Researches on the Realization of Wool-type Yarns with Elastomer Core on Classical Spinning Technology

I. Characterization of specific behaviour of elastomer-core yarns

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Utilization of relatively simple devices fitted for the ring frames permits the realization of yarns with filamentary elastomer core. The aspect of yarns is similar with that of the classical yarns, but their structure and characteristics are very different. Depending on the core-sheath combination, filaments and fibers nature and characteristics, the quota of components participation, yarn twisting degree etc., the range of these yarns assortment is practically unlimited. Due to the large capacity of deformation and recovery of the elastomer filaments, the classical methodologies used to determine the classical yarns characteristics cannot be applied to the elastomer-containing yarns, and these yarns show specific indicators for characteristics assessment. This work presents a synthesis of some ample researches on the methods and characteristics of wool-type yarns with elastomer core, as well as the transfer of elastomer filament characteristics to the composite yarns that contain elastomer.

Keywords: elastomer, core yarns, staple fibres clasic spinning process, characteristics of wool-type yarn

Within the general tendency to diversify the assortment, the yarn manufacturers have developed new spinning technologies able to offer advantages in terms of productivity and economic efficiency and to ensure competitive products realization. The new technologies have created mutations in the structure of the assortments range of yarns destined to knitted articles [1-5]. Due to their structure, these yarns impose an adequate adjustment of the technological parameters, leading to the development of knitted or woven structures with targeted properties and characteristics depending on the chosen destination. Through classical spinning technology, using certain procedures, one can obtain new yarns structures. Utilization of devices with a simple design adapted to the drafting system and the feeding screen of the ring frame enable the realization of yarns with aspect similar to that of the classical yarns, but with very different structures and characteristics [6-8].

In the specialized literature, one can find such yarns under the name of *core*, composed, reinforced or composite yarns. They have in their structure a filamentary core coated with a layer of fibers (sheath). Each of the constituting components of the obtained composite yarn has certain defining properties that will impose themselves, thus influencing the properties of the final textile product (fabric, knitting, sewing thread). Namely, depending on its characteristics, the core offers the textile product uniformity, elasticity, dimensional stability, durability etc., while the sheath fibers offer a pleasant touch, wearing comfort, finish and adequate dyeing [6-10].

The polyurethane fibers (Elastan or Spandex) are only produced as filamentary yarns and are used in nude or as coated yarns (composite yarns). The principle of realization of elastomer-core yarns on the ring frame consists in simultaneous feeding of the fore yarn and filamentary core in the drafting board. The transfer of elastomer fibers elasticity within the structure of the elastomer-core yarns is only possible through previous elastomer tensioning prior to composite yarn formation. The figures 1 and 2 present as an example yarns with different structures realized on the ring frame [11-15].

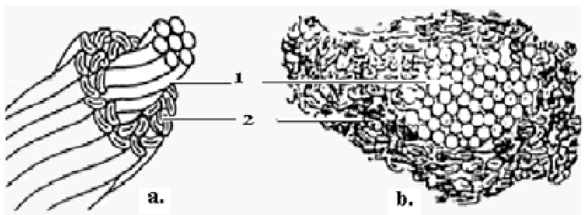

Fig. 1. Cross section of yarns with core and sheath of fibers obtained on the ring frame: a - longitudinal section; b - cross section

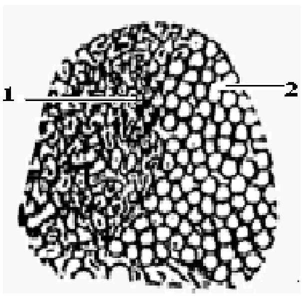

Fig. 2. Cross section of the side-by-side yarns

The elastic filaments are included in the textile structure under different form: a - nude yarns, especially in the knitted structures; b - filaments wrapped or twisted with spun yarns and/or chemical filamentary yarns of other nature (polyamide, as a rule); c - filaments wrapped with stapel

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fibers; d - yarns obtains from elastomer fibers and stapel blend.

