Influence of Torsion Degree and the Elastomer Content on Yarn Characteristics

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Present requirements of the modern man impose the realization of textile products with an increased comfort that should provide, besides their basic functions, the conditions of easy motion, aesthetic aspect, easy maintenance etc. These requirements are conferred by the textile products containing elastomer. The development of elastomer fibers and filaments based on polyurethanes, as well as the progress in textile mechanical and chemical technologies, offer the possibility to obtain textile products with increased elasticity. Wool-types yarns with different torsion degree (twist factor 72÷128) and elastomer content between 4.5 and 11.5% have been realized. This work studies the influence of torsion degree and the elastomer content on yarn characteristics.

Keywords*: torsion degree, twist factor, elastomer, yarn, characteristics*

New spinning technologies appeared and were refined during the last decades, which led to the production of yarns with a structure different from that of the classical yarns. Yet, these yarn structures do not cover the entire range of classical yarns utilization [1-7]. By using new relatively simple devices fitted to the draft board and feed creel of the ring frame, one can obtain yarns with an aspect similar to that of classical yarns, yet with different structures and characteristics [8-15]. These yarns, currently named core yarns, elastomers or composed yarns, consist in a filamentary core covered with a fiber sheath. Manufacturing technology permits to realize various assortment ranges, which results in the diversification of yarns and textile products range, with increased aesthetic characteristics and comfort. The elastomer yarns included in textile products, even in reduced quantities, confer them characteristics that cannot be obtained with other fibers. The elastomer fibers included in textile products, depending on their destination, ranges between 2% and 50%, a content that provides an elasticity range between 15% and 60%. Unlike other chemical filamentary yarns, the elastomer yarns are only used in combination with textile yarns or fibers of other nature. The realization of these kind of structures is destined to provide a maximum utilization of the properties of the components of the final textile products (cloth, knitting, threads with different destinations etc.). Depending on its characteristics, the core confers to the unitary structure of composite yarn, and not lastly, to the final structure of the knitted or woven product, uniformity, resistance, elasticity and stability. The sheath yarns confer them a pleasant aspect, comfort, optimum finishing and dyeing conditions. One cannot apply the current methodologies used to characterize the classical yarns, to elastomer filaments or to yarns with elastomer core. Their high deformation and recovering capacity, besides the impossibility to be rendered evident with usual methods, have a negative influence on the values of some determined characteristics. This work studies the influence of the torsion degree and the elastomer content on wool-type yarns characteristics.

Experimental part

For the study of simultaneous action of two independent variables, namely torsion degree (twist factor) and elastomer content, on the physico-mechanical characteristics of elastomer-core yarns, a mathematical model was realized by applying experiment planning by means of the second order centered complex program. The program permits to describe the functional dependence of a dependent variable on two independent variables [1-6]. The study was performed for the elastic wool-type yarn of 19.23tex, with sheath of 55/45% PES/ wool S70, assortments with high quota in the elastic wool-type woven structures. The characteristics of the utilized basic material (core- elastomer filaments type Lycra 60dtex, sheath - PES and S70 wool fibers) are summarized in the table 1 (physical characteristics) and table 2 (mechanical characteristics).

The characteristics of the elastomer filaments – Lycra are: count 59.54dtex values corresponding to the relaxed state of the testing device), 15.24dtex, values corresponding to the tensioned state of the testing device, extension capacity 3.87, breaking force 65.05cN, breaking elongation 585.4%, tenacity 10.92cN/tex, initial module 0.75cN/mm^2. The elastomer participation quota in the core yarn was modified by modifying the draft at the draft board of the spinning machine and/or modifying the roving linear density.

The considered independent variables were: twist factor and elastomer content; yarns with twist factors of 72, 80, 100, 120 and 128 were realized, and the elastomer percentage varied within the interval 4.5 - 11.5%, namely 4.5, 5.5, 8, 10.5, 11.5%. Table 3 presents the variables coding [16-19].

