STUDY OF TENSIONAL PROPERTIES OF POLYPROPYLENE YARNS USING THE REGRESSION AND CORRELATION METHOD

Drd. ing. **Alexandra DRUG (LUCA),** Prof. dr. ing. **Ioan CIOARA,**
Ş. l. dr. ing. **Liliana HRISTIAN,** Drd. ing. **Cristinel LUCA**

"Gheorghe Asachi" Technical University of Iaşi,
Faculty of Textiles & Leather Engineering and Industrial Management

REZUMAT. În cadrul lucrării s-a efectuat un studiu asupra proprietăţilor tensionale ale firelor polifilamentare din polipropilenă, destinate realizării ţesăturilor înguste pentru confecţionarea centurilor de siguranţă auto. Cu ajutorul programului IBM SPSS 19.0, utilizând metoda regresiei şi corelaţiei, se studiază dependenţa dintre o variabilă rezultativă/dependentă *y* – forţa de rupere, P_r (N) şi o variabilă independentă *x*-lucrul mecanic de deformare la rupere, *L* (N · m). Metoda de regresie şi corelaţie utilizată în cadrul studiului, a condus la rezolvarea următoarelor aspecte: identificarea existenţei legăturii dintre variabila dependentă şi variabila independentă; determinarea gradului de intensitate a legăturii şi stabilirea sensului şi formei legăturii dintre cele două variabile. Regresia ne arată cum (ca formă analitică) o variabilă este dependentă de altă variabilă (sau de alte variabile), iar corelaţia ne arată gradul în care o variabilă este dependentă de o altă variabilă (sau alte variabile).

Cuvinte cheie: polipropilenă, fire, forță de rupere, metoda regresiei, corelație.

ABSTRACT. In this paper it was done a study about the tensional properties of the polyfilamentary yarns made from polypropylene, used in weaving seat belts made from webbing. With the program IBM SPSS 19.0, using the regression and correlation method, studding the dependency between a resulting/dependent variable *y* – breaking force, P_r (N) and an independent variable *x* – breakdown deformation energy, *L* (N·m). The regression and correlation method, used in this paper, led to the issue of the following aspects: identification of the existence of the connection between the dependent variable and an independent variable; the determination of intensity degree of the connection and establishing the direction and shape of the connection between the two variables. The regression shows us how (the analytical form) a variable is dependent of another variable (or other variables), and the correlation shows us the degree in which a variable is dependent of another variable (or other variables).

Keywords: polypropylene, yarns, breaking force, regression method, correlation.

1. INTRODUCTION

Among the methods that can be applied to determine a relationship of dependency between two quantities of interest, called variables include correlation and regression analysis and used in various fields (psychology, economics, medicine, engineering) [1-4].

It should be noted that neither the regression analysis nor correlation does not reveal a relationship type cause-effect between the variables involved in the model, they only show to what extent are they related one with another. If the analysis is correct, if it turns out that there are solid arguments in this respect, the causality is an issue that can be discussed later [5, 6].

The tensional properties cues define the behavior of the textile products at the tensile stress, summarizes the technological achievement and standardizes, constituting quality criteria [7, 8]. Characterization products straight / flat cues properties tensional requires peculiarities definition determined by the product structure and metrological conditions test (trial basis, the size of the specimen, the initial state of the specimen, pretension and orientation towards axles technological product) [8] .

Propylene is the based monomer from which it is produced polypropylene (PP) by Ziegler-Natta catalysis process. Polypropylene has a good heat resistance, along with low cost, a higher modulus of elasticity and the possibility of obtaining a number of improved variants, this makes the polypropylene to be one of the most used polymers used in the automotive industry [9, 10].

Recent developments in polypropylene sector will provide priority position of this group of plastics materials in automotive applications. High crystallinity polypropylene (HCPP) with improved rigidity, is now used in applications of automotive interior and engine compartment applications, without the need to add 10% - 20% talc [11]. Due to the registered progresses of the properties of plastic material, bumpers can be produced with a thickness of 2.4 - 2.6 mm, down from about 3.2 mm, thus providing a significant cost and weight reduction [12, 13] .

