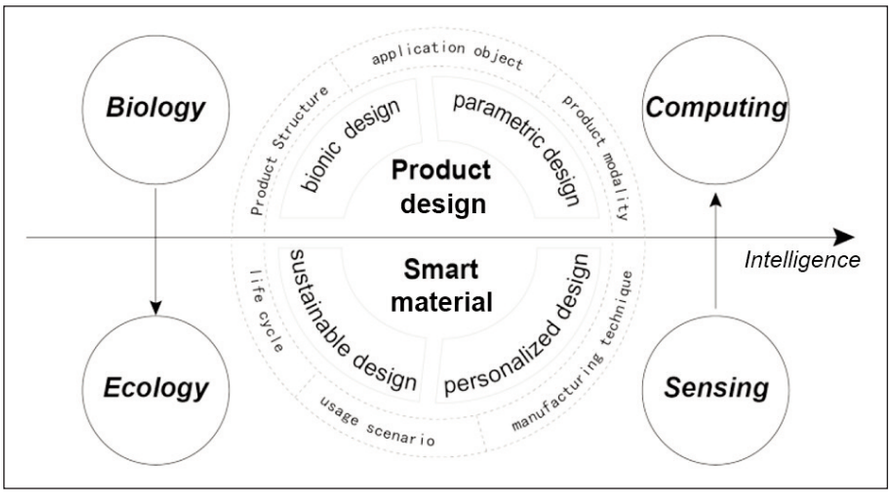


Fig. 4. New trends in the integration of design intelligence and smart materials

methods of smart materials nowadays, such as 4D printing and flexible manufacturing.

CONCLUSION

The integrated innovation of design intelligence and smart materials has brought new methods to product design, as well as more possibilities for product design in terms of function, form and structure, but also brings new problems, needs and challenges. From the perspective of design intelligence, this study analyses the current situation of the application of smart materials in the winning entries of internationally influential industrial design awards and explores new ways for the integration of product design and smart materials. Combining the development of natural science and life science, future product design and smart materials can be integrated and innovated from the perspective of biology and ecology, mapping the laws of nature to product design through the use of smart materials, and promoting the symbiotic relationship between nature and design and materials. Combined with the development of industrial and information technology, sensing and computing will also be an important way to integrate product design and intelligent materials, and sensing technology and computing technology can achieve more creative functions in product design and promote the generation of innovative design solutions.

In the era of intelligent design and manufacturing, the integration and development of product design and intelligent materials are not only a single-chain connection. In the process of integration and innovation of product design and intelligent materials, different dimensions need to be coordinated to establish a new integration relationship, such as The integration of biological science, integration with natural ecology, integration with intelligent sensing, and integration with computing science, etc., reconstructs a new relationship and new network between design and material integration in the intelligent era, and explores the more possible application of intelligent materials in product design.

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Worker saving attitude towards retirement planning: A study on Indian textile industry

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ABSTRACT – REZUMAT

Worker saving attitude towards retirement planning: A study on Indian textile industry

The uneven and polarised nature of development has propagated disparities in access to services. Uncertainties in the textile sector have not only affected the economy but have impacted the livelihood of workers dependent on this sector. Systematic retirement planning could have eased the anxiety and inconvenience to a larger extent but was non-existent to a larger extent. This has further become a critical problem as life expectancy has grown, as have health-care expenditures. The purpose of this research is to look at the link between saving attitudes about "personal financial planning and retirement planning behaviour "of workers from textile factories within the industrial area of Solapur and Pune, in the Indian state of Maharashtra. A total of 200 workers were polled, and the chi-square test with regression analysis tested the data. The study found a strong association between the idea of financial awareness and superannuation planning within textile workers leading to improved savings attitude. Workshops, seminars, and other mediums of communication were revealed as means for improved retirement savings. A sound financial attitude may not be limited to the stages of retirement financial behaviour; a potential issue for future research would be to use the created financial literacy scale to explore its association with a broader spectrum of financial behaviour.

Keywords: *saving attitude, financial literacy, retirement planning, retirement behaviour, textile industry*

Atitudinea de economisire a angajaților față de planificarea pensionării: Un studiu de caz privind industria textilă din India

Natura neuniformă și polarizată a dezvoltării s-a propagat la nivelul unor disparități în accesul la servicii. Incertitudinile din sectorul textil nu au afectat doar economia, ci au avut un impact asupra vieții angajaților dependenți de acest sector. Planificarea sistematică a pensionării ar fi putut atenua anxietatea și neplăcerile într-o măsură mai mare, dar a fost inexistentă într-un procent semnificativ. Aceasta a devenit și mai mult o problemă critică pe măsură ce speranța de viață a crescut, la fel ca și cheltuielile pentru îngrijirea sănătății. Scopul acestei cercetări empirice este de a analiza legătura dintre atitudinile de economisire privind „planificarea financiară personală și comportamentul de planificare a pensionării" ale lucrătorilor din fabricile textile din zona industrială Solapur și Pune, în statul indian Maharashtra. Un total de 200 de lucrători au fost chestionați, iar testul chi-pătrat cu analiză de regresie a analizat datele. Studiul a constatat o asociere puternică între ideea de conștientizare financiară și planificarea pensionării în rândul lucrătorilor din domeniul textil, ceea ce conduce la îmbunătățirea atitudinii de economisire. Workshop-urile, seminariile și alte mijloace de comunicare au fost evidențiate ca mijloace pentru îmbunătățirea economiilor pentru pensii. O atitudine financiară solidă poate să nu se limiteze la etapele comportamentului financiar de pensionare. O problemă potențială pentru cercetările viitoare ar fi utilizarea scalei de alfabetizare financiară creată pentru a explora asocierea acesteia cu un spectru mai larg de comportament financiar.