Table 4 presents the characteristics of the yarns obtained based on the experimental matrix. As the mathematical model of the dependence between the independent variables x_1 and x_2 and yarn characteristics y, one proposes the regression equation under the form:

$$y = b_0 + b_1x_1 + b_2x_2 + b_{11}x_1^2 + b_{22}x_2^2 + b_{12}x_1x_2 .$$

The regression coefficients (b_1, b_2, b_{11}, b_{22}, b_{12}) were

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No.	Characteristics	U.M.	Determined values	
			Wool	PES 4/88
1	**Count**	dtex	3.98	4.51
		Cv%	21.75	0.9
2	**Medium length**	mm	56.4	82.1
		Cv%	48.2	26.8
3	**Short fibres 25 mm**	%	11.6	2.9
	40 mm	%	20.5	15.0
4	Long fibres 105 mm	%	12.9	8.05
5	Blade flaws small nop large nop agglomerations frail fibres	piece/g	2.55	0,18
		piece/g	0.89	0.10
		piece/g	0.80	0.18
		piece/g	-	0.015

Table 1
THE PHYSICAL CHARACTERISTICS FOF THE FIBRES FROM THE SHEATH

No.	Characteristics	U.M.	Determined values	
			Wool	PES 4/88
1.	Breaking force	cN	7.8	19.3
2.	Breaking elongation	%	28.6	31.4

Table 2
THE MECHANICAL CHARACTERISTICS FOF THE FIBRES FROM THE SHEATH

Independent variables	Cod				
	-1.414	-1	0	1	1.414
x_1 (twist factor)	72	80	100	120	128
x_2 (% elastomer)	4.5	5.5	8	10.5	11.5

Table 3
INDEPENDENT VARIABLES CODING

Table 4
CHARACTERISTICS OF THE YARNS OBTAINED BASED ON THE EXPERIMENTAL MATRIX

No.	Independent variables				Dependent variables								
	X_1		X_2		Count (tex)			Extension capacity	Breaking force		Breaking elongation		Tenacity (cN/tex)
	cod	real	cod	real	T_1	T_2	CV (%)		cN	CV (%)	%	CV (%)	
1	-1	80	-1	5.5	22.19	19.47	6.27	1.14	225.4	13.91	19.73	12.12	11.57
2	1	120	-1	5.5	20.28	19.52	6.18	1.039	265.6	13.60	19.37	9.80	13.61
3	-1	80	1	10.5	22.14	19.06	6.03	1.162	216.1	14.60	20.07	12.90	11.34
4	1	120	1	10.5	21.02	19.20	5.89	1.095	234.3	14.50	18.99	10.69	12.20
5	-1.414	72	0	8	21.51	19.02	5.94	1.131	198.7	14.21	19.50	12.30	10,47
6	1.414	128	0	8	19.96	18.94	5.77	1.054	256.8	15.07	18.44	11.04	13.56
7	0	100	-1.414	4.5	20.30	19.06	5.92	1.065	241.6	15.74	18.95	9.15	12.67
8	0	100	1.414	11.5	21.86	19.09	6.13	1.145	220.6	15.70	20.6	12.50	11.55
9	0	100	0	8	20.20	18.98	5.35	1.065	221.1	14.20	19.55	12.39	11.65
10	0	100	0	8	20.45	18.87	6.32	1.084	212.7	15.30	19.15	11.01	11.54
11	0	100	0	8	20.32	19.01	5.23	1.069	215.7	15.02	18.84	12.10	11.19
12	0	100	0	8	20.85	19.11	5.74	1.091	215.3	15.28	19.26	11.15	11.27
13	0	100	0	8	20.33	19.29	6.52	1.054	220.5	15.11	19.25	12.55	11.43

determined by means of the least squares method, using the experimental data automatic processing [20-26].

The regression equations of the physico-mechanical characteristics of elastomer-core yarns, in terms of the two independent parameters, resulted from testing the coefficients credibility and the model adequacy [6-12] are summarized in table 5.