Standard polypropylene is in the form of monofilament and polyfilamentary yarns and fibers. The fibers are obtained by cutting the cable in different lengths depending on the destination, or antistatic treated, wrinkled and painted in mass. High strength polypropylene is in the form of monofilament or polyfilamentary yarns, obtained by spinning water-cooled and air-cooled (more commonly used, but the wires have less resistance) [14]. High strength polypropylene yarns are used in making technical textiles with destinations in various fields such as agriculture, construction and automotives [15-18].

2. MATERIALS AND METHODS

Materials used in this study were polypropylene yarns of linear density of 1100 dtex, designed to achieve webbing for manufacturing automotive safety belts. Checking tensile properties of polypropylene yarns was done by dynamometric tests on samples with standardized dimensions (500mm) in accordance with EN 13934-1 standard ISO / 2002 [19], the dynamometer H5K – Tinius Olsen T calculation software QMAT textiles, TEXTILEXPERT research Laboratory, department of Textile Engineering and Design.

The obtained experimental data were statistical processed using IBM SPSS 19.0 software using regression and correlation method.

In regression and correlation analysis using SPSS software the following steps are:

− identification of the existence of the connection through the graphical method which involves construction of the graphical correlation curve;

− setting the direction and form of the connection by analytical methods to study the connections (determining the regression model, estimating model parameters and test their significance).

3. RESULTS AND DISCUSSIONS

After processing the data in SPSS and by regression and correlation analysis the following results were obtained on statistical variables: descriptive statistics indicators (Descriptive Statistics); estimated coefficients (Estimates); confidence intervals of the coefficients (Confidence intervals); calculating statistics R, R^2 and ANOVA table (Model fit); change of the determination coefficient and testing change significance adding each block of variables (R squared change). In the Residual zone occurs an analysis of residues to decide on their normality and diagnose outliers [20, 21].

The statistical parameters calculated for each variable are shown in Table 1. (output Descriptive Statistics), in which is observed the homogeneity of values of the two variables.

Analyzing the data in Table 2, which contains information about each variable analyzed independently, indicator Skewness used in distribution analysis of a series of data to indicate deviation of empirical distribution in relation to a symmetrical distribution around the mean and indicator Kurtosis used in distribution analysis of a series of data to indicate the degree of flattening or sharpening a distribution, may be observed that:

− dependent variable "Pr (N), breaking force" is characterized by an average of 65.79 and variance of 26.95; Skewness (-0.300) <0 indicates that the distribution is tilted to the right, with more extreme values to the left; Kurtosis (-0.612) <3 indicates a platikurtic distribution, a distribution flatter than a normal one, with values spread out over a longer interval around the mean. The probability for extreme values is less than for a normal distribution.

− independent variable L (N.m), breakdown deformation energy is characterized by a mean value of 2.38 and variance of 0.382; Skewness (0784)> 0 - the distribution is tilted to the left, with more extreme values to the right; Kurtosis (1.145 <3) - leptokurtic distribution, a distribution sharper than a normal one; having more concentrated around the mean values and thicker tails parallels what high probabilities for extreme values.

Table 1. **Descriptive Statistics**

	N	Min	Max	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
							Statist.	Std. Error	Statist.	Std. Error
Pr [N]	50	54.3	74.5	65.79	5.19137	26.950	-0.300	0.337	-0.612	0.662
L [N.m]	50	1.22	4.31	2.382	0.61800	0.382	0.784	0.337	1.145	0.662

Table 2. **Model Summary and Parameter Estimates. Dependent Variable: *Pr* [N]**

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	0.725	126.777	1	48	0.000	48.744	7.154		
Logarithmic	0.786	176.661	1	48	0.000	50.762	17.974		
Quadratic	0.813	102.185	2	47	0.000	31.704	21.057	-2.658	
Cubic	0.819	69.237	3	46	0.000	45.830	3.505	4.172	-0.833
Exponential	0.714	120.052	1	48	0.000	50.489	0.110		

The independent variable is *L* [N.m].