Cuvinte-cheie*: atitudine de economisire, alfabetizare financiară, planificare a pensionării, comportament de pensionare, industria textilă*

INTRODUCTION

The Indian textile industry dates back several centuries and is among the oldest economies in India. Textiles from India are famous throughout the world for their fine texture, exquisite thread work, elegant colours and delicate hand-crafted embroideries. Depending upon the types of textiles produced these industries have a large variety ranging from hand-spun and hand-woven labour-intensive industries to highly mechanized state-of-art capital-intensive industries. A large variety of textiles are produced within these mills. These may be produced and manufactured from natural fibres such as cotton, jute, silk, and wool, or synthetic fibres such as polyester nylon, viscose, and acrylic.

The textile industry strengthens India's economy immensely comprising up to 2% of the Gross Domestic Product (GDP) and up to 7% of industry output in terms of volume. Four per cent of the global trade in textiles and apparel comes from India. Textiles and handicrafts contributed to 11.4% of the

total exports from India in 2020–21. According to 'The Slowdown Shadow' report by the Credit Rating Information Services of India Limited (CRISIL), India's labour-intensive sectors such as textiles and leather have experienced a major downtrend. CRISIL has attributed this slackening primarily to the slowing down of the advanced global economies, especially the Eurozone and the US. This can be due to the massive dependence of disproportionately large exports from India to these regions of the world. For example, 46.2% and 42.7% of India's leather and footwear exports, respectively are to the European Union (EU). Similarly, the US commands a large share of items made up of textiles and rags. However, in recent times, there has been a rise in input costs and a fall in demand, both in the domestic and foreign markets. The change in these global markets affects India directly in terms of income and employment. Due to a falling demand textile hubs resort to cost-cutting and downsizing, resulting in fear of loss of jobs in one of India's largest employment-generating sectors. This ends up in a disastrous outcome of loss of manpower and, ultimately untimely unemployment which leads to major financial losses in the present, adversely affecting future financial security. In such unprecedented circumstances, the importance of adequate and timely planning of finances cannot be overlooked.

The contemporary issue in the textile industry is focused on the consumers' social viewpoint, neglecting the wide variety of health hazards to which the textile industry workers are exposed. Employees work long hours among corrosive and erosive chemicals; solvents and fixatives such as aromatic hydrocarbons including benzene, toluene, phenol, and aniline; crease-resistance agents such as formaldehyde; flame retardants including the highly toxic organophosphorus and organobromine compounds; and bacterial endotoxins from the raw unprocessed organic fibres. These chemicals are highly mutagenic and carcinogenic and are well-documented causative agents of cancers of the urinary bladder, lung, and colon [1]. Apart from the chemical exposure, the workers in the textile industry have long-term exposure to textile microfibres causing diseases such as byssinosis, asthma, skin allergies and musculoskeletal abnormalities [2]. High levels of noise in textile factories, caused hearing loss in many textile workers, and can also cause sleep disorders, changes in blood pressure, anxiety and other ailments. A study of textile workers in Nagpur, India revealed that 76.6% of them were at risk for hearing loss caused by noise in their work environment. A fire in a Bangladesh garment factory killed 112 workers tragically highlighting the terrible conditions of the industry. Smaller scale issues include cramped work environments with poor lighting and ventilation. Problems in garment factories run the gamut from uncomfortable to extremely unsafe. These health risks result in serious life-threatening diseases which may manifest at any time during life, and pose a potential financial burden, even when a worker is in active employment [3]. Many cancers occur in the ripe years of life or when the employee is nearing retirement and cause immense financial stress on the family.

Keeping these challenges of an ever-changing scenario, the Government of India has laid down schemes and acts for the welfare of the workers associated with these mills. All employees, including those who were workmen within the meaning of the Industrial Disputes Act, of 1947 became employees of the National Textile Corporation on and from the appointed date with rights and privileges as to pension, gratuity and other benefits including retirement age.

Mindful financial management and strategic planning for retirement will ensure a stable post-retirement life for textile workers. The "life-cycle model" explains that the quality of life after retirement is greatly influenced by finances. People with low subjective survival probabilities claim social security early, whereas those with a high survival probability delay, although the effects are small [4]. The cost of living rises with age for textile workers due to occupational health hazards attributed entirely to the environment of the mills. Even though there are better healthcare facilities available due to advancements in technology, resulting in an increased life expectancy, the possibility of availing of these facilities remains delusional to most of these workers due to a poor or complete lack of financial stability and planning. The cascading effect follows through the retirement phase for the majority of these workers. Effective financial literacy can affect retirement planning [5] as financial knowledge underpins financial decision-making [6, 7]. Strong financial awareness among workers increases retirement planning and increases the potential for better investments and savings for the retirement phase of their lives [8].

REVIEW OF LITERATURE

Workers attitude towards retirement and retirement planning

Retirement attitude(s) determines a person's plan for their retired life and their behaviour to achieve it. Textile and garment industries usually flourish due to the high fashion-conscious society in the current world. This implies that textile markets will always remain a considerable source of employment and hence, mandates that the employees have a secure future and focused plans for retirement. Workers with positive attitudes lay down well-thought-out plans for the betterment of life post-retirement [9]. People with appropriate retirement planning are more evolved and have favourable views regarding retirement [10]. A study on garment workers showed that workers with relatively fair literacy on money matters have greater influence over moulding a happy retirement experience when they prepare ahead of time. Fruitful retirement planning involves conscious decision-making towards healthy financial behaviour starting at a young age and continuing through life.

