ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

MULTIVARIATE ANALYSIS OF THE PHYSICO MECHANICAL PARAMETERS VARIATION FOR HYDROPHOBIC TEXTILE

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Abstract: *This work presents a multivariate analyse regarding textile surfaces treated with fluorocarbon chemicals in order to obtain hydrophobic effect. The hydrophobic characteristics of the textile samples (cotton 100%) were obtained after hydrophobization treatement in the laboratory, by using chemicals based on fluorocarbon and by process parameters variation (temperature, time). Experimental data were evaluated by means of laboratory tests and multivariate analysis in order to observe covariance and the connections between the process parameters and the final characteristics of the fabric hydrophobizated.*
For evaluating the hydrophobic effect, some investigations were performed by qualitative method Spraytest for determinating the resistance to surface wetting in accordance with the standard SR EN ISO 4920-2013, air permeability according to SR EN ISO 9237:1999 standard and contact angle computing by using the device VCA Optima for contact angle measuring, in accordance to the standard ASTM D7490-2008. In order to highlight the morphological changes that appear on the cotton fibers, samples were examined using scanning electron microscopy device (SEM) with the magnitude of X2000 X4000, X8000.
The purpose of multivariate analysis for parameters and influence factors for hydrophobization process, based on fluorocarbon, is to obtain information relating to the dependent variables and independent, which influence the process.
We establish some dependence between parameters (contact angle, spray test resistance, air permeability) by using covariance matrix analysis.
This analysis shows that contact angle and the resistance to spray test are in direct dependence and in reverse dependence with the air permeability.

Key words: *hydrophobic, textiles, multivariate, impact, environment.*

1. INTRODUCTION

The multivariate approach enables to explore the joint performance of the variables and determine the effect of each variablein the presence of the others. Multivariate analysis provides both descriptive and inferential and allow searching for pattern and test hypotheses about pattern [1].

In the scientific literature there are information regarding hydrophobization agents used for cotton, such as bifunctional polysiloxanes with various contents of functional groups [2], maleic-anhydride grafted poly[styrene-b-(ethylene-co-butylene)-b-styrene] triblock copolymer solutions based on calcium carbonate particles [3] . In case of addition of W/V $CaCO_3$ 6% was obtain the highest contact angle value of 154° [3].

The fluorinated polymeric products gases are used for a large number of articles (clothing and household linen stofe furniture, bedspreads, gaskets earth) because the ultimate effect increases, in general, the value of use and provide the maintenance process. Now, on the market are available commercial products with water-repellent properties, most of them being protection materials anti-staining, such as StainSmart (Milliken), Advanced Dual action and ultra Teflon launched by Invista, Scotchgard Protector (3M). Almost all the finishing treatments provide the repellency of water and oils, such as Crypton®, TEFLON®, Gore TM, and Scotchguard TM, because are based on fluorocarbon. Fabrics treated in this way are used for clothing active, travel, clothing and protective equipment; military uniform, medical and school, equipment for hospitals, public places, tents for emergency situations etc. The hydrophobic properties are produced by covering with nanoparticule [4] and polymers as the NanoSphere technology. For super-hydrophobic effect novel approaches to decrease the surface free energy of fibers was studied in the last years, such as silane chemistry, nanocomposite structures, or physically applied thin layers [5, 6, 7].

Fabrics that are coated with nanosferele created by Schoeller are used for sports equipment, rucksacks, t-shirts, slacks and other products by companies as well as the Cloudveil, Granite Gear, Mammut, Outdoor Research, Beyond Fleece and Westcomb.

2. EXPERIMENTAL PART

For obtaining the hydrophobic characteristics, the textile samples made from cotton 100% and with the mass 401g/m^2, were treated by using chemicals based on fluorocarbon and by process parameters variation (temperature, time) in the laboratory.

Experimental data, obtained in the laboratory processes, were investigated by means of laboratory tests and multivariate analysis in order to observe the joint variability of two random variables and the connections between the process parameters and the final characteristics of the fabric hydrophobizated.

The multivariate analysis was based on bivariate random variable (x, y) in order to observe the tendence of x and y to covary [1]. The population covariance is defined as cov(x, y) (1).

$$\mathrm{Cov}(x,y) = \sigma_{xy} = E[(x - \mu_x)(y - \mu_y)] \quad \textbf{(1)}$$

Where:
μ_x is the mean of x.
μ_y is the mean y.