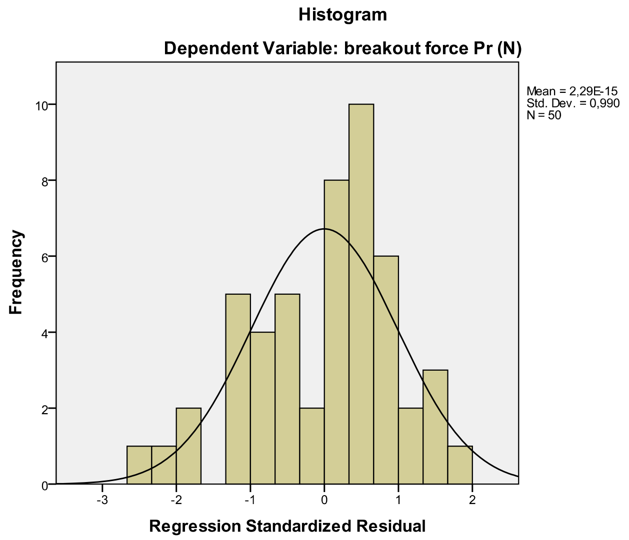

Fig. 1. The histogram and the normal distribution curve.

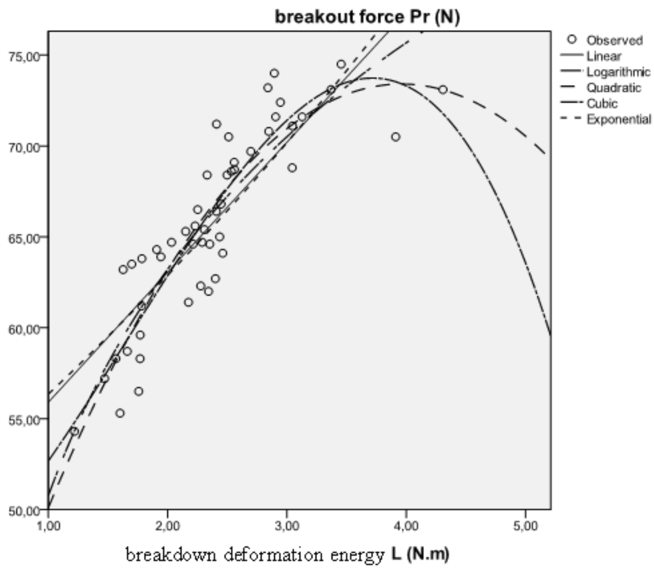

Fig. 2. Diagrama de dispersie sau Scatterplot.

Graphic representation as histograms (Fig. 1) is another way of checking the normality of distribution by viewing graphical differences between empirical and theoretical distribution (Gauss Curve). It finds that the distribution is below a normal curve to the left having a slight elongation (sk <0) and in terms of sharpness there is a platikurtic tendency (k <3) meaning that the results are scattered toward the mean. The values of the two indicators for assessing the normality of distribution were determined in Table 1.

Choosing the best regression and correlation model for the two studied variables, using SPSS, can be achieved by interpretation of the most important results of the output presented in Table 2 and the Scatterplot - Fig. 2.

From Table 2 it is observed that for each regression model we find in the Model Sumamary columns the determination report (R Square) and its testing with test F and in Parameter Estimates columns equation regression coefficients. Based on the R Square from the Summary Model ,it will decide the best regression model, finally, the more R Square is closer to value 1 the more the regression model it's most appropriate.

Analyzing the data in Table 2, we see that the highest value for R Square of all regression models are registered to function Cubic - by grade 3 (R Square = 0.819), the function Quadratic - function Grade 2 (R Square = 0813).

