THE IMPLICATIONS OF THE TANDEM MOISTENING TIME IN THE SPINNING FRAME VAT – WATER TEMPERATURE UPON THE CHARACTERISTICS OF HEMP AND POLYPROPYLENE WET SPUN YARNS

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REZUMAT. Semitortul crud cu o densitate de lungime de 500 tex a fost prelucrat pe o maşină de filat în stare udă, dotată cu o cuvă specială care permite prelucrarea materialului fibros în condiții diferite, respectiv temperatura apei și durata de umezire a semitortului în timpul prelucrării. Experimentele efectuate au avut ca obiectiv analiza modificărilor coeficientului de variație a torsiunii firului (Y), care are o densitate de lungime medie de 69.23 tex și a fost filat din 33% cânepă și 67% polipropilenă, în funcţie de timpul de umezire (X1) și de temperatura apei din cuva maşinii de filat în stare umedă (X2). Metodele matematice de analiză dispersională, regresie și programe experimentale au fost aplicate cu scopul de a asigura valorile optime ale parametrilor dependenți. O valoare minimă pentru coeficientul de variație a torsiunii firului poate fi obținut în cazul în care timpul de umezire a semitortului este de aproximativ 8 secunde şi temperatura apei din cuva maşinii de filat în stare umedă este în jur de 31 °C.

Cuvinte cheie: cânepă, polipropilenă, filare în stare udă, torsiunea firului.

ABSTRACT. Raw roving with linear density of 500 tex was manufactured on a wet spinning frame, equipped with a special vat that allows material processing under different conditions, water temperature and moistening duration of roving during processing, respectively. The performed experiments has as objective the analyse of the changes in the variation coefficient of the yarn twist (Y) of the yarn, which has a average length density of 69.23 tex and was spun from 33% hemp and 67% polypropylene, according to the moistening time of the roving (X1) and the water temperature from the vat of the wet spinning device (X2). Mathematical methods of dispersion analysis, regression and experimental programs were applied with the aim to assure optimum values of the dependent parameters. A minimum value for the variation coefficient of yarn twist may be obtained if the moistening time of the roving is of approximately 8 seconds and the water temperature from the vat of the wet spinning device is about 31 °C.

Keywords: hemp, polypropylene, wet spinning, yarn twist.

1. INTRODUCTION

Following the evolution of production and consumption of polypropylene in recent years and the forecasts for the coming years it can be assumed that this fiber will remain one of the categories of basic raw materials for the textile industry [1]; [2]; [3].

Polypropylene fibers have low density, good resistance to abrasion and tensile strength, high biological and chemical resistance, as well as low wettability [4]. Fibers have very low water absorption capacity, property that favours textiles items which required a very quick drying. Analyzing the factors mentioned above, it is justified the market demand for this category of fibers for numerous technical articles, such as protective articles, packaging materials, bags and multi-ply yarns.

These products are not affected by the properties which disadvantage polypropylene fibers, namely: wettability almost zero, dyeing and printing difficult to achieve, static electricity accumulation, increased sensitivity to light, difficult dry cleaning.

These were the reasons that led to interventions for polymer modifying, aiming to improve the capacity of dyeing, the hydrophilicity and the resistance to light [4]; [5] [6]. By changing the polymer composition good results have been obtained which have led to achieve properties which allow to extend the field of use of the polypropylene fibers.

The other fibers that have been taken into consideration in this research were hemp fiber. These fibers have a wide application in the textile industry, i.e. all kinds of hemp pure yarns, hemp blended yarns, hemp woven fabrics, hemp knitted fabrics, hemp composite materials and nonwoven [7]; [8]; [12]. In order to obtain a specific set of yarn with increased uniformity, experiments were conducted with two types of fibers, which were considered incompatible, hemp and polypropylene.

Processing the roving obtained from the two types of fibers is possible only through wet spinning, when in the drafting process of moistened roving participate fibers dissociated by gelling the pectic substances from the middle lamella. Behaving as a lubricant, the gel controls the movement of fibers, increased in number, making it possible to enhance the yarn fineness. Meanwhile, it contributes to this result the process of drafting by fibers breakings [10] [11] [12] [6].