In table 1 are presented information about process parameters used for hydrophobization and the results for spray tests and contact angle in order to evaluate the hydrophobization. The sample P0 is the untreated textile surface. In Fig. 1 is presented the contact angle in function of air permeability and spray test resistance.

Table 1: *Hydrophobic textile samples parameters and results*

		Samples				Standard
		P0	**P1**	**P2**	**P3**	
Spray test resistance	Grade scale ISO	0	3.5	4.5	4	SR EN ISO 4920/2013
	Photographic scale AATCC	0	85	95	90	
Contact angle		<1	150.20	148.10	153	ASTM D7490-08
Temperature		-	140 °C	150 °C	160 °C	
Condensation time [minutes]		-	2	4	2	

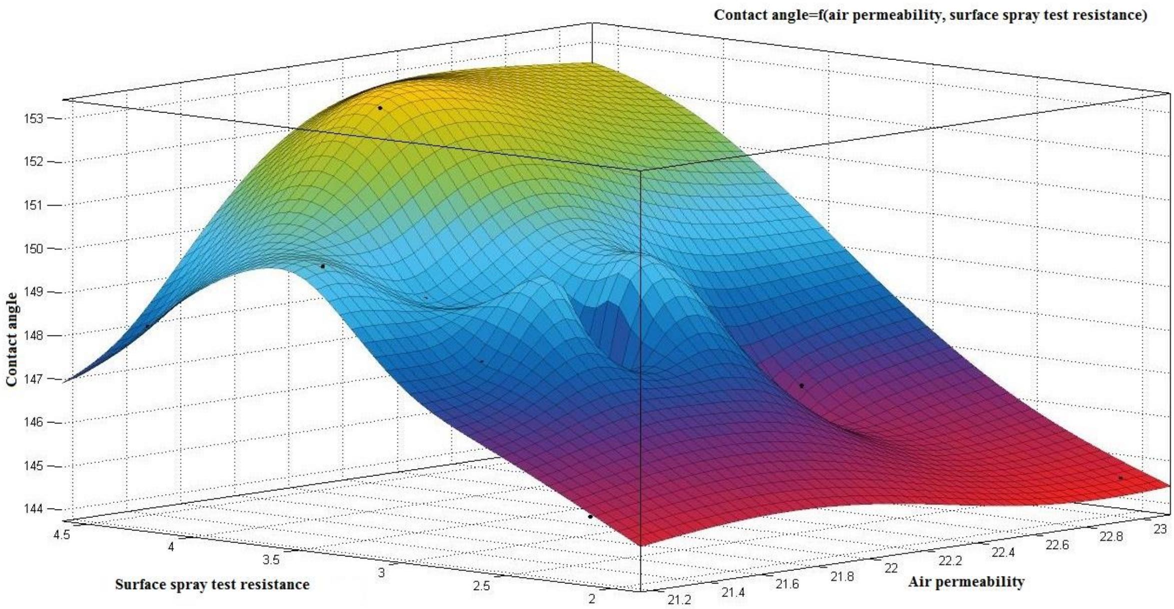


Fig.1: *3D prepresentation – Contact angle in function of surface spray test resistance and air permeability*

By mapping of 2D contact angle depending on the air permeability and surface spray test resistance (Fig. 2) we can observe that the values for which they have the best spray test resistance have the air permeability less than 22l/m^3/sec. For the samples with the air permeability exceeding 22l/m^3/sec have not been obtained good resistance to spray surface tension.

