ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

INFLUENCE OF TECHNOLOGICAL PARAMETERS ON AGROTEXTILES WATER ABSORBENCY USING ANOVA MODEL

LUPU Iuliana G.[1]**, GROSU Marian C.**[2]

[1] "Gheorghe Asachi" Technical University from Iaşi, Faculty of Textile-Leather Engineering and Industrial Management, Dimitrie Mangeron no.28, 700050, Iaşi, Romania, iuliana68lupu@yahoo.com

[2] The National Research and Development Institute for Textiles-Leather, 16th Lucreţiu Pătrăşcanu Street, 030508, Bucharest, Romania, catalin.grosu@certex.ro:

Corresponding author: Lupu Iuliana Gabriela, iuliana68lupu@yahoo.com

Abstract: *Agrotextiles are now days extensively being used in horticulture, farming and other agricultural activities. Agriculture and textiles are the largest industries in the world providing basic needs such as food and clothing. Agrotextiles plays a significant role to help control environment for crop protection, eliminate variations in climate, weather change and generate optimum condition for plant growth.*

Water absorptive capacity is a very important property of needle-punched nonwovens used as irrigation substrate in horticulture. Nonwovens used as watering substrate distribute water uniformly and act as slight water buffer owing to the absorbent capacity. The paper analyzes the influence of needling process parameters on water absorptive capacity of needle-punched nonwovens by using ANOVA model. The model allows the identification of optimal action parameters in a shorter time and with less material expenses than by experimental research. The frequency of needle board and needle depth penetration has been used as independent variables while the water absorptive capacity as dependent variable for ANOVA regression model. Based on employed ANOVA model we have established that there is a significant influence of needling parameters on water absorbent capacity. The higher of depth needle penetration and needle board frequency, the higher is the compactness of fabric. A less porous structure has a lower water absorptive capacity.

Key words: *nonwoven, viscose, polypropylene, horticulture, absorptive capacity, ANOVA*

1. INTRODUCTION

Nonwovens are used effectively for optimising the productivity of crops, gardens and greenhouses. Their protective nature means that the need for pesticides is reduced and manual labour is kept to a minimum.

Water absorptive capacity is a very important property and an important criterion for the performance of needle-punched nonwovens used as irrigation substrate in horticulture [1]. Nonwovens used as watering substrate distribute water uniformly and act as slight water buffer owing to the absorptive capacity. So, the irrigation solution is brought directly to the root zone. At the same time, the using of nonwovens with higher water holding capacity affects the frequency of irrigation which depends by existing environmental conditions. Nonwovens can have a higher water absorbency if contain in the composition cellulose-based fibers. The advantages of using in the fibrous blend of PP fibers include lighter weight, high wet strength, resistance to rot and chemicals and quick wicking action.

Needle punching is a process for converting webs of fibre into coherent fabric structures, normally by means of barbed needles, which produce mechanical bonds within the web [2, 3]. In order to understand more about the influence of needling process parameters on nonwoven water absorbent capacity it is essential to use mathematical modelling which is an investigation method of technological processes based on experimental data collection and processing [4].

ANOVA model allows the identification of optimal action parameters in a shorter time and with less material expenses than the experimental research. One of the attributes of ANOVA which ensured its early was computational elegance. The structure of the additive model allows solution for the additive coefficients by simple algebra rather than by the matrix calculations. The determination of statistical significance also required access to tables of the Fisher function which were supplied by early statistics test [4, 5, 6, 7].

2. EXPERIMENTAL

2.1 Materials

A blend of 50% polypropylene (6.7dtex/50mm) + 50% viscose (3.3dtex/38mm) was used for the preparation of needle-punched nonwoven fabrics.

2.2 Methods

Web of polypropylene/viscose fibers was formed by carding and lapping process, respectively. The basis weight of the web was controlled as 150g/m^2. Then the nonwoven fabrics were made by using an Automatex needle loom having 15x18x42x3CBA Foster needles. The experiments took place under pilot unit condition.

Before performing the water absorptive capacity measurements, the samples were conditioned at 65%, relative humidity and 20^{0}C temperature for 24 h. The fabric water absorptive capacity was tested according to ISO 9073-6 using a cylindrical wire basket that has been dropped on to the surface of the liquid from a hight of 25 mm.

The water absorptive capacity in % was calculated using the following relation:

$$C_a = \frac{M_d - M_w}{M_w} x100(\%) \qquad \textbf{(1)}$$

where:

Md: mass in g of the dry test sample,

Mw: mass in g of the wet test sample at the end of test.

There is an increase of water absorptive capacity at low values of needle board frequency and depth penetration. A porous structure has a higher absorptive capacity because of a higher number of pores which contain a higher air amount.

Experimental results concerning the needle-punched nonwoven water absorptive capacity were statistically processed using ANOVA model.

3. RESULTS AND DISCUSSION

3.1. Collection, systematization and processing of experimental data

Econometric modelling is performed using numeric variables. In ANOVA regression model were included the following variables:

- dependent variable (Y) representing the water absorptive capacity, expressed in %;
- independent variables representing needle board frequency (X_1) respective needle depth penetration (X_2), expressed in cycles/min respective in mm.