From the analysis of linear numeric coefficients of the mathematical model, one can notice a 33% higher influence of the parameter x_1 - twist factor, as compared to the parameter x_2 - elastomer content. The variation of the two parameters determines opposite effects on the extension capacity. One can obtain high values of the extension capacity by diminishing the twist factor and

Table 5
THE REGRESSION EQUATIONS OF THE PHYSICO-MECHANICAL CHARACTERISTICS OF ELASTOMER-CORE OF WOOL-TYPE YARNS

No.	Characteristics	The regression equations	Multiple correlation coefficients
1	CV Count	$y = 5.833$	0.1009
2	Extension capacity	$y = 1.073 - 0.035X_1 + 0.024X_2 + 0.012X_1^2 + 0.019X_2^2$	0.9474
3	Breaking force	$y = 217.54 + 17.56X_1 - 8.78X_2 + 6.567X_1^2 + 8.242X_2^2 - 5.503X_1X_2$	0.9746
4	CV Breaking force	$y = 14.98 - 0.43X_1^2$	0.493
5	Breaking elongation	$y = 19.21 - 0.36X_1 + 0.28X_2 + 0.32X_2^2$	0.8187
6	CV Breaking elongation	$y = 11.84 - 0.78X_1 + 0.80X_2$	0.74
7	Tenacity	$y = 11.42 + 0.9X_1 - 0.4X_2 + 0.32X_1^2 + 0.37X_2^2 - 0.29X_1X_2$	0.978

increasing the elastomer content, while the increase of twist factor combined with the diminution of elastomer content will result in the diminution of the extension capacity.

Results and discussions

The coefficients of the quadratic terms, with a relative deviation of 58% in favor of the parameter x_2 (elastomer content) confirms the existence of a clean-cut surface with a point of minimum. The positive sign of the coefficients of the quadratic terms shows that they influence the resulative in the direction of the increase, irrespective of the direction of considered parameters variation. The effect of the simultaneous variations of the parameters x_1 and x_2 on the resultative is not cumulative- the interaction coefficient b_{12} is not significant. Figure 1 presents graphically the modification of the extension capacity (Y) as function of the modification of the twist factor (x_1) for $x_2 = 0$, and as function of the modification of elastomer content (x_2) for $x_1 = 0$.

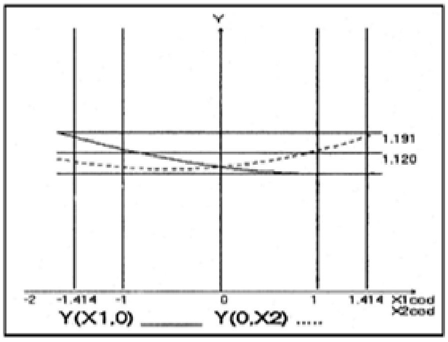

Fig.1. Evolution of the extension capacity (Y) (Y (x_1, 0) and Y (0, x_2))

From figure 1 one can see that for the same elastomer content the increase of the twist factor results in the extension capacity diminution, and for the same twist factor, the increase of the elastomer content results in the increase of the extension capacity. These effects are explicable, because the increase of the twist factor will increase the number of fibers fixed into the yarn structure, fibers that will diminish the deformation capacity of the elastomer from the yarn and implicitly that of the core yarn. For the same number of fibers fixed into the yarn, higher elastomer content implies also a higher deformation capacity, which is transferred to the core yarn.

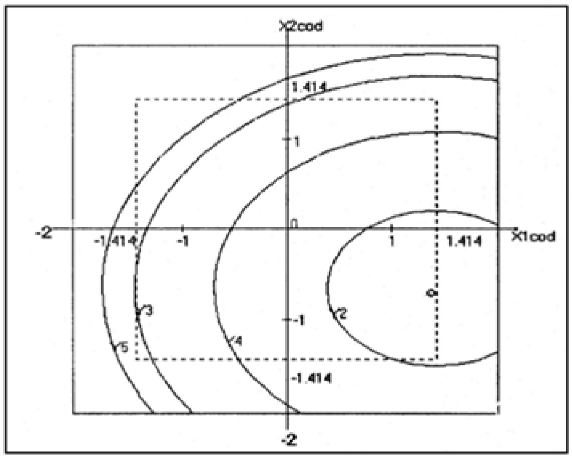

Fig. 2. Constant level curves for the extension capacity of the elastic wool-type yarns

From the analysis of the constant level curves presented in figure 2, it follows that the minimum value of the extension capacity is placed in the IV quadrant, in the point with the coordinates: (x_1 = 1.407; x_2 = 0.644), corresponding to the real values α_m = 127; elastomer content = 5.24%.

