

EMPLOYING THE ANOVA MODEL FOR THE DIFFERENTIATION OF WOOL TYPE WOVEN MATERIALS BASED ON THEIR HANDLE PROPERTIES

Liliana Hristian, Ph.D, eng.
Iuliana Gabriela Lupu, Ph.D, eng.
Lăcrămioara Demetra Bordeianu, Ph.D, eng.
Technical University "Gh. Asachi", Jassy, Romania
hristian@tex.tuiasi.ro

Abstract

The paper is analyzing the differentiation of woven materials made from wool type yarns depending on their handle as surface characteristic by using the ANOVA (Analysis of Variance) model. The number of fibers agglomerations formed on the surface of woven materials after the friction – wear testing has been used to differentiate the materials.

Keywords: number of fibers agglomerations, analysis of variance, number of pilling.

1. INTRODUCTION

The complexity of modern industrial technological processes is motivating the research on mathematical models without excluding however experimental investigation. The mathematical models reproduce the researched phenomenon by means of some functional relationships. These models allow, in relation with the factors that influence the decision making process, the identification of optimal action parameters in a shorter time and with less material expenses than by experimental research. Thus, high quality products can be obtained with minimal costs.

The mathematical modeling of technological processes represents a research method which uses experimentally collected input parameters that are further processed for the computer simulation and optimization of the processes.

The complexity of real processes imposes two possible directions in statistical research:

- describing a population by pointing out one or more characteristics:
- comparing some of the populations among themselves.

The selection of a single characteristic is based on the concept of univariate analysis

while the multivariate analysis supposes the selection of two or more characteristics. The application of multivariate techniques does not imply juxtaposition of univariate techniques in an established order of the studied characteristics, nor the comparison of the characteristics taken two by two. Multivariate techniques imply the development of methods which are able to consider simultaneously all the characteristics under study.

The part of statistics dealing with an ensemble of such statistical techniques is called dispersional analysis or analysis of variance (ANOVA).

2. EXPERIMENTAL PART

2.1. Collection, systematization and processing of experimental data

Pilling is a typical manifestation of plane textiles which results in the formation of some fiber agglomerations at the textile surface as a result of friction. 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 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. At the same time, open flexible textile structures like knitted fabrics are more prone to pilling which is caused in this case by fiber emergence and the persistence of the generated fiber agglomerations.

The experimental work was done under laboratory conditions on a Rubtester Metrim-pex 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.

Figure 1 present the experimental data regarding the quantitative analysis for three woven materials groups and indicate 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 ($P=10$ N).

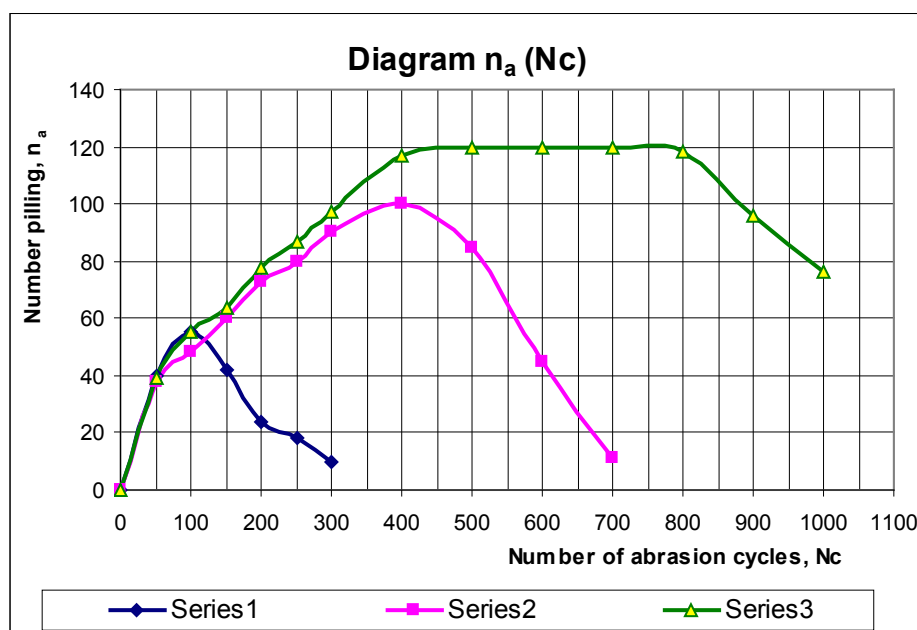


Fig.1. Variation diagram of fiber agglomerations/mass unit, n_M , formed and detached

Series 1	Group 1	100%Wool
Series 2	Group 2	45%Wool+55%PES
Series 3	Group 3	44%Wool+53%PES+3%D

The ANOVA model permits the differentiation of the analyzed woven materials with respect to the woven's handle function based on the number of fiber agglomerations/ pilling effect at the surface.

Based on the experimental data, the following variables were included in the ANOVA regression model:

- the dependent variable (Y) representing the number of agglomerations/pilling effect;
- the independent variable representing the woven material handle (soft, rough, cold) – two dummy variables.

2.2. 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).

2.3. Formulation of the regression model

The ANOVA model with two dummy variables is defined by relation (1):

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

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

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

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 cold handle.