In Table 1 are indicated the experimental data regarding the influence of independent variables on water absorptive capacity of needle-punched nonwovens comprising PP fibers and viscose fibers.

Table 1: *Experimental data*

Independent variables		**Mean measured value of dependent variable**
X_1	**X_2**	**Y**
94	6	1850
115	8	1979
165	6	2119
165	9	2102
215	8	2017
236	6	1974

3.2. Hypotheses formulation

H_0: Needle board frequency respective needle depth penetration has not significant influence on mean values of water absorptive capacity;

H_1: Needle board frequency respective needle depth penetration has significant influence on mean values of water absorptive capacity (H_0 is reject).

3.3. Formulation of the regression model

The Anova model is defined by relation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon \tag{2}$$

The SPSS (Statistical Package for the Social Sciences) program was used in the modelling process. The coefficients defined in Table 2 were determined for the established model and the t-test show if the influence of the needle board frequency respective needle depth penetration is “significant” on mean values of water absorptive capacity.

Table 2: *Coefficients of ANOVA model*

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
1	**(Constant)**	1639.838	123.005		13.331	0.000
	Needle board frequency	0.703	0.359	0.396	1.958	0.039
	Needle depth penetration	35.138	14.832	0.479	2.369	0.032

a. *Dependent Variable: Water absorbent capacity*

From Table 2 it can be noticed that Sig<0.05, so the H_0 is rejected and H_1 accepted. Hence, the needle board frequency and needle depth penetration has a significant influence on water absorptive capacity.

The estimated ANOVA model has the following expression:

$$Y = 1639.84 + 0.703 X_1 + 35.138 X_2 \tag{3}$$

3.4. Hypotheses confirmation over errors

3.4.1. M(ε)=0 (errors mean is null)

The hypotheses are the following:

$$H_0 : M(\varepsilon) = 0$$
$$H_1 : M(\varepsilon) \neq 0 \tag{4}$$

The student t-test for errors (unstandardized residual) evaluation was applied as see in Table 3.

Table 3: *Student t-test for testing of mean errors*

	Test Value = 0					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Water absorptive capacity	93.030	17	0.000	2007.611	1962.08	2053.14
Unstandardized Residual	0.000	17	1.000	0.000	-35.67	35.67

Sig=1>0.05, so hypothesis H_0 is accepted

3.4.2. $V(\varepsilon_i) = \sigma^2$ (homoscedasticity hypotheses)

A non-parametric correlation test is applied between the estimated errors and dependent variable. The correlation coefficient Spearman was calculated and the Student t-test for this coefficient was performed (see table 4). The hypotheses are:

- H_0: correlation coefficient is insignificantly larger than zero (null hypothesis of Student t-test is accepted),
- H_1: correlation coefficient is significantly larger than zero (null hypothesis of Student t-test is rejected).

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

Correlations				
			Water absorptive capacity	**Unstandardized Residual**
Spearman's rho	**Water absorptive capacity**	**Correlation Coefficient**	1.000	0.720^{**}
		Sig. (2-tailed)	0.000	0.001
		N	18	18
	Unstandardized Residual	**Correlation Coefficient**	0.720^{**}	1.000
		Sig. (2-tailed)	0.001	0.000
		N	18	18

***. Correlation is significant at the 0.01 level (2-tailed).*

The values of sig. for correlations water absorptive capacity – estimated errors (Sig=0.000) are equal and constant. The correlation Spearman coefficient (r = 0.720) and Student t-test for this Spearman coefficient are indicated in Table 4. The significance of Student t-test (Sig t = 0.000) leads to the decision to reject the null hypothesis of Student test (hypothesis that correlation coefficient is insignificantly larger than zero). Therefore, is rejected the homoscedasticity hypothesis for regression model between the water absorptive capacity and dependent variables (needle board frequency and needle depth penetration) with a probability of 0.95.

3.4.3. $\varepsilon i \sim N(0, \sigma^2)$ – normality hypothesis

Testing normality errors distribution can be done using non-parametric tests like Kolmogorov-Smirnov test, Skewness test and Kurtosis test [3] (see Table 5 and Table 6).

Table 5: *Kolmogorov-Smirnov Test*

		Water absorptive capacity
N		18
Normal Parameters^{a,b}	**Mean**	2007.61
	Std. Deviation	91.557
Most Extreme Differences	**Absolute**	0.190
	Positive	0.096
	Negative	-0.190
Kolmogorov-Smirnov Z		0.807
Asymp. Sig. (2-tailed)		0.534

a. Test distribution is Normal. *b. Calculated from data.*

The Sig = 0.534 >0.05, so it is accepted the normality hypothesis (H_0).
Estimates of distribution errors form are the folowing:

- Fisher asymmetry coefficient: sw = 0.924, for a positive asymmetry (sw > 0);
- Fisher vaulting coefficients: k = - 0.109 for a flattened distribution (k <0).