There are several spinning procedure to obtain composite yarns [16-19], among which one can mention Rotofil procedure; Novacore procedure, Repco- Sepco-Selfil procedure, differentiate torsion procedure, Parafil spinning procedure, Prenomit-on spinning procedure. As an example, figure 3 presents the aspect of the yarn obtained through Repco- Selfil procedure, and figure 4 the aspect of the yarn obtained through differentiate torsion procedure. Figure 5 shows the basic principle for obtaining composite yarns through Novacore procedure [1-7].

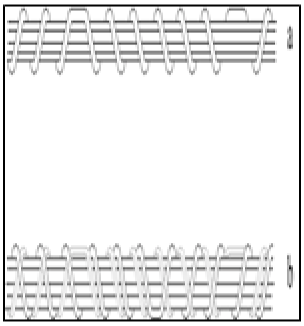

Fig. 3. Aspect of the yarn obtained through Repco-Selfil procedure:
a - after the first wrapping;
b - after the second wrapping

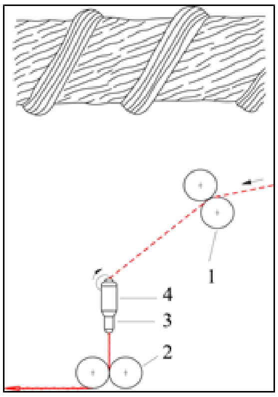

Fig. 4. Aspect of the yarn obtained through differentiate torsion procedure: 1 - draft board cylinders; 2 - bored spindle; 3 - bobbin with filamentary yarn

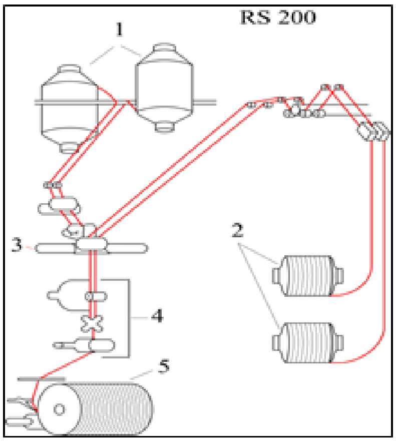

Fig. 5. NOVACORE procedure to obtain core yarns: 1 - roving spool; 2 - spinning bobbin; 3 - pendular pressure arm; 4 - at 200 device; 5 - deposit pattern

The main structures of core yarns on the ring frames are: yarns with fiber core and fiber sheath; yarns from double spun fiber (side-by-side fibers or parallel fibers); yarns with filamentary core and fiber sheath; doubled yarns from spun fibers and core yarns; doubled yarns with core; doubled yarns from core yarns [20-26].

Elastomer filaments show high breaking strains, have high tenacity at medium elongation, unlike the textured or rubber filaments. Textured filaments included in the textile products confer them bulkiness and less elastic effects, and in the case of rubber, a increased content is necessary (due to filaments thickness) to obtain an acceptable elasticity, which restricts the range of textile products in terms of thickness [27-33]. The polyurethane fibers (Elastan or Spandex) are used in knitted products and in nude to obtain a wide range of products: post-surgery products (brassieres, under things and vests), products for treatment and care (contention stockings, compressive supports for knee, arm, anti-cellulites stockings etc.), anti-bedsore pillows etc.

Among the fields of utilization of articles containing composite yarns, one can mention, in terms of the combination of the two yarns: technical textiles (waterproof, fireproof) military textiles, knitted products (corset ware, medical articles, outdoor sport ware, etc.). At knitted articles, the content of filaments with increased elasticity can be provided by including the filament into the knitting by means of positive feeding devices attached to the knitting machines or by using coated elastic fibers [34-39]. At woven articles, the elastomer content can only be provided by using elastic yarns included in the warp or weft systems or in both systems. In the knitting factories, there is rubber tickle machines on which one can obtained a limited range of elastic yarns, generally used for gaskets [40-45]. This work presents a synthesis of some ample researches meant to obtain and produce a complex characterization of the wool-type yarns with elastomer core, as well as a synthesis of the transfer of elastomer filaments characteristics to the composite yarns characteristics.