For the Cubic model we analyze the most important results of the output presented in Tables 3, 4 and 5

Table 3. **Model Summary**

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.905	0.819	0.807	2.281

The independent variable is *L* [N.m].

Table 3. Model Summary contains information concerning the correlation coefficient and standard error of the estimation. Note the correlation coefficient R (0.905) and determination coefficient

R Square (0.819) shows that between breakdown deformation energy to breakage and breakout force there is a link type parabolic Grade 3 (Fig. 3), direct and strong meaning 81.9% of the variance of the dependent variable (breaking strength) is explained by the regression equation.

In Table 4. ANOVA the important information is statistical test F which tests the global significance of independent variables (only one in the case of simple regression, the procedure acquires substance when multiple regression). In column Sig. critical probability of the test is displayed, Sig <0.05 confirms that the parabolic relationship Grade 3 between the two considered variables is significant, rejecting the irrelevant signification hypothesis of the independent variables in favor of the hypothesis regression model, is significant. They say that the test is a significant test of R Square.

The values shown in Table 5 column Unstandardized Coefficients B, help us write the equation regression for our model

$$y = a + bx + cx^2 + dx^3 \quad (1)$$

Where: a = (Constant); b = mechanical work; c = mechanical work **2; d = mechanical work **3

So the equation becomes:

$$y = 45.830 + 3.505 \cdot x + 4.172 \cdot x^2 - 0.833 \cdot x^3 \quad (2)$$

Table 4. **ANOVA**

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1081.134	3	360.378	69.237	0.000
Residual	239.431	46	5.205		
Total	1320.565	49			

The independent variable is *L* [N.m].

Table 5. **Coefficients**

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
L [N·m]	3.505	14.942	0.417	0.235	0.816
L [N·m] ** 2	4.172	5.725	2.639	0.729	0.470
L [N·m] ** 3	-0.833	0.695	-2.294	-1.199	0.237
(Constant)	45.830	12.390		3.699	0.001

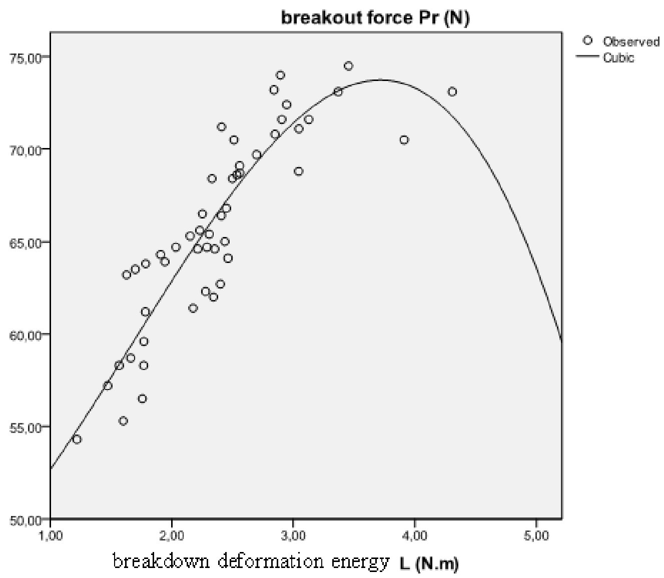

Fig. 3. Scatter Plot Chart for cubic model.

If we are testing coefficients regression equation using t test for the hypothesis that they would be significantly different from zero, it is observed that the significance threshold for the coefficients *b, c* and *d* is greater than 0.05, therefore these coefficients are not reliable to build a regression equation to define clearly a significant link parabolic grade 3 for the two variables.

In conclusion to choose the most appropriate regression model must simultaneously meet the three conditions of the table:

− high value R-Square;

− in the ANOVA analysis A value for F Sig less than 0.05;

− Sig values of test t for the independent variable of the equation coefficients to be below 0.05.

For the Quadratic model we will analyze the most important results of the output presented in Tables 6; 7; 8.