Avoidance of reckless spending significantly helps to build a stronger foundation for achieving admirable and desired financial stability post-retirement.

According to a survey report, retirement planning should begin more than two decades before one is about to attain the age [11]. Previous research on savings attitude distinguishes between "savers" and "non-savers" irrespective of their motivations to save [12]. However, separate investigations on the variations in "motivations and savings intentions" [13], as well as motives linked with savings [14] should be conducted, independent of knowledge and purpose, in experimental activities to estimate real savings. As a result, controlling the strength of intention and the degree of plan implementation for retirement is desired [12].

Financial planning among textile workers for retirement

Adequate planning for the security of financial outcomes can be rightly predicted by sound financial knowledge [15, 16], and clarity of the post-retirement goals [17, 18]. Awareness of the exact demands of post-retirement life can help to create a more organized step-wise approach to retirement after a period of life-long employment. The traditional approach in finance intervention programs that lay down blanket guidelines of "one size fits all" often fails to achieve desired results as they are not customized to address an individual's basic concerns at the grassroots level. These are usually manifested as differences in personality traits, knowledge and attitude towards expenditures, investments, and unique retirement goals [19]. Comprehensive financial planning for retirement must be included for textile workers as this sector has a higher rate of unskilled and semi-skilled workers. Plans and strategies to cover all needs, such as those related to health and nutrition, recreation, hobbies, and tiding over any unforeseeable calamities, in the post-retirement stage of life [20, 21] should be tailored to meet the diverse population found in this sector. The "Capacity-Willingness-Opportunity Model" proposes certain ideas for financial planning and states financial planning should be *'specific'* considering the diversity of the workforce, to design optimal financial activities for retirement, *'broad'* so that it can be multi-dimensional and be used as a blueprint for others, and finally, *'procedural'* to incorporate age and interaction with the other facets [22]. The development of a complete retirement planning process places the wholesome future at the centre of the planning for retirement, and not merely financial analysis.

Superior financial literacy and saving intentions

Financial literacy combines behaviour, attitude, and experience in managing finances most efficiently to ensure a secure, wholesome post-retirement life, without compromising one's passions and hobbies [23–26]. When workers prepare ahead of time, they are more likely to save for a better future. Reason, purpose, and motivation play a significant role in accumulating wealth. Attitude toward saving is the degree to which a worker has a favourable or unfavourable evaluation of the behaviour [27]. In an industry where a change in fashion of garment/textile may suddenly go out of demand, understanding difficulties based on one's thoughts has been overlooked in empirical experiments to predict real savings. This may affect the industry significantly and calls for a quick change to meet the revenue streams. The purpose of this study is to determine how attitudes and financial literacy influence behaviour and motivate workers to plan a retirement life. The study will focus on the consequences and importance of all the factors, such as behaviour, attitude, literacy, and awareness, related to the planning of retirement. The objectives of this study are:

1. Understanding the connection between financial knowledge and planning for retirement among textile workers.
2. Studying the consequences of workers' financial literacy level.
3. Examining the factors for educating workers about saving for retirement.
4. Exploring the connection concerning the planning a worker does for retirement and the knowledge related to it.

Based on the above objectives, the following hypothesis can be proposed:

H1: There is a decisive association between planning and literacy.

H2: There are significant consequences of being financially aware and indulging in planning.

H3: Resources like a workshop, seminars, and correspondence to educate workers about saving for retirement.

H4: There is a mediating role of financial literacy in the retirement planning of employees.

METHOD AND TESTING PROCEDURES

Study design

This study was conducted among skilled workers in an industrial district in Solapur and Pune, Maharashtra. Based on the status of employment and their willingness to participate in the study, respondents were chosen.

Data collection

A well-organised questionnaire was designed. A quantitative approach was used and self-reported questionnaires administered online were used as a method of data collection.

Data analysis

Microsoft Office Excel 365, SPSS version 26 and Smart Pls4 were employed for statistical analyses. Chi-Square test and regression analysis were used to understand the impact of saving attitude for superannuation as well as the mediating the importance of knowledge of personal finance management in post-retirement planning of employees.

RESULT AND DISCUSSION

The reforms implemented in the textile sector have transformed the retirement initiatives into a multi-pillar system with increased individual responsibility to provide privately for retirement. The finance ministry has encouraged employers to take cognizance of the retirement needs of its employees, though one of the oldest, but with constant volatility. The complexity of financial decisions that a worker needs to make has increased to unprecedented levels. Studies on financial capability and money management highlight significant heterogeneity in financial behaviour. The typical household of a textile worker does not manage household finances well [5, 28]. Table 1 shows a summary of statistics for the performance of the respondents on planning and literacy questions. In particular, it examines whether workers understand the connotation of retirement saving and retirement planning.

The chi-square test value for employer-driven retirement planning is 4.261 with only 35% of workers agreeing to the question. The majority of the workers are unaware of the concept of retirement planning and are confused 0.41 on the modalities of the process. However, they agree that financial education will improve the propensity to plan 7.986 in general and motivate them to plan for retirement. Further, the p values 0.045 and 0.01 have substantiated the fact that the result is lesser than the threshold value of less than 0.05, thus justifying hypothesis 1.