Maximum values of the extension capacity are placed in the II quadrant for the interval of coded values x_1 = (-1.414 +0) and x_2 = (0+ 1.414); real values: α_m = 72 to 100 and elastomer content = 8+ 11.5%.

Tenacity of elastomer-core yarns

In this case too, the value of the multiple correlation coefficient (0.978) confirms the strong correlation between the resultative characteristic - elastic yarns tenacity- and the independent variables- twist factor and elastomer content. The coefficients of the quadratic terms do not significantly differ (about 14% relative difference) and they influence the resultative in the increasing direction (additive signs are positive). The effect of the simultaneous variation of the two parameters is cumulative and they act in the direction of decreasing the resultative (b_{12} = - 0.295). The evolution of the elastomer core yarn tenacity (Y) in terms of the modification of one of parameters- Y(x_1, 0) and Y(0, x_2) is presented in figure 3.

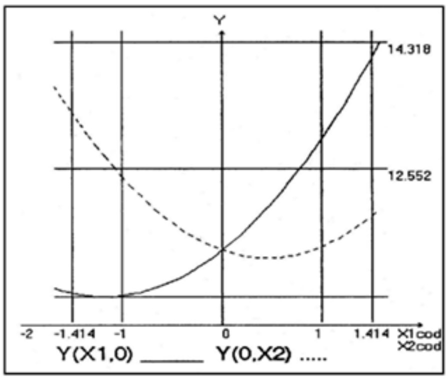

Fig. 3. Evolution of elastomer core yarn tenacity, Y (x_1, 0) and Y (0, x_2)

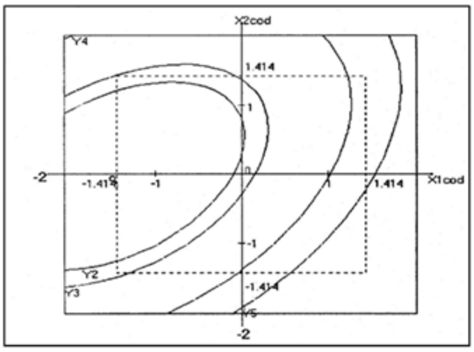

Fig. 4. Constant level curves for the tenacity of elastic wool-type yarns

For the same elastomer content (x_2 = const.), twisting increase determines the increase of the number of fibers fixed within the structure, contributing to the breaking force of the yarns and implicitly to their tenacity. For the same twist degree (x_1 = const.), the increase of the elastomer content results in the diminution of the number of fibers from the yarn section and accordingly, the diminution of the breaking force and of the tenacity of the elastomer-core yarn. The analysis of the constant level curves presented in figure 4 reveals that one can obtain maximum tenacities with values of the independent parameters situated in the IV quadrant; coded values x_1(0,1.414) and x_2(-1.414; 0), respectively real values: α_m = 100÷128 and elastomer content = 4.5÷ 8%.

The critical point of the experimental program is the point of minimum corresponding to the pair of coded values x_1 = -1.418; x_2 = - 0.021, and real values α_m = 72, elastomer content = 7.8% respectively.

Breaking elongation

The mathematical model of the breaking elongation presents with 95% probability the dependence of this characteristic on the twist factor and elastomer participation quota, the maximum deviation being 2.52%. Figure 5 presents the level curves for breaking elongation.