Given that it has manufactured a type of fibrous blend, about whom it could not be said with certainty how it will behave during processing on the wet spinning frame, experiments have been made following which it was tried to establish the optimal temperature of water from the vat of the wet spinning machine and the duration of roving moistening corresponding to a correct processing of fibers.

2. MATERIALS AND METHODS

The variables that might influence the coefficient of variation of the main physical and mechanical characteristics of the yarns and which have been considered were the water temperature and the moistening time of the roving in the vat with water of the spinning machine.

To adjust the temperature of water from the vat of the wet spinning machine at the levels required by the experimental program, on the vat were mounted electrical resistances, a thermostat and a sensor for temperature.

The modification of the interval when the roving is moisten in the water of the vat of the wet spinning machine can be done in two ways: through changing the supplying speed or through the modification of the length of the path that the roving takes in the vat.

The modification of the feeding speed, without affecting the drafting or the twisting of the obtained yarn, can be achieved practically on the machine through changing the belt pulleys D1 and D2, which are part of the first transmission after the electric motor of the spinning machine, as shown in figure 1.

Through changing this transmission ratio, the drafting and the torsion are not modified, but the working parameters after the feeding creel and the water vat will not be identical, as the speed of the working devices will change at the same time with the feeding speed. Therefore, although the same draft will be kept, with a different delivery speed and a different spindle speed, one cannot assert that the processing of fibers strand after the water tank could be done in the same conditions, so that no other influences might be suspected on the characteristics of the yarns, than the ones used in the experiment. Therefore, in order to follow the way in which the moistening time of the roving affects the characteristics of the yarns, the variant of modifying the path length through the water vat was chosen instead of the one in which the feeding speed was modified.

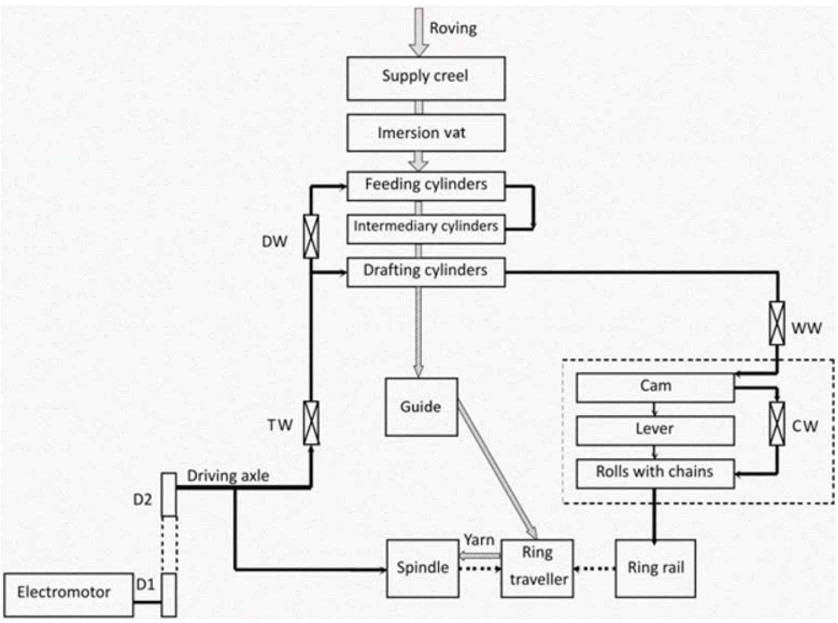

Fig. 1. The block diagram of the wet-spinning frame: D1, D2 – belt pulleys; TW – twist changing wheel; DW- drafting changing wheel; WW – winding changing wheel; CW – click wheel.