***Table 6**: Skewness and Kurtosis test for normality hypothesis*

Statistics			
		Water absorptive capacity	**Unstandardized Residual**
N	**Valid**	18	18
	Missing	0	0
Skewness		-0.508	0.924
Std. Error of Skewness		0.536	0.536
Kurtosis		-0.222	-0.109
Std. Error of Kurtosis		1.038	1.038

As seen in Figure 1, the parameter estimations indicate a deviation of errors distribution from the normal distribution.

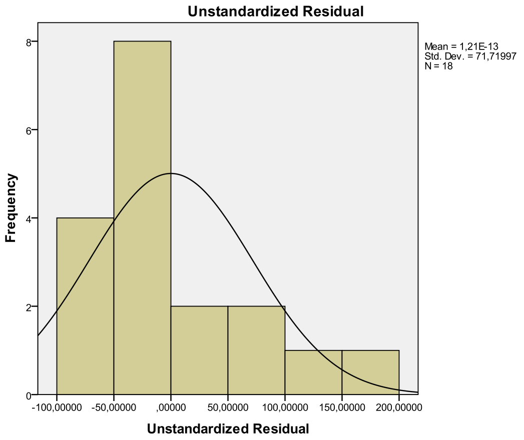

***Fig. 1**: Estimated errors distribution*

3.4.4. cov (εi, εi) - testing of errors autocorrelation

The hypotheses are:

- H_0: $\rho = 0$ (the errors are not auto-correlated);
- H_1: $\rho \neq 0$ (the errors are auto-correlated).

For the verification was used the Durbin-Watson test and the results are presented in Table 7.

***Table 7**: Durbin Watson test for errors auto-correlated testing*

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Durbin-Watson**
1	0.783	0.614	0.589	58.663	0.681

The value of 0.681 is compared with test calculated value (dl, du). It is noted that the obtained value is in the range (0, dl). Therefore, the null hypothesis is rejected which means that the recorded errors have a positive auto-correlation.

The test statistic is the following: $DW = d = 2(1-\hat{\rho})$ where $\hat{\rho}$ is the correlation coefficient error estimator and fulfilling the following condition: $-1 \le \hat{\rho} \le 1$. If $d = 2(1-\hat{\rho})$, the statistic values are in the range: $0 \le d \le 4$. In table 7 is shown the calculated value of Durbin-Watson statistic d_{calc} = 0.681. This value is compared with the critical values, noted d_L = 1.158 (lower limit) and d_U=1.391 (upper limit) which are read from the Durbin-Watson table for a threshold of significance 0.05, for a regression model with two parameters.

4. CONCLUSIONS

To establish the influence of independent variables (X_1 and X_2) and dependent variable (Y), a mathematical modelling was performed as described in “Experimental” section.

ANOVA model permits us to evaluate the homogeneous character of population by separating and testing of the effects caused by considered factors. Based on ANOVA model has been established that sig < 0.05. So, the hypothesis H_0 is rejected and H_1 is accepted. Hence, employing ANOVA model on needle-punched nonwovens used in horticulture has revealed that needling process parameters have a significant influence on water absorptive capacity.

It is known that the water absorptive capacity of nonwoven increases with the increasing of proportion of cellulose-based fibers. Even the needling process parameters, namely, needle board frequency and needle depth penetration in web can increase water absorptive capacity until to certain values. Based on experimental data, it is noticed that an increase of needle frequency and depth penetration have the same effect on nonwoven water absorptive capacity. It is found that 6 mm depth of needle penetration and 165 cycles/min needle board frequency is an optimum combination which might be considered for a maximum value of absorptive capacity because deviation from any of the independent variables may be responsible for the decreasing in absorptive capacity.

In general, with the increase of needle board frequency or depth penetration, absorptive capacity parameter decreases. The higher is fabric compactness, the lower is the number of pores (amount of voids) in structure. A less porous structure has a lower absorptive capacity.

The using of nonwovens with higher water holding capacity affects the frequency of irrigation which depends by existing environmental conditions.

REFERENCES

[1] S. Sengupta, “*Water absorbency of jute needle-punched nonwoven fabric”*, in Indian Journal of Fibre & Textile Research, Vol. 34, No. 4, 2009, pp. 345-351.

[2] A. T. Purdy, “*Needle punching”*, The Textile Institute Manchester, North Carolina State University, ISBN 10: 0900739320/0-900739-32-0, 1980.

[3] S. J. Rusell, “*Handbook of nonwovens”*, Woodhead Publishing Limited, Cambridge, England, ISBN-13: 978-1-85573-603-0, 2007.

[4] A. Gelman, “*Analysis of variance - why it is more important than ever”*, The Annals of Statistics, Vol. 33, No.1, pp.1-53, 2005.

[5] D. Jemna, “*Econometrics”*, Editura Sedcom Libris, Iaşi, ISBN: 978-973-670-345-4, pp. 180-182, 2009.

[6] Cojocaru N., Clocotici V., Dobra D., “*Metode statistice aplicate în industria textilă”*, Editura Bucureşti, România, 1968

[7] D. Taloi, “*Optimization of metallurgical processes”*, Editura Bucureşti, România, 1987.