The regression has the following form:

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

The estimators of the model parameters are described by the following relations:

$$\begin{aligned} \alpha_0 &= \mu_1 \\ \alpha_0 + \alpha_1 &= \mu_2 \\ \alpha_1 &= \mu_2 - \mu_1 \\ \alpha_0 + \alpha_2 &= \mu_3 \end{aligned} \quad (4)$$

$$\alpha_2 = \mu_3 - \mu_1$$

The estimations of the model parameters are:

$$\begin{aligned} a_0 &= \bar{y}_1 = (1/n_1) \sum y_i \\ a_0 + a_1 &= \bar{y}_2 = (1/n_2) \sum y_i \\ a_0 + a_2 &= \bar{y}_3 = (1/n_3) \sum y_i \end{aligned} \quad (5)$$

$$\begin{aligned} a_1 &= y_2 - y_1 \\ a_2 &= y_3 - y_1 \end{aligned}$$

The dummy variables are defined in table

Tabelul 1 - Definition of dummy variables

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

The SPSS (Statistical Package for the Social Sciences) program was used in the modeling process.

The coefficients defined in table 2 were determined for the established model.

Table 2 – Coefficients of the ANOVA model

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta		
1	(Constant)	39,357	,668		58,921	,000
	D1	-14,429	1,336	-,412	-10,800	,000
	D2	-24,494	,934	-1,001	-26,228	,000

a: Dependent Variable: nraglfb

The estimated ANOVA model has the following expression:

$$y = 39,357 - 14,429 D_1 - 24,494 D_2 \quad (6)$$

and the estimations for the considered parameters are:

$$\begin{aligned} a_0 &= 39,357 \\ a_1 &= -14,429 \\ a_2 &= -24,494 \end{aligned} \quad (7)$$

2.4. Model interpretation

The model interpretation is the following:

a) $a_0 = 39,357$ is the mean of fiber agglomerations for the woven materials with soft handle:

b) $a_0 + a_1 = 39,357 - 14,429 = 24,928$ is the mean of the fiber agglomerations for woven materials with cold handle.

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

2.5. Hypothesis confirmation over errors

2.5.1. $M(\varepsilon) = 0$ (errors mean is nule)

Hypothesis:

$$H_0: M(\varepsilon) = 0$$

$H_1: M(\varepsilon) \neq 0$ (8)
The Student t-test t for error (Unstandardized

Residual) evaluation is applied as shown in table 3.

Table 3 – Student t-test for testing of errors mean

	Test Value = 0					
	t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Unstandardized Residual	,000	99	1,000	-2,274E-15	-,850	,850

(Sig.=1 > 0,05), so hypothesis H_0 is accepted.

The errors mean is zero.

2.5.2. $V(\varepsilon_i) = \sigma^2$ 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.

Hypothesis:

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	-,358**	,002
		Sig. (2-tailed)	,	,000	,984
		N	100	100	100
	D2	Correlation Coefficient	-,358**	1,000	,066
		Sig. (2-tailed)	,000	,	,516
		N	100	100	100
	Unstandardized Residual	Correlation Coefficient	,002	,066	1,000
		Sig. (2-tailed)	,984	,516	,
		N	100	100	100

** 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 ($r = -0,358$) 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 nule 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 regresion model between the *number of fiber agglomerations* as variable and *handle* as variable with a probability of 0,95.

2.5.3. $\varepsilon_i \sim N(0, \sigma^2)$ – normality hypothesis

Table 5 – Testing of the normality hypothesis

		Unstandardized Residual
N		100
Normal Parameters	Mean	3,501773E-09
	Std. Deviation	4,2849908
Most Extreme Differences	Absolute	,090
	Positive	,090
	Negative	-,059
Kolmogorov-Smirnov Z		,899
Asymp. Sig. (2-tailed)		,395

a Test distribution is Normal.b Calculated from data.

(Sig = 0,899 > 0,05), therefore, the normality hypothesis is accepted.

2.5.4. cov (ϵ_i , ϵ_i) – testing of errors autocorrelation

Hypothesis:

$H_0: \rho = 0$ (the errors are not auto-correlated);

$H_1: \rho \neq 0$ (the errors are auto-correlated).

The verification is done with the Durbin Watson test and the results are shown in Table 6.

Table 6 – Durbin Watson test for errors auto-correlated testing

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0,351	0,123	0,114	11,49	0,024

The value of 0,024 is compared with the calculated value of test (d_L, d_U). It has been observed that the obtained value is contained in the $(0, d_L)$ interval. Therefore, the nule hypothesis is rejected and the recorded errors are considered to have positive autocorrelation.

3. CONCLUSIONS

1. The ANOVA model permits us to evaluate the homogeneous character of a population by separating and testing of the effects caused by the considered factors.
2. If the test data obtained after trials on the elements of a sample taken from one homogeneous population are divided in distinct groups, then the mean values of the groups do not differ significantly between themselves.
3. In the case of a non-homogeneous population, the deviations of the individual values as compare to the mean value are not anymore accidental and when dividing the test data in distinct groups the mean values are differ between themselves significantly because of some causes having a systematic action.
4. ANOVA (Analysis of Variance) is a statistical process that can be used to compare the mean

values of a variable when there are at least three independent samples.

5. Is has been established based on the ANOVA model that sig < 0,05. Therefore, the hypothesis H_0 is rejected and H_1 is accepted. This implies that significant differences exist between the fiber agglomeration media of woven materials made from yarns type wool having soft, rough or cold handle.
6. The ANOVA model permits the differentiation of the analyzed woven materials with respect to the woven's handle function based on the number of fiber agglomerations at the surface. The woven materials having soft handle are situate on the first place ($a_0 = 39,357$), followed next by the woven materials with rough handle ($a_0 + a_1 = 39,357 - 14,429 = 24,928$) and last by the wovens with cold handle ($a_0 + a_2 = 39,357 - 24,494 = 14,863$).
7. Three hypothesizes of independence, normality and equality of the variance are verified before the real testing is performed.
8. 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.

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