Experimental part

On the classic spinning system, there were achieved yarns of wool type, with elastomer core; on a spinning machine with rings of FLP type, adjusted for the spinning of yarns with elastomer core, there were made composite yarns. For the core, we used 60dtex elastomer filaments of Lycra type and for the sheath, fibrous array of 55% PES and 45% S70 wool. The characteristics of utilized raw materials (core-elastomer core type Lycra 60dtex- PES fibers, and wool S70) are summarized in tables 1 and 2 [6].

Table 1
THE PHYSICAL AND MECHANICAL CHARACTERISTICS FOF THE FIBRES FROM THE SHEATH

No.	Characteristics	U.M.	Determined values	
			Wool	PES 4/88
1	Count	dtex(μm)	3.98 (19.60)	4.51
		Cv%	21.75	0.90
2		mm	56.40	82.10
	Medium length	Cv%	48.20	26.80
3	Short fibres 25 mm	%	11.60	2.90
	40 mm	%	20.50	15.00
4	Long fibres 105 mm	%	12.90	8.05
5	Breaking force	cN	7.80	19.30
6	Breaking elongation	%	28.60	31.40
7	Blade flaws	piece/g	2.55	0.18
	small nop.	piece/g	0.89	0.10
	large nop.	piece/g	0.80	0.18
	agglomerations frail fibres	piece/g	-	0.015

No.	Characteristics		U.M.	60 dtex
1	Count	T_1^x	dtex	59.540
		T_2^x	dtex	15.240
2	Extension capacity		-	3.874
3	Breaking force*		cN	65.050
			Cv%	7,220
4	Breaking elongation*		%	585.40
			Cv%	10.71
5	Tenacity		cN/tex	10.92
6	Initial module*		cN/mm^2	0.75

*The determined characteristics with a pre-tensioning force of 0,01cN/tex;
T_1^x - Values corresponding to the relaxed state of the testing device;
T_2^x - Values corresponding to the tensioned state of the testing device

Table 2
THE CHARACTERISTICS OF THE ELASTOMER FILAMENTS – LYCRA

Aspects concerning the processing of elastomer - containing composite yarns

Our investigations have revealed that the value of mechanical draft influences both the spinning process and the elastic characteristics of the core yarn, namely: a - the higher the value of mechanical draft, the higher the elasticity of the elastomer core; b - going beyond certain values determines the breaking of elastomer filaments in the feeding zone or later in the yarn; the breakages within the feeding zone can be noticed and repaired by diminishing the mechanical draft, while the elastomer breakage after yarn formation (hidden breakage) cannot be seized during spinning, because the processing does not stop; this kind of breakages occur in the spinning balloon or after winding. These are only noticed through an organoleptic analysis of the relaxed yarn, as elastic portions alternate with the classical ones in the yarn [1-6, 46].

Processing under normal technological conditions and obtaining quality yarns is possible by establishing the mechanical draft in terms of the maximum elongation which elastomer can stand without diminishing its elastic properties. The elongation (1%) for which the elastomer preserves its elastic properties corresponds to filaments elastic limit and it can be determined by means of stress-strain diagram [3-10, 47-51]. The elastomer core yarns must be produced with higher torsion degrees as compared to classical yarns with equivalent linear density. High torsion degrees ensure the stability of core yarn structure, as well as the uniformity of elastomer core coating with fibers, by facilitating the torsion propagation as close as possible to the attachment line of the delivery rollers. The modification of elastomer participation quota within the core yarn was realized by modifying the drafting in the drafting board of the spinning machine and/or modification of the yarn linear count.