Table 1. **Minimum and maximum values of the independent variables**

Number	Independent variable	Measurement unit	Code	Minimum and maximum values
1.	Roving moistening time	[s]	X_1	2.23 - 24.60
2.	Water temperature	[°C]	X_2	20 - 90

Table 2. **Independent parameter values in the experimental field**

Codification	- 1.414	-1	0	1	1.414	Measurement unit	Range of variation
X_1	2.23	5.51	13.41	21.32	24.60	[s]	22,37
X_2	20	30.25	55	79.74	90	[°C]	50

To draw conclusions regarding the influence of wet spinning conditions on the coefficients of variation of the yarn twist the correlation analysis was used.

The two variables that were taken into consideration have been noted as follows:

− moistening time of the roving in the vat with water of the spinning machine – X_1;

− water temperature from the vat of the spinning machine – X_2.

The experiment presented in this paper aimed to the way in which the coefficient of variation of yarn twist (Y) changes, yarn with medium linear density of 69.23 tex, spun from raw roving with linear density of 500 tex, made of 33% hemp/ 67% polypropylene, depending on the roving moistening time (X_1) and the temperature of the water from the vat of the wet spinning machine (X_2). The twist of yarn spun in different conditions (different moistening times and different water temperatures) where measured according to the standardized methodology.

The experiments have been planned so as to be uniformly distributed throughout the experimental field and in such a way as to decrease the consumption of time and materials by reducing the number of experiments. For each independent variables were taken five values in the experimental field, at intervals which can be followed in tables 1 and 2.

It should be noted that the period chosen for the moistening time of the roving, although it seems very small, is equivalent to a path of roving through the vat with water of the wet spinning machine between 70 mm and 770 mm, at a feed rate of 1.87 m/min, which highlights the possible influence that the moistening time of the roving might have on yarn characteristics.

Testing of the normality of the resultative random variable was achieved through statistical software package STATISTICA. The variance being distributed approximately normally, standard deviation can be considered a random variable with a normal distribution. Therefore it can be accepted the idea that the coefficient of variation is normally distributed random variable. Planning of experiments was done using a rotatable composed centered program [13]; [14]; [15]. Total number of experiences for such a program could be calculated with:

$$N = 2^k + 2k + n_1 \qquad (1)$$

where: k is the number of independent variables; n_1 – number of experiences in the centre of experimental area.

For two variables studied, the total number of experiences was 13. For each of the 13 variants were taken samples that were subjected to the analysis.

One of the fundamental problems of correlation analysis is the selection of appropriate regression model because the manner in which this issue is resolved depends the confidence that can be given indicators obtained from the calculations.

The polynomial regression model was proposed as model. It has the following form:

$$Y = b_0 + b_{11} \cdot X_1 + b_2 \cdot X_2 + b_{11} \cdot X_{11} + b_{22} \cdot X_{22} + b_{12} \cdot X_1 \cdot X_2 \qquad (2)$$

In this equation, Y is the dependent variable, X_1, X_2 are independent variables, and b_0, b_1, ..., b_{12} are regression coefficients. Regression coefficients determination is performed by least squares, minimizing the sum of squared deviations of values calculated from those measured.

$$Q = \sum(Y - Y_c)^2;\ Q = \sum[Y - (b_0 + b_1 \cdot X_1 + b_2 \cdot X_2 + b_{11} \cdot X_{12} + b_{22} \cdot X_{22} + b_{12} \cdot X_1 \cdot X_2)]^2;\ Q = minimum \qquad (3)$$

Q will be a minimum value equating to zero partial derivatives of the above expression with respect to b_0, b_1, ..., b_{12}. This results in a system of equations with a number of unknowns equals to the number of regression coefficients.

3. RESULTS AND DISCUSSIONS

Regression equation resulting from testing the coefficients veracity and the adequacy model has the following form:

$$Y = 0.762 + 0.556 \cdot X_1 + 0.395 \cdot X_2 + 0.506 \cdot X_{12} + 0.206 \cdot X_{22} \qquad (4)$$

The influence of the two parameters, X_1 (roving moistening time) and X_2 (water temperature) on the coefficient of variation of yarn twist is evidenced by the value of multiple correlation coefficient, $r = 0,957$. The coefficients of the regression equation were verified using the Student test for a significance level of 0,05% .

