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ANALYSIS OF THE FABRIC CHARACTERISTICS USING THE ANOVA MODEL

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Abstract: *In this paper, it's analyzed the surface characteristics of woven fabrics. Of these features, the pilling effect is a typical pattern of flat textiles, which consists in forming, on their surface, of clusters of adherent fibers consisting of three types of fibers: outer ends (fibers with one end fixed in the base structure), outer loops (with both ends in the base structure) and marginal / wild fibers (fixed at least at one end) as a result of the action of the friction forces, affecting their appearance. Pilling is recognized as major aesthetic attribute of a woven apparel fabric. The study presents a new approach to the problem of objectively evaluating woven pilling by employing image analysis techniques and ANOVA (analysis of variance) model. The number of pills resulted on the fabric surface after abrasion testing and handle has been used as dependent, respective independent variables for ANOVA regression model. Processing of the testing results allowed an objective hierarchical classification of woolen woven materials according to their pilling resistance. Based on employed ANOVA model we have been established that there are significant differences between mean pills number depending on the handle (soft, cold or rough) of woolen fabrics. The results revealed that the formation of the pilling is characterized not only by the rate of formation and the ease of removal of the fiber agglomerations but also by the total and residual amplitude of the pilling.*

Key words: *wool woven, adherent fibers handle, ANOVA model, pilling, surface characteristics*

1. INTRODUCTION

The Anova model is used to show the main and interface effects of independent variables on dependent variables. The primary effect has a direct effect on independent variables on dependent variables, points out the effect of the interaction on an already built base [1, 2]. The pilling phenomenon is one of the most serious visual imperfections of textile fabric because it causes not only bad appearance but also a bad touch, both being especially important for fabrics are used in clothing. It is generally recognized that pilling is more pronounced in fabrics made of synthetic fibers or blends of synthetic fibers and natural fibers [3, 4, 5]. Evaluating the pilling defects, we can assess these properties of fibers, yarns and fabrics and also the probability of problem occurrence in production line [6, 7]. Pills are formed by entangling fibres into discrete balls on the surface of fabrics which are usually the result of wear, abrasion, washing or a combination of all three [7, 8, 9]. At present attempts to classify and standardise textile quality requirements for textiles devoted to clothing manufacturing pilling tendency plays a very important factor [10].

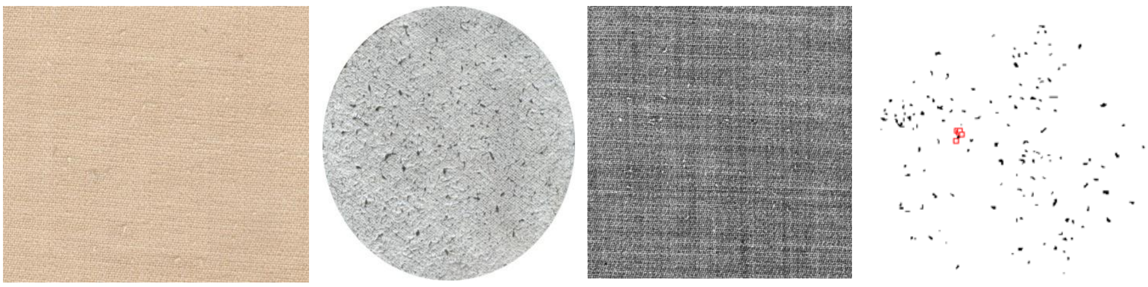
2. MATERIALS AND METHODS

The study was conducted on woven materials made of combed wool type yarns used for manufacturing outwear clothing, on 50 articles structured as follows. The variation limits of the composition and structural characteristics for the tested woven materials are indicated in table 1.

Table 1: *Variation limits of composition and structural characteristics*

Group/Fibrous composition		Nm_{Warp}	Nm_{Weft}	Coded article
Group A 100%Wool	min	50/2	30/1	A1-A10
	max	64/2	37/1	
Group B 45%Wool +55% PES	min	50/2	30/1	B1-B10
	max	64/2	64/2	
Group C 45% Wool + 50%PES + 5% Dorlastan	min	56/2	37/1	C1-C10
	max	50/2	50/2	

For pilling evaluation of woven fabrics type wool were proposed two original methods namely finger printing method followed by samples fingerprint scanning after testing and direct tested sample scanning method (Fig.1) and results interpreting through digital processing of images usinf CorelDRAW and Matlab programs. The experimental work was done under laboratory conditions on a Rubtester Metrimpex FF 25 machine in accordance with the SR EN ISO 12743-3-2003 standard. The sample size was determined by the fixation device. The samples were tested for homogeneous friction on one side. The indirect method of pilling evaluation involves the fabric weight and thickness measuring both before and after abrasion testing. Based on quantitative analysis of tested samples (Fig.1) were determined: initial/final sample weight; initial/final sample thickness; number of fiber agglomerations/unit area formed/detached; number of fiber agglomerations/unit mass formed/detached; agglomerations mass of detached fibers from unit area.
Experimental results concering quantitative analysis for the three gropus of woven fabrics that illustrated the pilling effect intensity obtained by objective methods were statistically processed using ANOVA model.