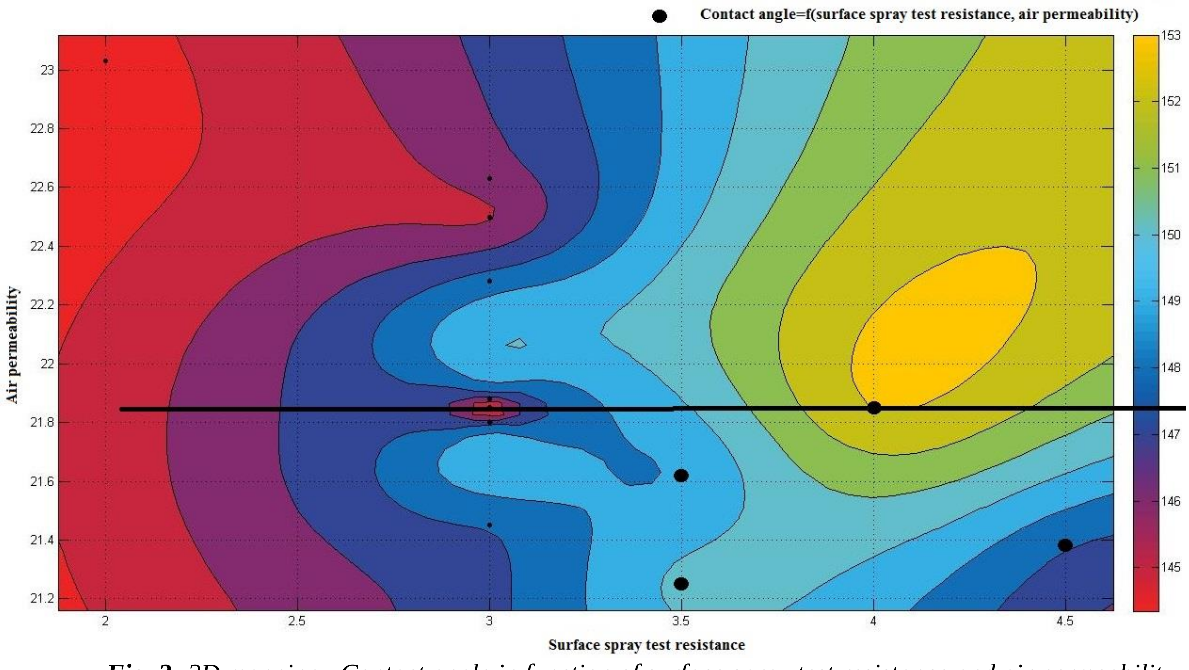


Fig. 2: *2D mapping –Contact angle in function of surface spray test resistance and air permeability*

In table 2 are presented the contact angle obtained for samples P1, P2 and P3 by OPTIMA VCA. In table 3 are presented the images with samples P0, P1, P2, P3 using scanning electron microscopy (SEM) with magnitude X2000, X4000, X8000.

Table 2: *Contact angle values*

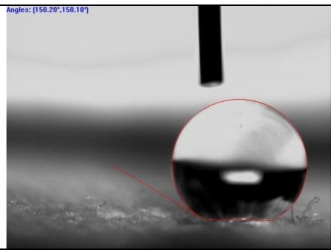
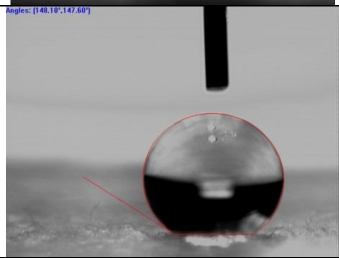
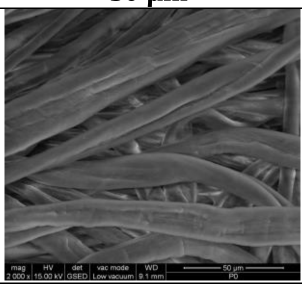
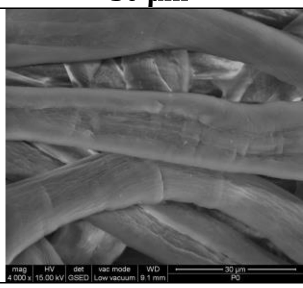
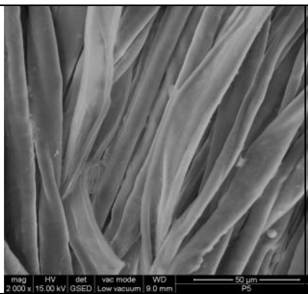
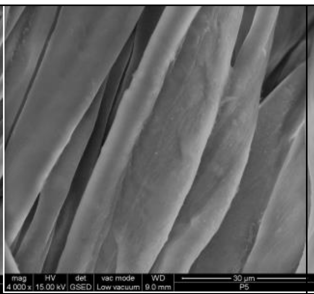
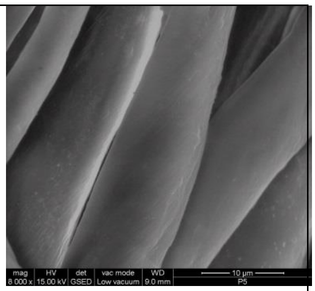
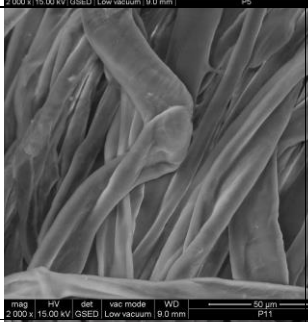
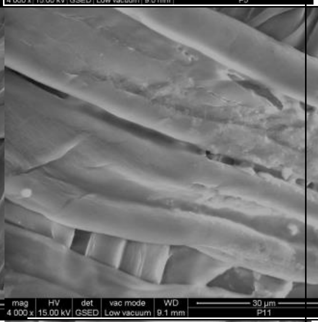
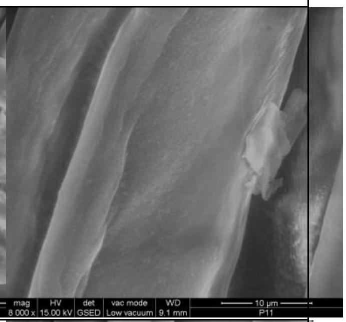
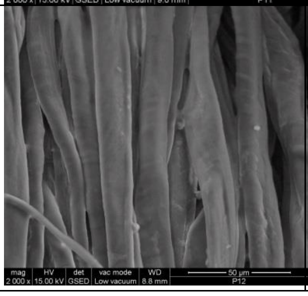
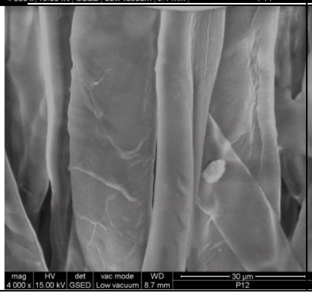
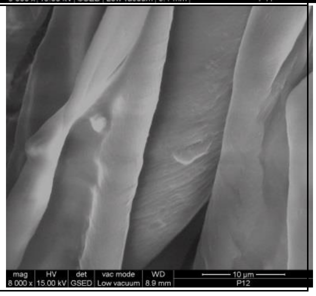
Samples	Contact angle value [º]	Image
P0	-	-
P1	150.20	
P2	148.10	
P3	153	