Analyzing the regression equation (4) it can be noted that the interaction coefficient b_{12} is missing, which means that the effect of the simultaneous variation of the two parameters is not cumulative.

Analyzing the linear part of the equation it is noted that:

− between the two analyzed parameters, greater influence on outcome variable has the moistening time of the roving, as the coefficient of the independent X_1 variable is approximately 65% higher than that of the variable X_2;

− the linear part's signs are positive for both parameters; since the resultant is the coefficient of variation of yarn twist, the minimization of this function is evidently aimed at, for which reason it shall be analyzed the behaviour of the model for simultaneous variation of the two parameters X_1 and X_2, to the limits of experimental region.

Regarding the square parts of the equation it has been found that:

− the existence of both square parts for X_1 and X_2 confirms the presence of an well drawn surface, a rotational ellipsoid with a minimum point, which corresponds to the minimizing presence of the resultant;

− in this case too, it exists a difference between the values of the coefficients of the square parts, X_{12} having the coefficient with 146% greater than the one of X_{22};

− the positive sign of these coefficients has shown that the square parts influences the resultant by increasing, no matter the moving direction of parameters.

In figure 2 is represented graphically the variation of the dependent variable (Y) with changes in the independent variable (X_1) for $X_2 = X_{2c}$ and the variation of the dependent variable (Y) with the variation of the independent variable (X2) for $X_1 = X_{1c}$, being the values of the independent variables in the center of experiment.

Analyzing constant level curves shown in figure 3 it is observed that the elongation is in the direction of the axis X_2, which means that greater influence on Y has X_1, because smaller variances of this parameter causes the passing from one outline curve to another. As can be seen from the figure 3, the minimum value of the variation coefficient twist yarn is placed in quadrant three. Consequently, aiming at a reduced value of the coefficient of variation, for setting the parameters of technological process X_1 and X_2 , values placed in quadrants I, II and IV will be ignored.

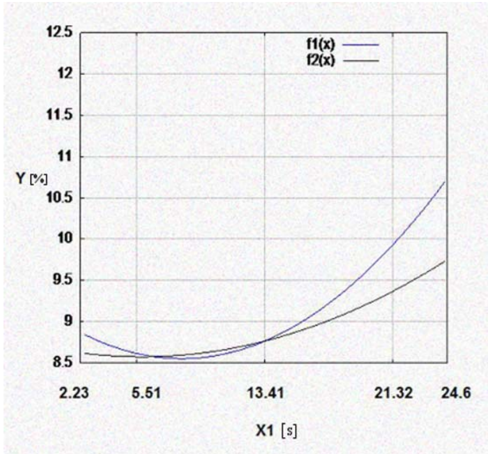

Fig. 2. Modification of the coefficient of variation of yarn twist (Y), %, depending on roving moistening time (X1), in seconds, for X2 = X2c (f1(x)) and modification of the coefficient of variation of yarn twist (Y), %, with changes in water temperature (X2), in °C, for X1 = X1c (f2(x)).

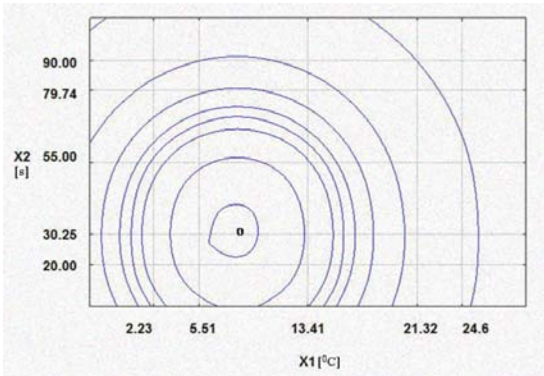

Fig. 3. Outline curves of constant level of the resultant characteristic (Y), the variation coefficient of the yarn twist.