Measuring the consequence of literacy is of utmost importance to retirement planning. Superior literacy encourages individuals to involve themselves in making financial decisions that would benefit them and their families in the long run. It also impacts societal development as knowledge is shared among workers of the same locality which also flows down to the company in which they work. Table 2 shows a huge majority of workers 0.32, are not involved in financial decision-making. It is alarming to note that 24% of the workers are not aware of any kind of investment or savings avenues with over 49% of the workers not satisfied with their financial status.

The chi-square test values of the association between the variables are 15.072 and 25.498 with p-values is 0.048 and 0.001 which is less than 0.05 of significant p-value substantiating the importance of being financially aware of the assets and the debt position and also involves oneself into matters of financial importance. Thus, Hypothesis 2 is justified.

Resources play a vital role in educating workers towards literacy as a majority of the textile workers are either unskilled or semi-skilled. Financial institutions should focus on the textile industry workers as there is a huge potential for investments. Further financial institutions' involvement would benefit this sector as they are capable of simplifying and suggesting the right kind of product with earmarked training manuals, focused workshops and seminars on investment and saving plans. Our study has discovered that the majority of the respondents agree that their financial literacy can be improved through regular workshops, seminars and printed brochures.

Table 3 demonstrates the results of regression analysis on the impact of financial resources towards superior knowledge on saving for retirement and the mediating role of financial literacy on retirement planning. The regression analysis has been done considering a 95% confidence level. It implies that coefficient values are significant if the p-values are less than 5% or 0.05. Regression analysis revealed that resources educating workers on savings for retirement significantly influence workers to invest in retirement portfolios.

The analysis further revealed that workers' attitude toward savings for retirement is significantly improved when they are provided with resources that enable them to gain higher subject knowledge which

Table 1

FUNDAMENTAL CONNECTION BETWEEN RETIREMENT PLANNING AND FINANCIAL LITERACY

Crosstab

Count		**Understanding retirement saving and retirement planning**			**Total**
		Yes	No	Confused	
Financial literacy regarding retirement planning	Yes	21	20	20	61
	No	20	21	16	57
	Confused	29	25	28	82
Total		70	66	64	200
Chi-square		**4.261**		**p-value=0.045**	
Source available for financial literacy	Workshop	18	13	19	50
	Seminar	25	15	18	58
	Written correspondence	15	21	15	51
	Other	12	17	12	41
Total		70	66	64	200
Chi-square		**7.986**		**p-value=0.01**	

Table 2

IMPORTANT CONSEQUENCES OF BEING FINANCIALLY AWARE AND INDULGING IN PLANNING					
Crosstab					
Count		**Do you understand the meaning of retirement saving and retirement planning?**			**Total**
		Yes	No	Confused	
Do you enjoy dealing with financial matters?	Always	10	12	16	38
	Usually	13	12	15	40
	Never	16	20	5	41
	Don't know	17	7	15	39
	Refused	14	15	13	42
Total		70	66	64	200
Chi-square		**15.072**		**p-value=0.048**	
Overall, thinking of your assets, debts and savings, how satisfied are you	Extremely satisfied	10	17	4	31
	Satisfied	9	17	13	39
	Neutral	17	9	18	44
	Dissatisfied	15	7	21	43
	Not at all satisfied	19	16	8	43
Total		70	66	64	200
Chi-square		**25.498**		**p-value=0.001**	

Table 3

REGRESSION ANALYSIS								
Hypothesis	**Particulars**	**Coefficients (β)**	**SE**	**T value**	**p-value**	**2.50%**	**97.50%**	**Decision**
H3	Resources on savings for retirement	–0.182	0.063	2.782	0.006	–0.298	–0.051	Supported
H4	Mediation of financial Literacy on retirement planning	0.428	0.073	5.644	0.000	0.267	0.553	Supported
Coefficient	**R2**	0.317						
	Durbin-Watson stat	1.22						

is substantiated by the coefficient value β 0.182, p-value – 0.006. An increase in the availability of resources leads to an 18% increase in their attitude toward saving for retirement. Similarly, a coefficient value β 0.428, p-value – 0.000 means that financial literacy has a significant positive impact on retirement planning. An increase in financial literacy impacts a 43% increase in workers' attitudes to plan for retirement. Further, R2 indicates the explanatory power of the variables that ranged from 0 to 1. A greater value of R2 is considered to be greater than the explanatory power of the variables. R2 = 0.317 explains that 31.7% change in worker attitude towards savings for retirement.

Additionally, multi-collinearity has been verified using VIF (Variable Inflation Factors) values which evaluate the strength of the correlation. In our study, all the VIF values are less than 5. Hence, regression analysis is free from issues with collinearity problems.