B10 (Nc=500, P=30 N)* | Sample print of B10 (Nc=500, P=30 N) | C9 (Nc=500, P=30 N) | Sample print of C9 (Nc=500, P=30 N)

* Nc= number of abrasion cycles: P= pressure force

Fig. 1. *Scanned images of tested and print samples*

3. EXPERIMENTAL PART

3.1. Collection, systematization and processing of experimental data

Econometric modeling is performed using numeric variables. To extend this restriction to non-numeric variables or attributive variables, are constructed alternative variables called dummy variables. For a nominal variable, it can be established one or more alternative variables, depending on the purpose or modeling interest. Also, is shown the differentiation of woven materials by the variation of the number of formed fiber agglomerations/surface unit and the number of formed and detached fiber agglomerations/surface unit, depending on the number of abrasion cycles and pressure force (P=30 N).

Based on the experimental data, the following variables were included in the ANOVA regression model: dependent variable (Y) representing the number of agglomerations/pilling effect; independent variable representing the woven material handle (soft, rough, cold) – two dummy variables.

3.2. Hypothesis formulation

H_0: There are no significant differences between the fiber agglomerations for woven materials having soft, rough or cold handle;

H_1: There are significant differences between the fiber agglomerations for woven materials having soft, rough or cold handle (H_0 is reject).

3.3. Formulation of the regression model

The ANOVA model with two dummy variables is defined by relation:

$$Y = \alpha_0 + \alpha_1 D_1 + \alpha_2 D_2 + \varepsilon \quad \textbf{(1)}$$

The regression, as a conditioned mean, has the following form:

$$\begin{aligned} M(Y/D) &= \alpha_0, & D_1 = 0, D_2 = 0 \\ M(Y/D) &= \alpha_0 + \alpha_1, & D_1 = 1, D_2 = 0 \\ M(Y/D) &= \alpha_0 + \alpha_2, & D_1 = 0, D_2 = 1 \end{aligned} \quad \textbf{(2)}$$

The notations for the model are μ_1 for the mean of fiber agglomerations for woven materials having soft handle, μ_2 for the mean of fiber agglomerations for woven materials having rough handle and μ_3 for the mean of fiber agglomerations for woven materials having rough handle.

The regression has the following form:

$$\begin{aligned} M(Y/D) &= \alpha_0 = \mu_1, & D_1 = 0, D_2 = 0 \\ M(Y/D) &= \alpha_0 + \alpha_1 = \mu_2, & D_1 = 1, D_2 = 0 \\ M(Y/D) &= \alpha_0 + \alpha_2 = \mu_3 & D_1 = 0, D_2 = 1 \end{aligned} \quad \textbf{(3)}$$

The dummy variables are defined in Table 1.

Table 1. *Definition of dummy variables*

Group	D1	D2	Handle
1	1	0	Cold
2	0	1	Rough
3	0	0	Soft

The coefficients defined in table 2 were determined for the established model. The t-test show if the variation between those three groups of woven fabrics is "significant" depending on number of fiber agglomerations formed on unit area.

The estimated ANOVA model has the following expression:

$$y = 27.345 - 14.456 D_1 - 24.468 D_2 \quad \textbf{(4)}$$

and the estimations for the considered parameters are:

$a_o = 27.345$; $a_1 = -14.456$; $a_2 = -24.468$ **(5)**

***Table 2**: Coefficients of the ANOVA model*

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta		
1	(Constant)	27.345	0.467		46.328	0.000
	D1	-14.456	1.132	-0.245	-8.251	0.000
	D2	-24,468	0.784	-1.001	-22.527	0.000

Dependent Variable: number of agglomerations/pilling

3.4. Model interpretation

The model interpretation is the following:

a) estimate a_o = **27.345** is the mean of fiber agglomerations for the woven materials with soft handle:

b) estimate $a_o + a_1 = 27.345 - 14.456 =$ **12.889** is the mean of the fiber agglomerations for woven materials with cold handle.

Values of Sig. associated to t-test for those two regression coefficients are less than 0.05 and therefore the coefficients have significant values. The coefficient values indicate that the fiber agglomerations number are 27.345 for fabrics having soft handle respectively 12.889 for those fabrics with cold handle. So the fiber agglomerations number of woven fabrics with cold handle is lower than 12.889 comparative with the agglomeration number of soft handle fabrics.