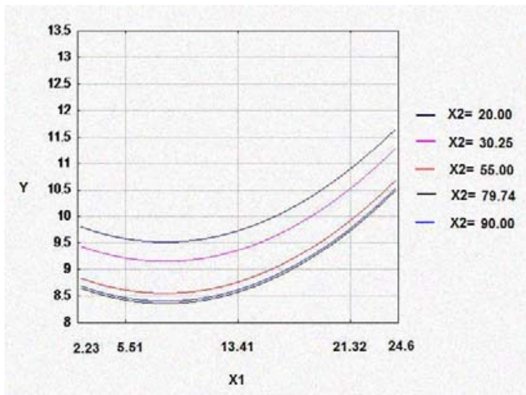

Fig. 4. The modification of the variation coefficient of the yarn twist (Y), %, with the moistening time of the roving (X_1), in seconds, for various values of temperature (X_2), in °C.

The answering surface in three-dimensional space of the resultant characteristic has confirmed the existence of a well-drawn surface with a minimum point, as shown in figure 5.

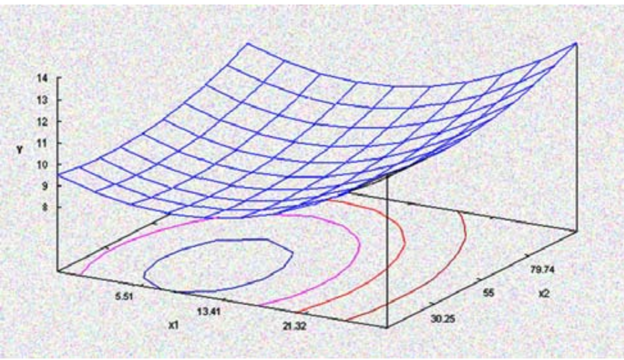

Fig. 5. The answering surface in 3D space of the resultant characteristic (Y), the variation coefficient of the yarn twist, %.

There are chosen a set of pairs of values X1 and X2, as near the minimum, value pairs that are supposed to generate the minimum values for the resultant characteristic (Y), the variation coefficient of the yarn twist.

Table 3. **Pairs of values X1 and X2 that generate the minimum values for the resultant characteristic, Y**

X1		X2		The variation coefficient of the yarn twist	
Code	Real	Code	Real	Calculated value	Measured value
-	[s]	-	[^{0}C]	[%]	[%]
-0,75	7,5	-1,09	28	8,367	7,63
-0,75	7,5	-1,01	30	8,365	7,96
-0,75	7,5	-0,87	33,5	8,365	7,84
-0,65	8,3	-0,97	31	8,357	7,58
-0,5	9,5	-0,77	36	8,378	7,89

The moistening time of the roving in the vat with water of the spinning machine and the water temperature were adjusted to values corresponding to the pairs of values taken and presented in table 3. The differences between calculated and measured values show that the mathematical model can be used to wet spinning parameters optimization.

4. CONCLUSIONS

In order to obtain yarns with increased uniformity, experiments were conducted with two types of fibers, which were considered incompatible, hemp and polypropylene. Processing the roving obtained from these two types of fibers is possible only through wet spinning, when in the drafting process of moistened roving participate hemp fibers dissociated by gelling the pectic substances from the middle lamella. Behaving as a lubricant, the gel controls the movement of fibers, increased in number, making it possible to enhance the yarn fineness. Meanwhile, it contributes to this result the process of drafting by fibers breakings.

Thus, from the technological point of view, aiming to the minimizing of the variation coefficient of the yarn characteristics, the values of the wet spinning parameters, the moistening time of the roving and the water temperature, have to be close to the center of experimental program, in the third frames. Because the moistening time of the roving has a greater influence on the variation coefficient of the yarn twist than the water temperature, it is recommended that the passing time of the roving through the water tank to be in the interval of 7.5 and 8.5 seconds.

A minimum value of the variation coefficient of twist for a yarn with average linear density of 69.23 tex, spun from 33% hemp/67% polypropylene, can be obtained if the water temperature from the vat of the spinning machine is about 31 ^{0}C.

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