Table 5 details the statistical analysis of the worker's financial literacy which would empower them to plan for a better retirement. Workers thought that Q1 borrowing of individuals should be limited to enhance financial efficacy. Further, the statistics proved that regular monitoring of the cash flow and expenses are the principal criteria for managing a better retirement life which can be promoted by retirement planning. This would also allow them to engage in more complex saving and spending strategies [29–31]. The study further highlights the mechanism for delayed

Table 4

CO-LINEARITY TEST	
Particulars	**VIF**
Connection between retirement planning and financial literacy	1.025
Consequence of financial awareness and planning	2.344
Availability of resources on savings for retirement	1.859
Mediation of financial Literacy on retirement planning	1.046

Table 5

STATISTICAL ANALYSIS ON THE FINANCIAL LITERACY OF TEXTILE WORKERS								
Coefficient	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
N- valid	200	200	200	200	200	200	200	200
Mean	2.47	2.29	2.58	2.31	2.25	2.18	2.18	1.82
Std. Error on Mean	0.128	0.122	0.134	0.118	0.115	0.108	0.100	0.101
Median	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00
Mode	2	1	2	2	2	2	2	1
Std. Deviation	1.285	1.227	1.344	1.189	1.152	1.090	1.004	1.014
Variance	1.651	1.507	1.805	1.415	1.328	1.188	1.008	1.028
Skewness	0.54	0.622	0.524	0.872	0.939	0.866	0.903	1.131
Std Err on Skewness	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240
Kurtosis	–0.807	–0.725	–0.946	–0.028	0.221	0.135	0.512	0.653
Std. Error on Kurtosis	0.476	0.476	0.476	0.476	0.476	0.476	0.476	0.476

gratification when it comes to retirement planning with textile workers, not only in the context of financial attitudes and behaviour but also about more discerning activities among textile workers, to the extent to which the workers relate critically to varied stimuli, including materialistic stimuli [32].

CONCLUSION

This study examined the saving attitude of textile workers to better understand their intention towards retirement planning and explored the relationship between a worker's financial literacy and their attitude towards savings for retirement. The results indicate a sizeable connection between “employees' financial literacy” and their plans for life after retirement. Post-retirement planning is significantly influenced by several factors which are directly and indirectly related to their level of financial literacy. These findings strengthen the findings of Ng et al. [33] which revealed people with financial literacy were efficient in personal financial planning. The considerable importance of financial behaviour may be explained by the level of financial literacy. Superior literacy towards planning for finance was found among workers who educated themselves wisely through mediums such as workshops, seminars, correspondence, and other similar opportunities though the number of such workers was insignificant. The majority of workers were confused about saving money [30], and associated savings with temporary allocation of funds for spending on fairs, festivities and celebrations. In addition, the mechanism for delaying gratification is still developing among most semi-skilled and unskilled workers, and they are not always capable of resisting temptation [34, 35] when it comes to spending on frivolous activities. This impediment can be redirected by tutoring their attitude and behaviour toward saving, a tool that may help them cope better with the new media-marketing environment.

Our study also sheds light on the relationship between financial literacy and the planning for superannuation. The importance of prior planning for a secured future cannot be over-emphasized and our study has immensely enriched the existing research and provides a nidus for further conversations and discussions towards the expansion of financial literacy in the textile sector. As far as financial literacy and retirement are concerned a blanket approach may not be feasible. Finances vary greatly among workers of the same background and hence, the decisions need to be thoughtful and customized to the needs. The study will greatly benefit when further studies compare the Indian scenario of financial literacy and retirement planning among the textile industries with the financial behaviour of other countries.

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Strength of cotton dual-core elastane yarn splice

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ABSTRACT – REZUMAT

Strength of cotton dual-core elastane yarn splice

Cotton/elastane yarns are composite yarns composed of a blend of elastane core covered with cotton fibres. An increase in the demand for sports and leisure garments with high comfort and elasticity has led to more significant usage of elastane filaments. New yarn using two elastane filaments with a high ratio of elastane are introduced.
An experimental study was established to define the most appropriate parameters for spliced cotton dual-core elastane yarn strength. The splice strength was enhanced when binding air pressure, joining air duration, and preparation duration were raised. Increased preparation air pressure does not affect the strength of the splice.

Keywords: *splice strength, dual-core elastane yarn, splicing conditions, experimental design*

Rezistența îmbinării firului de elastan cu miez dublu acoperit cu bumbac

Firele din bumbac/elastan sunt fire compozite compuse dintr-un amestec de miez de elastan acoperit cu fibre de bumbac. O creștere a cererii de articole de îmbrăcăminte sport și pentru agrement cu confort și elasticitate ridicate a condus la o utilizare mai intensă a filamentelor de elastan. Recent, au fost introduse fire noi care utilizează două filamente de elastan cu un raport ridicat de elastan.
A fost stabilit un studiu experimental pentru a defini cei mai adecvați parametri pentru rezistența firului din elastan cu miez dublu îmbinat cu bumbac. Rezistența îmbinării a fost îmbunătățită atunci când presiunea aerului de legare, durata aplicării aerului de legare și durata pregătirii au crescut. Creșterea presiunii aerului de preparare nu a afectat rezistența îmbinării.

Cuvinte-cheie*: rezistența îmbinării, fire din elastan cu miez dublu, condiții de îmbinare, design experimental*