Table 3: *Scanning electron microscope images for textile samples*

Samples	50 µm	30 µm	10 µm
P0			

P1			
P2			
P3			

3. DISCUSSIONS AND RESULTS

We observed that the contact angle higher value is for sample P3, which has resistance at the surface spray test less than the value obtained for the sample P2. By analysing the covariation between the resistance at the surface spray (SS) and the angle of the contract (UC) (1) it can be said that they are in direct dependence and the increase of the value contact angle by hidrophobization determines the increasing of the spray test resistance).

$$Cov(SS,\ UC)=\begin{vmatrix} 0.3845 & 0.9841 \\ 0.9841 & 5.8427 \end{vmatrix} \Rightarrow Cov_{1,2}(SS,UC)=Cov_{2,1}(SS,\ UC)=0.9841\approx 1 \quad \textbf{(2)}$$

Taking into account the values obtained to the permeability to air and the resistance to the superficial spraying, it can be said that the contact angle is in direct proportionality with resistance to the spray superficial test and in reverse proportionality with the permeability to air (Fig. 1).

By analysing the covariation coefficients of the covariance matrix (2, 3) it can be concluded that the resistance at the superficila spray (SS), namely the contact angle (UC) are in a relationship of proportionality reverse with the permeability to air (PA).

$$Cov(UC,PA)=\begin{vmatrix} 5.8427 & -0.6971 \\ -0.6971 & 0.2958 \end{vmatrix} \Rightarrow Cov_{1,2}=Cov_{2,1}=-0.6971 \quad \textbf{(3)}$$

$$Cov(SS,PA)=\begin{vmatrix} 0.3845 & -0.2338 \\ -0.2338 & 0.2958 \end{vmatrix} => Cov_{1,2}=Cov_{2,1}=0.2338 \quad \textbf{(4)}$$

5. CONCLUSIONS

By multivariate analysis can be observed the independent or dependent variable, how they covary.

We can conclude that contact angle and the resistance to spray test are in direct dependence and in reverse dependence with the air permeability.

The knowledge about dependent and independent variable which influence the hydrophobization process is important for advanced material designers in order to create a new material stating from the parameters already known.

ACKNOWLEDGMENTS

The reseach presented on this paper was developed in the INCDTP laboratories.

This work is supported by funds from ANCSI, National Project ″The assessment of the life cycle of the hydrophobic textile materials″, Contract PN 16 34 04 07.

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