Choice of parameters and range

The chosen independent variables were torsion degree and elastomer content; yarns with torsion degrees of $\alpha_m = 72$, $\alpha_m = 80$, $\alpha_m = 100$, $\alpha_m = 120$ and $\alpha_m = 128$ were realized, and the elastomer percentage varied within the range 4.5 - 11.5%, namely 4.5, 5.5, 8, 10.5 and 11.5%. The chosen dependent variables were the yarn characteristics (extension capacity, tenacity, irregularities of breaking load, breaking elongation, coefficient of extension capacity transfer and the coefficient of transfer of the raw materials

No.	Characteristics		U.M.	Yarns with core	
				$\alpha_m = 80$	$\alpha_m = 120$
1	Yarn count	T_1^X	tex	25.43	22.34
		T_2^X	tex	18.98	18.94
			CV%	7.77	6.03
2	Extension capacity		-	1.34	1.18
3	The filament count in yarn	T_1^X	tex	2.185	1.79
		T_2^X	tex	1.510	1.52
4	The extension capacity of the filament in yarn		-	1.37	1.115
5	Participation sheath ratio elastomer		%	92.05	91.98
			%	7.95	8.02
6	Breaking force		cN	202.9	227.4
			CV%	19.08	20.6
7	Breaking elongation		%	21.56	21.65
			CV%	13.23	13.16
8	Tenacity		cN/tex	10.69	12.00
9	Torsion		tors/m	610	871
			CV%	7.17	6.66
			αtex	2657	3760
10	The real elongation of the filament in the yarn		%	394	392

Table 3
THE CHARACTERISTICS OF THE YARNS $\alpha_m = 80$, $\alpha_m = 120$

T_1^X - Values corresponding to the relaxed state of the testing device
T_2^X - Values corresponding to the tensioned state of the testing device

resistance to the yarn resistance. The characteristics of the classic yarns with elastomer core, α_m = 80, α_m = 120 are show in table 3 [6].

Results and discussions

Specific methods to assess the elastomer filaments characteristics

The high deformation and recovery capacity of the filamentary core is transferred to the composite yarn, which imposes the determination of the core yarn characteristics through other methods than those applied to the classical yarns [4-10, 48].

In order to determine *the linear density of filamentary elastomer yarns,* one has studied as an example the stress-strain diagram plotted for a yarn made of Lycra 60dtex elastomer filaments realized with standardized tension of 0.01cN/tex; The linear densities determined for the classical yarns will have erroneous values, for which reason, as the result of our own studies [1-8], one has concluded that the optimum value of the pre-tensioning necessary for the determination of linear density of elastomer filamentary yarns is of 0.01cN/tex, and the samples length is up to 1000mm [3-10].

By tensioning the elastomer prior to its incorporation in the composite yarn structure, the elastomer yarn elasticity is transferred to the ulterior structure of the elastomer core yarn. When the pre-tensioning value is big, the elastomer core composite yarns will be more elastic, but going beyond a certain limit will result in the diminution of the deformation recovery capacity, with implications on the quality characteristics of the core yarns and on the spinning process quality. One has thus realized that it is necessary to adopt a certain optimum admitted value of this tensioning, a value that permits the integral utilization of elastic capacity of the filamentary elastomer yarn within the structure of the composite yarn [4-10].

In order to assess the deformation capacity of elastomer filaments, one has proposed the utilization of a new index, named *extension capacity* (Ce) as the elongation to which one can subject an elastomer yarn without significantly modifying its elastic properties. This index can be determined through: a. utilization of stress- strain diagram, from which one establishes the elongation corresponding to the elastic limit; b. determination of linear density in relaxed state (pre-tensioning 0.01cN/dtex) and tensioned state (3cN/tex) for the filamentary elastomer yarn, 5cN/tex for the elastomer- core yarn) [5-9]. The knowledge of the extension capacity offers information on the maximum elongation that a composite yarn with elastomer core can stand.

The tension characteristics (force and breaking elongation) of elastomer filaments can be determined on tensile testing machine used for classical yarns, with forces of 0.01cN/tex, sample length of 50mm or 100mm, depending on: a. possibility to adjust the inter-clamps distance; b. maximum limit of the deformation that can be recorded by the apparatus [1-8, 49].