INTRODUCTION

Cotton/elastane yarns are composite yarns composed of a blend of elastane core covered with cotton fibres. An increase in the demand for sports and leisure garments with high comfort and elasticity has led to greater use of elastane filaments [1, 2].
Recently New yarn using two elastane filaments with a high ratio of elastane are introduced. Winding aims to obtain a large package and eliminate undesirable faults.
Splicing is the most used method to joint yarn together. Different splicing methods, pneumatic, mechanical, and electrostatic, were developed [3].
Most of the research papers conducted in splicing concentrated on pneumatic splicing. The principle of pneumatic splicing consists of untwisting and later retwisting two yarn ends using an air blast. First, the yarn is opened, then fibres are intermingled and finally twisted in the same direction as that of the parent yarn.
The most important parameter that characterizes pneumatic splicing is appearance and mechanical properties.
Retained Splice Strength RSS is the most relevant factor in evaluating the splice's mechanical properties. RSS is expressed by dividing the strength of the spliced yarn by the strength of the parent Yarn [4]:

$$RSS\ (\%)\ 100 \times \frac{SYS}{PYS} \quad (1)$$

where *SYS* is the Strength of Spliced Yarn and *PYS* is the Strength of Parent Yarn.
A value of *RSS* more than 80% is considered acceptable properties [5–10].
Retained Splice Elongation *RSE* is expressed by dividing the elongation of the spliced yarn by the elongation of the parent Yarn.
Except for wool yarns, it was found that a good relationship exists between *RSS* and *RSE* [9]. This means that analysing one property is sufficient to evaluate the mechanical properties of the splice. There is a lack of research in the field of splicing. The reason is that the structure of the splice is very complex and that the velocity of the winding machine is essential (more than 1500 m/min).
Some numerical models were proposed for the analysis of the splice device (parameters and geometry) and the splice morphology (case of multi-filament yarns) where the splice operation is realized using different simulations software [11].
The experimental study was conducted to study the effect of yarn characteristics and splicing parameters on *RSS* and the appearance of the splice [12].

Most of the studies mentioned above have been elaborated on classical yarns, and some research concerns elastic yarns.
The primary purpose of this work is to optimize the splice parameters of cotton dual-core yarn with a high ratio of elastane. Taguchi's experimental design was investigated to analyse the effect of splicing process parameters on the strength of the splice of the obtained yarn.
The elastomeric yarn utilized in our study is a cotton/elastane denim yarn with 42 tex linear density and an elastane percentage of 24%.
The splices were equipped on the Autoconer Schlafhorst splicer X5 (Prism LC5), employing a direct blast of compressed air.
The assortments of the regulation points are organized according to a fractional set (six parameters, each one with two levels of values, integrated into 12 configurations).
We varied six regulation points for adapting the splicing conditions, two for “end preparation air volume” (Preparation pressure Pp and Preparation duration Pd) and four for “joining yarn ends” (Joining air pressure Jap, joining air duration 1 Jad1 (first impulsion), joining air duration 2 Jad2 (second impulsion) and joining air duration 3 Jad3 (third impulsion).
The response measured is the strength of the splice expressed by the Retained Splice Strength RSS (%)

MATERIALS AND METHODS

In our investigations, we utilized a cotton/elastane denim yarn with 42 tex linear density and an elastane percentage of 24% (for the two filaments, 5% for the first one E1 (Lycra ®) and 19% for the second one E2 (T400®). The elastomeric yarns were assembled according to the double core-spinning method (figure 1), introducing two extended elastane filament cores to the front drafting roller of a spinning frame where it infiltrates with staple fibres resulting in a core-spun yarn. The elastane exploited is constructed by Dupont. Moreover, the elastane counts are 78 dtex for E1 and 83 dtex for E2.

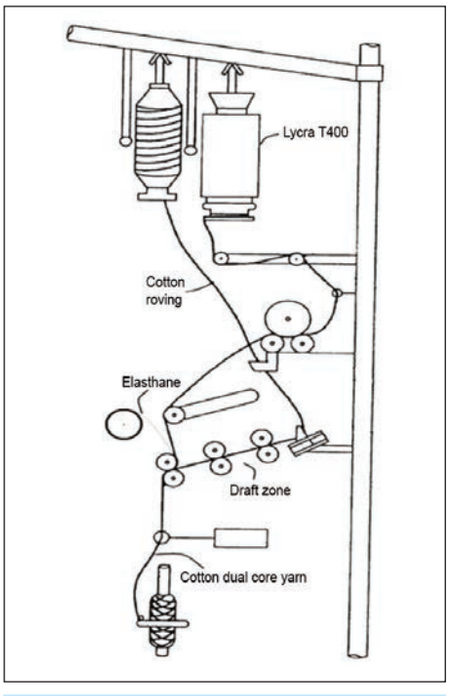

Fig. 1. The principle of the dual-core spinning method

The splices were trained on the Autoconer Schlafhorst splicer X5 (Prism LC5), utilizing a direct blast of compressed air. For The Schlafhorst splicer (figure 2), we varied six regulation points for altering the splicing conditions, two for “end preparation air volume” (Preparation pressure **Pp** and Preparation duration **Pd**) and four for “joining yarn ends” (Joining air pressure **Jap**, joining air duration 1 **Jad1** (first impulsion), joining air duration 2 **Jad2** (second impulsion) and joining air duration 3 **Jad3** (third impulsion).
The assortments of the regulation points are placed according to a fractional set (six parameters, each one with two levels of values, integrated in 12 configurations). The factors and levels employed in the orthogonal analysis are displayed in table 1.