Table 6. **Model Summary**

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.902	0.813	0.805	2.292

The independent variable is *L* [N.m].

The mathematical model is appropriate, because it is respected the condition for $F_C > F_T$

$$F_c = 102.185 > F_{(2,47)} = 3.23$$

So the best regression equation for the two variables is Quadratic regression and has the following form:

$$y = 31{,}704 + 21{,}057x - 2{,}658x^2 \quad (3)$$

As seen in Fig. 4 was obtained as curvilinear regression line, which highlights deviations from linear model. This is especially useful when the correlation is low, which may be due to the fact that the relationship between variables does not follow a linear pattern. Analyzing the associated tables of the Quadratic model kept into account we can say that it is the best regression model because the value R Square (0.813)is high and the degree of significance of the F and t tests is Sig. 0.000 < α = 0.05. The correlation coefficient R = 0.902 confirms the existence of significant positive link between the breakdown deformation energy and breaking strength polypropylene yarns, designed to achieve webbing for manufacturing automotive safety belts. A more accurate idea gives us the determination coefficient R Square = 0.813. It tells us that 81.3% of the variation breaking strength is explained by the variation of the variable values breakdown deformation energy. We infer that the remaining 18.7% of the variation of the breaking force is explained by other variables unknown at this stage.

Table 7 *ANOVA*

	Sum of Squares	*df*	Mean Square	F	Sig.
Regression	1073.651	2	536.826	102.185	0.000
Residual	246.914	47	5.253		
Total	1320.565	49			

The independent variable is L [N.m].

Table 8 *Coefficients*

	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	*t*	Sig.
L [N·m]	21.057	3.009	2.507	6.999	0.000
L [N·m] ** 2	-2.658	0.566	-1.681	-4.694	0.000
(Constant)	31.704	3.857		8.220	0.000

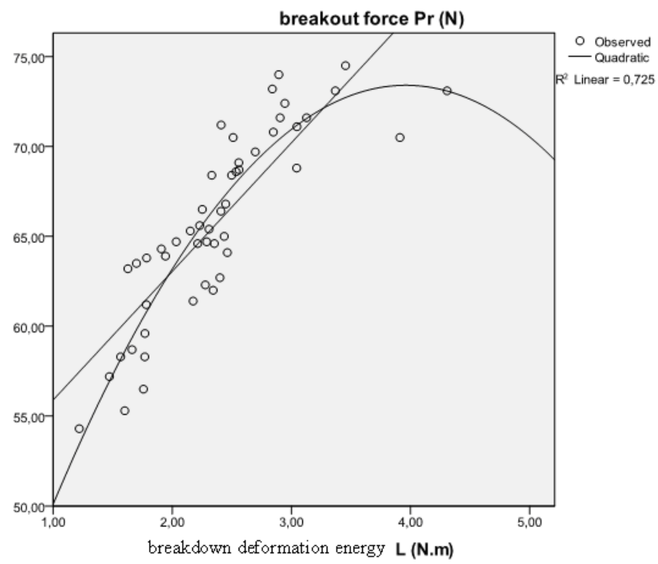

Fig. 4. Diagrama Scatterplot for the *Quadratic model.*

4. CONCLUSIONS

1. The simple regression is a prediction procedure, based on the correlation between two quantitative variables.

2. The precision prediction is given by the correlation coefficient between variables. As R is higher, so the prediction of the values of a variable (called criterion) starting from the values of the other variables (called predictor) is better. At the limit, when R = 1, the prediction is perfect.

3. The regression model is expressed graphically as a straight line whose route through the point cloud minimizes the distances between the line points and those of the correlation scatterplot.

4. The Skewness indicator value (-0.300) <0 in the case of the dependent variable, indicates the fact that the distribution is tilted to the right, with more extreme values to the left, and if the independent variable Skewness (0.784)> 0 - the distribution is tilted to the left having more extreme values to the right.