The determination of elastomer content within the composite yarns structure is necessary and important in order to establish the rigorous utilization field during the functional and technological design stages, as well as in designing the productivity of the woven or knitted structures. During our researches [6-10] meant to determine the elastomer content, sample tensioning at 5cN/tex was performed, this value allowing to determine the linear density of both the composite yarn (T_F) and of the elastomer filament included in the yarn (T_T). The elastomer content E(%) was computed with the relation E = T_E/T_F x 100%. The real elastomer extension within the structure of yarns with elastomer core (I_r) is defined by the relation: $I_r = \frac{T_{1E}}{T_{2E}} \cdot 100\ (\%)$,where T_{1E} is the linear density of the fed elastomer filament (tex), and T_{2E} is the linear density of the elastomer filament from the composite yarn tensioned at 5cN/tex, is the same as used for the determination of participation quota of the components from composite yarn structure [2-10].

Dynamometric characteristics of elastomer-core yarns

The elastomer-core yarns can be tested according to the methodology currently used for classical yarns (inter-clamps distance - 500mm, pre-tensioning 0.5cN/tex). Yet, while the classical yarns are destroyed through sudden breaking under the action of axial tensile force [5-10], in the case of core yarns one can distinguish the following breakages types: breakages at high elongations (produced through yarns sliding through the sheath, followed or not by elastomer core breakage); simultaneous breakages (provoked by simultaneous destruction of the two components).

Breakages at large elongations

At small torsions, the sheath fibers are not fixed within the structures, and therefore, during the axial traction stress, the yarn breakage occurs in stages: stage 1. sheath destruction by fibers sliding along the elastomer core (sheath fibers do not participate with their own resistance to the yarn resistance); stage II. filamentary core breakage. Under these conditions, the values of breaking force and elongation of the composite yarn are close to those of the elastomer filamentary yarn, which constitutes the core of the composite yarn.

The increase of the torsion results in fibers fixation within the structure of the composite yarn, and yarn breakage (structural breakage) occurs in stages: stage I- sheath destruction through yarns sliding and/or breakage; stage II- tensile strength is taken over by short core segments and segments without sheath respectively. After consuming the first stage, the tensile strength does not suffer essential modifications; the elongation gets higher values, yet without reaching the breaking elongation of the elastomer filamentary yarn. *At big torsions*, most of the sheath fibers are fixed and the tensile behavior of the blended yarn is similar to that of the classical yarn. Composite yarn destruction occurs through simultaneous breakage of the two components. For a certain yarn structure, there can be two or even three breakage types. The frequency of occurrence of a certain destruction (breakage) type of the three depends on the number of fibers fixed in the yarn structure, sheath fibers quality (count, length etc.), quotas of components participation and the degree of torsion of the constituent blended yarns. For the same yarn structure, given the appeared inherent non-uniformities (non-uniform fibers distribution, torsion etc.), two or even all three previously mentioned yarn breaking types can occur. The different behavior at mechanical stresses of the blended yarns, as compared to the classical ones (from short fibers) has also direct implications on the subsequent processing and the aspect of the realized textile structures. This behavior presumes introduction of other characteristics and specific assessment indices [5-10], such as breaking load at large elongations (S_M), elongation (A_M), structural load (S_s), simultaneous breaking load (Sm) and elongation (A_m).

Breaking load at big elongations (S_M) is an index specific for composite yarns at which the sheath fibers are not fixed within the structure and, during the tensile stresses, slide with respect to each other and the filamentary core. S_M represents the tensile strength, which provokes composite yarn breakage, by breaking only the filamentary core, without breaking the sheath. The elongation (A_M) is the elongation corresponding to the breaking load at big elongations. The structural load (S_s) is defined as the axially applied force, which provokes the breakage of the composite yarn structure through sliding and/or breaking of the sheath fibers, without breaking the filamentary core. Elongation (A_S) is the elongation corresponding to structural breaking load. Simultaneous breaking load (Sm) is the traction force that provokes yarn destruction by simultaneously breaking the two components. The elongation (A_m) is the elongation corresponding to simultaneous breaking load.