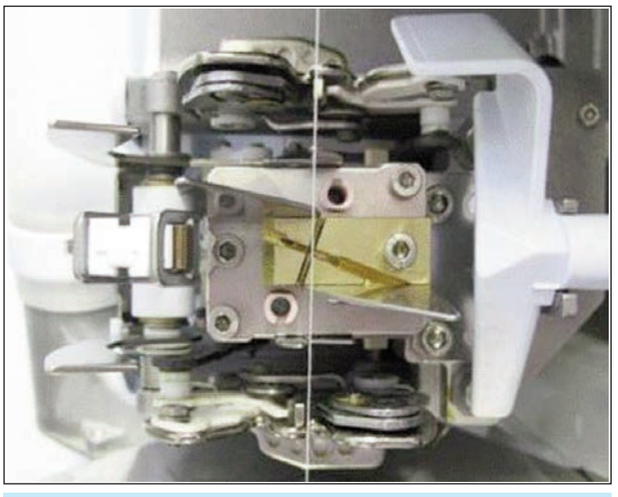

Fig. 2. The Schlafhort pneumatic splicer

Table 1

PARAMETER VALUES		
Parameters	**Low level 1**	**High level 2**
Preparation pressure Pp	4 bars	5 bars
Preparation duration Pd	400 ms	500 ms
Joining air pressure Jap	5 bars	6 bars
Joining air duration Jad1	60 ms	100 ms
Joining air duration Jad2	60 ms	100 ms
Joining air duration Jad 3	60 ms	100 ms

RESULTS AND DISCUSSIONS

The breaking strength is described in terms of Retained Spliced Strength (**RSS**). The RSS is the strength of the spliced yarn represented as the percentage of the parent yarn in which the splice is inserted.

The breaking strength of the splice yarn RSS was tested on the LLOYD tensile tester, and sample sizes for the core spun yarns were 40 ends. Results are resumed in table 2.

Table 2

RESULTS OF EXPERIMENTS						
Pp	**Pd**	**Jap**	**Jad1**	**Jad2**	**Jad3**	**RSS**
1	1	1	2	2	2	25.18
2	2	1	2	2	1	39.72
2	2	1	2	1	1	47.70
2	1	2	1	2	1	40.66
1	2	2	2	1	2	72.25
1	2	1	1	2	2	61.30
2	1	1	1	1	2	44.88
1	2	2	1	1	1	47.34
2	1	2	2	1	2	71.00
1	1	1	1	1	1	40.50
1	1	2	2	2	1	64.43
2	2	2	1	2	2	60.83

The analysis of variance is resumed in table 3, we accept the Hypothesis H_0 if Pvalue is less than 0.05. H_0: the factor has an effective influence on the response with a probability P.
The main effect plots for means are given in figure 3. To check the adequacy of our model, we check the normality assumption.

Table 3

ANALYSIS OF VARIANCE			
Factor	**DF**	**F**	**P**
Pp	1	1.555	0.213
Pd	1	72.787	<0.001
Jap	1	381.132	<0.001
Jad1	1	24.731	<0.001
Jad2	1	40.131	<0.001
Jad3	1	122.351	<0.001

Fig. 3. Main effect plots for means

Figure 4, illustrates the normal probability plot of residuals (error between estimated value and measured values)
The figure shows that this plot will resemble a straight line. This confirms the hypothesis that error distribution is normal.
According to practical design techniques, the effects of the parameters were computed. Results are shown in table 4 where the impact of a parameter – for example, the value of preparation pressure Pp – on the breaking strength of the splice, – such as RSS is calculated as:

$$\overline{RSS}_{HIGH\ Pp} - \overline{RSS}_{total} =$$

$$= 0.5 \cdot (\overline{RSS}_{HIGH\ Pp} - \overline{RSS}_{LOW\ Pp}) \qquad (2)$$

Regarding table 3, it is evident that the Joining air pressure **Jap**, the Join air duration 3 **Jad3**, and the Preparation duration **Pd** influence the mechanical splice properties. Figure 5 illustrates the **RSS** variations in terms of $\overline{RSS}_{HIGH}$ and $\overline{RSS}_{LOW}$.

Table 4

PARAMETER EFFECTS						
Parameter	**Pp**	**Pd**	**Jap**	**Jad1**	**Jad2**	**Jad3**
RSS	–1	**7.08**	**16.2**	4.13	–5.26	**9.18**