5. The Kurtosis indicator value (-0.612) <3 in the case of the independent variable, indicates a platikurtic distribution, a distribution flatter than a normal one, with values spread out over a longer interval around the mean, and in the case of a Kurtosis independent variable (1.145 <3) indicates a leptokurtic distribution, a distribution sharper than a normal one ; having more concentrated values around the mean and thicker tails which means high probabilities for extreme values.

6. The best regression and correlation model in this study was Quadratic model, because it meets simultaneously three conditions: high value for the coefficient of determination, R Square (0.813); the value from the ANOVA analysis for F Sig <0.05 and the values for Sig. t for the coefficients of the independent variable in the regression equation are below the significance threshold $\alpha = 0.05$.

7. The determination coefficient of R^2 shows that the variant of thedependent variable breakout force is explained by the variant of the independent variable breakdown deformation energy in proportion of 81.3%.

8. The existence of the strong and positive connection between breaking force and breakdown deformation energy of the polypropylene yarn is given by the correlation coefficient R = 0.902.

REFERENCES

[1] Akihito Takeshi Kurosawa, *Regression correlation coefficient for a Poisson regression model*, Computational Statistics & Data Analysis, Vol. 98, pg. 71-78, 2016.

[2] Rossi, F., Mirtchev, V., *Regression and Correlation*, Statistics for Food Scientists, ISBN: 978-0-12-417179-4, pg. 53-69, 2016.

[3] Hassani, S., Saidur, R., Mekhilef, S., Hepbasli, A., *A new correlation for predicting the thermal conductivity of nanofluids; using dimensional analysis*, International Journal of Heat and Mass Transfer, Vol. 90, pg. 121-130, 2015.

[4] Wuyi Ye, Yangguang Zhu, Yuehua Wu, Baiqi Miao, *Markov regime-switching quantile regression models and financial contagion detection Insurance*: Mathematics and Economics, Vol. 67, pg. 21-26, 2016.

[5] Jerin Jose, Jigisha N. Patel, Suprava Patnaik, *Application of regression analysis in K-SVD dictionary learning*, Optik - International Journal for Light and Electron Optics, Vol. 126, Issue 20, pg. 2295-2299, 2015.

[6] Hristian, L., Sandu, A. V., Manea, L. R., Tulbure, A. E., Earar, K., *Analysis of the Principal Components on the Durability and Comfort Indices of the Fabrics Made of Core-coating Filament Yarns*, Revista de Chimie (Bucharest), 66, No. 3, pg. 342-347, 2015.

[7] Neculăiasa, M., Hristian, L., *Metrologie textilă*, Vol. I, Ed. Performantica, ISBN 973-7994-36-1, Iaşi, 2004 .

[8] ****Manualul inginerului textilist*, Vol III, Sectiunea IX/Cap IX.6, pg. 292-315.

[9] Fulchiron, R., et. al., *Analysis Of Pressure Effect On The Crystallization Kinetics Of Polypropylene: Dilatometric Measurements And Thermal Gradient*, Modelling J. Macromol. Sciphys. Vol. (3-4), pg. 297-314, 2001.

[10] Dong Liu, Jiangping Ding, Xinyu Fan, Xinyao Lin, Yingdan Zhu, *Non-isothermal forming of glass fiber/polypropylene commingled yarn fabric composites*, Materials & Design, Vol. 57, pg. 608-615, 2014.

[11] Gejo, G., Kuruvilla J., Nagarajan, E. Tomlal, J., Skrifvars, M., *Thermal, calorimetric and crystallisation behaviour of polypropylene/jute yarn bio-composites fabricated by commingling technique*, Composites Part A: Applied Science and Manufacturing, Vol. 48, 2013, pg. 110-120, 2013.

[12] Rault, F., Pleyber, E., Campagne, C., Rochery, M., Giraud, S., Bourbigot, S., Devaux, E., *Effect of manganese nanoparticles on the mechanical, thermal and fire properties of polypropylene multifilament yarn*, Polymer Degradation and Stability, Vol. 94, Issue 6, pg. 955-96, 2009.