The destruction of the composite yarn through tensile stress occurs differently than that of similar classical yarns [4-10], namely: a. at small torsions, the sheath fibers are not fixed in the yarn structure; accordingly, at tensile stress, yarn breakage occurs in stages, namely in a first stage the sheath is destroyed by fibers sliding along the core, and in the second stage the filamentary core is broken; in this connection, the values of the breaking loads and elongations of the composite yarn are close to those of the filamentary yarn; b. the increase of torsion entails the fixation of some sheath fibers in the yarn structure, for which reason the yarn breakage also occurs in two stages: in the first stage, the sheath is destroyed due to fibers sliding and/or breaking and in the second stage the traction force is taken over by core segments without sheath. After sheath destruction, the value of the tensile strength suffers no essential modifications, and the elongation records higher values, yet without reaching the value of the filamentary yarn breaking elongation. c. At high torsions, most of the sheath fibers are fixed in the yarn structure and the traction behavior of the composite yarn is similar to that of the classical yarn; the destruction of the composite yarn occurs through simultaneous breakage of the two components (sheath and core). Other indices that assess the breakage behavior of the composite yarns are: breakage frequency at large elongation, F_M; frequency of sheath destruction through fibers sliding and/or breaking, F_s; frequency of simultaneous breakage, F_m [4-10].

At elastomer-core yarns, for testing conditions similar to those for classical yarns (sample length 0.5m, pre-tensioning 0.5cN/tex), breakages at big elongations, even if they occur, cannot be recorded because the deformations exceed the apparatus recording possibilities. The yarns at which one records breakages at big elongations or structural breakages, do not have a stable structure, having thus a negative influence on yarn behavior during the ulterior mechanical processing. The structure is considered stable from a structural standpoint if all the yarn destructions occur through structural breakages (Fe = 100%, Fs = F_M = 0). Accordingly, one can conclude that for elastomer-core yarns with stable structure, the determination of the breaking force and elongation can be carried out according to the methodology used for classical yarns.

The analysis of the contraction of elastomer-core yarns under the influence of heat treatments, correlated with the elastomer content, has revealed that a contraction occurs at temperatures ranging between 120 - 160°C. Temperatures between 160 and 200°C provoke a phenomenon opposite to contraction [50]. Our researches concerning the resistance transfer from the raw material to the core yarn resistance revealed the following aspects [3-9, 50, 51]:

a. the diminishing of the elastomer content from the yarn which is due to the increase of the elastomer elongation from 200 to 400% determines increases of the C_u coefficients with 3 ÷10.5%. The transfer C_u coefficients have lesser values in the case of the core yarns than in the case of classic yarns with count equivalent to the fibrous roving in the sheath.

b. The quality of the fibers in the sheath influences the values of the transfer coefficients of the yarns strength in the strength of the elastomer core yarns.

Conclusions

The work presents the synthetic results of researches concerning the realization of wool-type yarns containing elastomer, on the classical spinning system, and the characterization of specific behavior of elastomer-core yarns. The large capacity of deformation and recovery of the filamentary core is transferred to the composite yarn, and determines a specific behavior, which requires specific methods and indices to characterize these yarns. The work concisely defines indicators to assess the traction resistance and deformation of core yarns, heat treatments behavior of the composite yarns, methods to determine core yarns characteristics that differ from those currently applied to the classical yarns.

As in the case of elastic wool-type yarns, the real linear yarn count does not significantly differ from the designed value; the recorded deviation do not exceed the imposed limits for classical wool-type yarns. The irregularity of this characteristic does not depend on the variation of the studied independent parameters. The influence of the two independent variables on the resulting characteristics reveals, through the value of the coefficient of multiple correlations – 0.9474, indicates strong connections between the torsion degree, elastomer content and extension capacity.

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