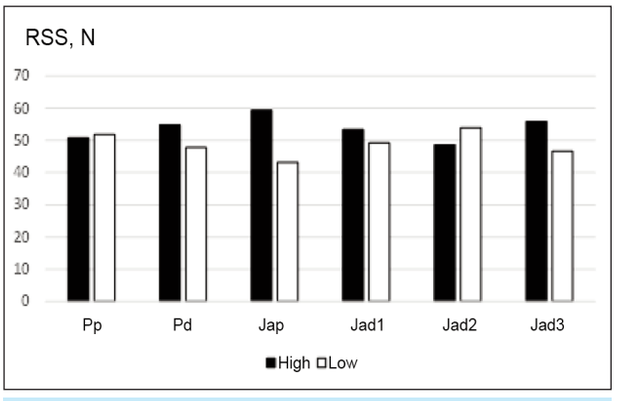

Fig. 5. RSS variation

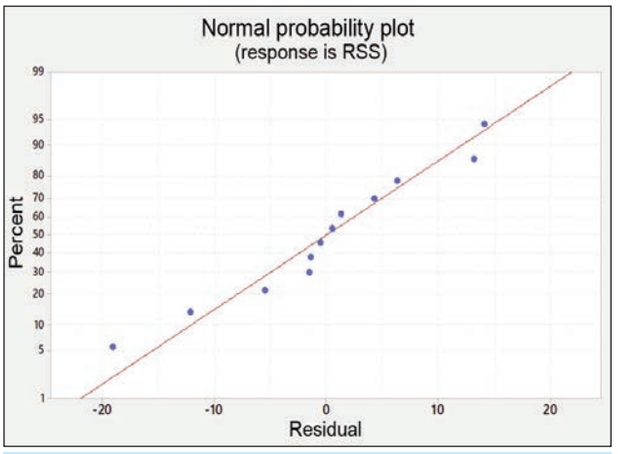

Fig. 4. Normal probability plot of residuals

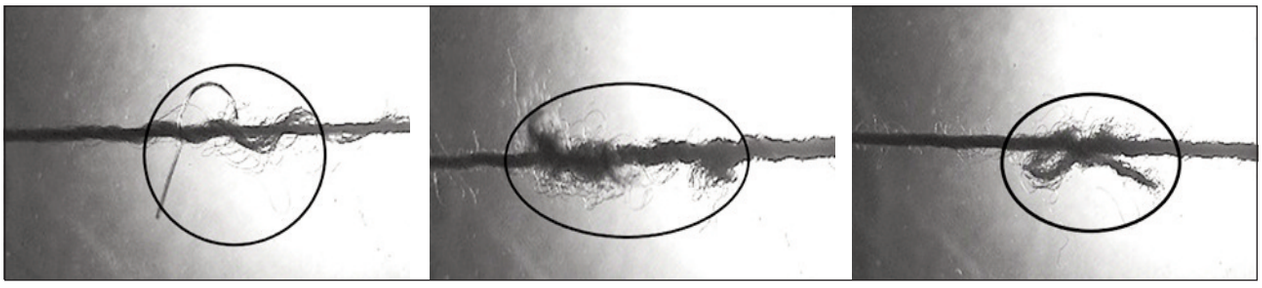

Fig. 6. Appearance of dual-core elastane yarn splice (low RSS)

The results demonstrate that the increase in the join air pressure of 20% (from 5 to 6 bars) leads to a rise in RSS of about 37%. On the other hand, the variation of preparation pressure from 4 to 5 bars does not affect the splice strength.

This result is different from that found by Ben Hassen for a splice of elastomeric yarn with a low amount of elastane. It was found that the effect of preparation pressure is equivalent to that of joining pressure [13]. The principle of pneumatic splicing consists of untwisting and later retwisting two yarn ends using an air blast. A pressure of 4 bars seems sufficient to untwist the two core-spun yarns to be joined together. An increase in this preparation pressure has no other positive effect on yarns' tail opening. We can then adjust the preparation pressure on a fixed value. On the other hand, the phenomena are more complex for the retwisting part.

Das [14] and Webb [15] demonstrated a minimum pressure P0 needed to force the intermingling of both yarns together to obtain the splice. Increasing splicing air pressure enhances the torque, which causes more intermingling and binding of fibres in the overlapped region until a specific limit. In our case, 6 bars do not exceed the limit and are more adequate to adjust for the core-spun yarns.

According to figure 6, when we change the joining air preparation from 400 to 500 ms, the RSS of the splice increases by about 15%. The RSS rise more than 18% when a total join air duration of 300 ms is adjusted in comparison to an initial value of 180 ms (possibility to add effects on the orthogonal design of experiment tables). These results agree with numerical models proposed for the analysis of the splice device using different simulation software which demonstrated that the quality of the yarn preparation will be affected by the speed and pressure of the compressed air, the volume and the length of the air injection time. Also improving of the duration of joining implicates an expansion of the aerodynamic acting forces and guides to further twisting and intermingling of the yarn ends.

Table 2 shows that the maximum RSS obtained is 72% (experiment 5). In practice, a value of RSS of more than 80% is considered an acceptable property. For pneumatically wet spliced cotton/elastane yarns with a low ratio of elastane (5%), Ben Hassen proved that in optimal conditions, an RSS of 90% can be obtained [13, 16, 17]. The design of the chamber used to produce our splice seems to be not adapted to the new double-covered yarn with a high level of elastane ratio.

The difference in structure between classic can also explain the difference in results, elastic yarn with a low rate of elastane and yarns with double-covered yarn with a high rate of elastane (our case). To illustrate this phenomenon, several images were taken to show the dual-core elastic yarns' appearance for some combinations with low RSS.

Kaushik [18, 19] proved that the splice portion is composed of two zones, splicing zone Z1 and transition zone Z2; he demonstrated that most breaks occur in Z1. In our case of low RSS (figure 6), we remark that the splicing zone is irregular, and the joining between the two yarn ends is not effectively done. This phenomenon causes a stress concentration and consequently breaking in the splicing zone

With a high rate of elastane, fibres-elastane cohesion will be reduced. This increases the migration of the elastane filament during splicing outside the yarn and minimizes the chance that elastane will be placed at the centre of the yarn after the joining operation.

CONCLUSIONS

The paper presents an experimental study of the mechanical properties of a dual-core elastane yarn splice. Results show that joining parameters have more effect than preparation parameters. In particular, the mechanical properties of the splice are susceptible to the variation of the joining pressure. The results demonstrated that the increase in the join air pressure of 20% (from 5 to 6 bars) leads to an increase of RSS of about 37%. The rise in splicing air pressure increases the torque, which causes more intermingling and binding of fibres in the overlapped region. According to our study, the maximum RSS obtained is 72%, less important than the value obtained in literature for classical and elastic yarn with a low elastane ratio. The difference in structure between yarns can explain the difference in results, elastic yarn with a low rate of elastane and yarns with double-covered yarn with a high rate of elastane (our case). More efforts should be made by the manufacturer of the splicing device to design a chamber

adequate for new complex yarn structures such as dual-core spun yarn with a high ratio of elastane. Further research can also be continued to study the appearance of the splice of this new yarn.

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