[13] Dick Mann, Jan C. Van den Bos, Arthur Way *Automotive Plastics and Composites*, *ISBN: 978-1-85617-349-0, pg 25-60,* 1999.

[14] Avram D., *Proiectarea firelor*, Ed. Performantica, Iasi, 2004.

[15] Tadic, B., Todorovic, P.M., Vukelic, D., Jeremic, B.M., *Failure analysis and effects of redesign of a polypropylene yarn twisting machine*, Engineering Failure Analysis, Vol. 18, Issue 5, pg. 1308-1321, 2011.

[16] Andrés, F., Vargas, V., Orozco, H., Francois, R., Giraud, S., Devaux, E., López, B.L., *Influence of fiber-like nanofillers on the rheological, mechanical, thermal and fire properties of poliypropylene: An application to multifilamen yarn,* Composites Part A: Applied Science and Manufacturing, Vol. 41, Issue 12, pg. 1797-1806, 2010.

[17] Mengjia Li, Y. Grace Hsuan, *Temperature and pressure effects on the degradation of polypropylene tape yarns-depletion of antioxidants,* Geotextiles and Geomembranes, Vol. 22, Issue 6, pg. 511-530, 2004.

[18] Hristian, L., Bordeianu, D.L., Iurea, P., Sandu, I., Earar, K., *Study of the Tensile Properties of Materials Destined to Manufacture Protective Clothing for Firemen,* Revista de Materiale Plastice, Vol. 51, no. 4, ISSN 0025 / 5289, pg. 405-409, 2014.

[19] Standards SR EN ISO 13934-1:2002-*Textiles-Tensile properties of fabrics −Determination of maximum force and elongation at maximum force using the strip method.*.

[20] Cojocaru, N., *Metode statistice aplicate in industria textile*, Ed. Tehnica, Bucuresti, 1986.

[21] Taloi, D., *Optimizarea proceselor metalurgice*, Ed. Didactica si Pedagogica, Bucuresti, 1983.

Despre autori

Drd. ing. **Alexandra (LUCA) DRUG**
Școala Doctorală a Facultății de Textile – Pielărie și Management Industrial

Absolventă a Universităţii Tehnice „Gheorghe Asachi“ din Iaşi, Facultatea de Textile-Pielărie – 2011, doctorand în cadrul Școlii Doctorale a Facultății de Textile, Pielărie și Management Industrial, în domeniul Inginerie Industrială din anul 2013. Domenii de competență: prelucrarea firelor și a țesăturilor.

Prof. univ. dr. ing. **Ioan CIOARĂ**
Universitatea Tehnică „Gheorghe Asachi”din Iași

Absolvent al Facultății de Textile din Iași -1977, doctor inginer din anul 1998, profesor la Facultatea de Textile – Pielărie şi Management Industrial din Iași, conducător de doctorat în domeniul Inginerie Industriala; domenii de competent: tehnologii de tesere, tehnologii de împletire, proiectare produse țesute și împletite cu destinație tehnică.

Şef lucr. dr. ing. **Liliana HRISTIAN**
Universitatea Tehnică „Gheorghe Asachi“ din Iaşi

Absolventă a Universităţii Tehnice „Gheorghe Asachi“ din Iaşi, Facultatea de Textile - Pielărie – 1997, doctor inginer din anul 2008, şef lucrări la Facultatea de Textile Pielărie şi Management Industrial – 2012. Domenii de competenţă: testarea şi controlul calităţii produselor textile, metode de prelucrare a datelor statistice.

Drd. ing. **Cristinel LUCA**
Universitatea Tehnică „Gheorghe Asachi“ din Iaşi

Absolvent al Universităţii Tehnice „Gheorghe Asachi“ din Iaşi, Facultatea de Construcţii şi Instalaţii – 2009, doctorand în domeniul Inginerie Industrială din anul 2013.