Based on the results presented in Table 2 the value of sig is smaller than 0.05 thus, the hypothesis H_0 it is rejected while hypothesis H_1 is accepted. Therefore, one can conclude that significant differences exist between the fiber agglomerations media of woven materials type wool having soft, rough or cold handle exists.

3.5. Hypothesis confirmation over errors

3.5.1. M(ε) = 0 (errors mean is null)

The hypothesis are the following:

H_0: $M(\varepsilon) = 0$

H_1: $M(\varepsilon) \neq 0$ **(6)**

The results obtained in SPSS program used to estimate the errors of this model are indicated in Table 3.

***Table 3**: Descriptive Statistics*

	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Unstandardized Residual	30	0.000	9.35961372	0.244	0.221	-1.216	0.477

Estimates of distribution errors form are the folowing:

-Fisher asymmetry coefficient: sw = 0.244, for a positive asymmetry (sw > 0);

-Fisher vaulting coefficients: k = -1.216 for a flattened distribution (k <0).

Estimates of form parameters indicate a deviation of errors distribution form from normal distribution. The significance of these deviations is confirmed by Jarque-Bera test.

The Jarque-Bera statistic values is:

$$JB_{calc} = \frac{n}{6}\left(sw^2 + \frac{k^2}{4}\right) = \frac{30}{6}(0.0595 + 0.3697) = 2.146 \quad \textbf{(7)}$$

Theoretical value [7] is: $\chi^2_{0,05;2} = 5.99$

In conclusion $JB_{calc} > \chi^2_{\alpha;2}$, leading to the decision to accept the H_0 hypothesis with a probability of 0.95. Since the sample volume is large, the mean errors does not differ significantlly from zero and the errors are concentrated around the mean we consider that the violating the assumption of normality do not significantlly affect the estimated model quality.

3.5.2. V (εi) = σ² - homoscedasticity hypothesis

A non-parametric correlation test is applied between the estimated errors and the dependent variable (D1, D2). The correlation coefficient Spearman is calculated and the Student t-test for this coefficient is performed. The results are shown in table 4.

The hypothesis are the following:

H_0: the correlation coefficient is insignificantly larger than zero (the null hypothesis of the Student t-test is accepted);

H_1: the correlation coefficient is significantly larger than zero (the null hypothesis of the Student t-test is rejected).

***Table 4**: Spearman test for verifying the homoscedasticity hypothesis*

			D1	D2	Unstandardized Residual
Spearman's rho	D1	Correlation Coefficient	1.000	-0.332**	0.002
		Sig. (2-tailed)	0.000	0.000	0.876
		N	30	30	30
	D2	Correlation Coefficient	-0.332**	1.000	0.063
		Sig. (2-tailed)	0.000	0.000	0.532
		N	30	30	30
	Unstandardized Residual	Correlation Coefficient	0.002	0.063	1.000
		Sig. (2-tailed)	0.876	0.532	0.000
		N	30	30	30

** Correlation is significant at the .01 level (2-tailed).

The values of sig. for the correlations D1-estimated errors *(0,000)* and D2-estimated errors *(0.000)* are equal and constant. The correlation Spearman coefficient *(r = - 0.332)* and the Student t-test for this Spearman coefficient are presented in table 4. The significance of the Student test *(Sig t= 0.000)* lead to the decision to reject the null hypothesis of Student test, that is the hypothesis corresponding to correlation coefficient is insignificantly different from zero. Therefore we reject the homoscedasticity hypothesis for the regression model between the number of fiber agglomerations as variable and handle as variable with a probability of 0.95.

3.5.3. εi ~ N (0, σ²) – normality hypothesis

Testing normality errors distribution can be done with a classic non-parametric test such as the chi-square test or Kolmogorov-Smirnov test. Significance test (Sig =0.473 >0.05) lead to the decision to accept the assumption of normality. So, we can accept the hypothesis of normality for the regression model between number of fiber agglomeration variable and handle variable, for a statistical certainty of 0.95.

4. CONCLUSIONS

According to the study, the phenomenon is more pronounced in textile products made of synthetic fibers or mixtures of synthetic and natural fibers, open and flexible textile structures, caused not only by the emergence of fibers but also by the persistence of clusters generated. Employing ANOVA on different groups of study has evidenced significant differences between the mean values of fiber agglomerations for woven materials having soft, rough or cold handle.

The results showed that the formation of the pilling is characterized not only by the speed of formation and the ease of elimination of the fiber agglomerations, but also by the total and residual overall amplitude of the pilling. The factors that significantly influence the piling resistance of fabrics are: the fibrous composition of the component yarns, the geometric structure of the fabrics defined by the structure phase (the yarn curl degree), the system of yarns on plane/side of the fabric that takes effort on friction, the yarn quality the yarn tickness.

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