The values of the linear coefficients of the regression equation indicate, with a relative difference of about 22% in favor of the parameter x_1 and their additive signs, the different influence with opposite effects on the breaking elongation. The parameter x_2 (elastomer content) acts in

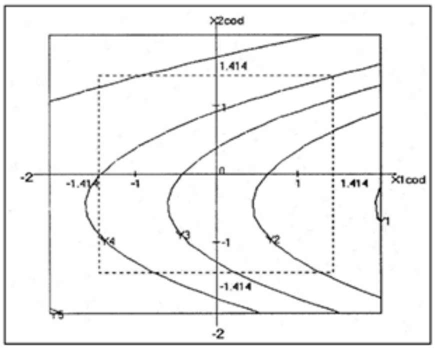

Fig. 5. Constant level curves for breaking elongation

the direction of increasing the values of the resultative characteristic.

Irregularities of the resultative characteristics

There are medium to strong interactions between the breaking elongation irregularities and the independent parameters x_1 and x_2, the correlation coefficient being 0.74. Breaking elongation irregularity shows a linear dependence on parameters, x_1 and x_2, without significant differences between them, but with opposite effects. The diminution of yarn twist combined with the increase of elastomer content results in the increase of breaking elongation irregularity. Under these conditions, besides total breakages (simultaneous breaking of the components), structural breakages can also appear (breaking and/or sliding of sheath fibers), when the breaking elongation presents values slightly increased as compared to those corresponding to the total breaking. In the case of elastic wool-type yarns with sheath of wool/PES, some structural breakages can be missed, due to high adhesion between fibers and their length. In the graphical representation of the constant level curves (fig. 6), the minimum values of breaking elongation irregularity correspond to values of the parameters x_1 and x_2, placed in the IV quadrant.

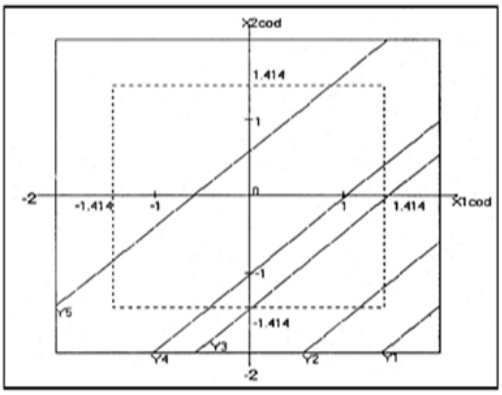

Fig. 6. Constant level curves for breaking elongation irregularity of the elastic wool-type yarns

The fact that the minimum values of breaking elongation irregularity are placed toward extreme values from the IV quadrant confirms the hypothesis that one can obtain stable structures of the core yarns with reduced elastomer participation quotas and especially with high twist factors. As the result of simultaneous study of the influence of the independent parameters: twist factor (x_1) and elastomer content (x_2) on the main characteristics of the core yarns-extension capacity and tenacity, one can ascertain the following: a. the variation of the independent parameters: twist factor (x_1) and elastomer content (x_2) determines opposite effects on these resultative characteristics; b. the increase of the twist factor (x_1) while maintaining constant the elastomer content (x_2 = const) determines the increase of tenacity and the decrease of the extension capacity; c. the increase of the elastomer content (x_2) while maintaining the same twist factor results in the increase of the extension capacity and the decrease of tenacity. For the performed experimental program, it followed that the minimum value of the extension capacity is placed in the IV quadrant, where the tenacity is maximum, while the maximum value of the extension capacity is placed in the II quadrant, but in this case, the tenacity has minimum values.

Conclusions

The twist factor has a bigger influence on the elastomer-core yarns tenacity than the elastomer content (relative difference between the linear coefficients is about 56% in favor of the twist factor; the twist factor is directly proportional with the resultative, while the elastomer content is inversely proportional). The breaking elongation shows a linear dependence on the twist factor and a parabolic dependence on the elastomer content. The values of the multiple correlation coefficients, of 0.1009 and 0.493, obtained for the linear density irregularity and breaking strength respectively, indicates the inexistence of a correlation or a poor connection between these characteristics and the independent parameters twist factor and elastomer content. In order to obtain elastic yarns that correspond to a certain purpose, a compromise is strictly necessary between their extension capacity and their tenacity, compromise that should provide normal yarn processability, as well as a transfer of the elastic characteristics to the products in which they are included.

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