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Quality of Wool-Type Compact Yarns from Twisted and Rubbed Roving

Abstract
This article presents a method of adapting classical ring spinning machines to compact spinning. Technological investigations carried out by the authors into the quality of yarns obtained by this system are described. In order to realise this aim, a reconstruction of the drawing apparatuses of ring spinning machines were made basing on mechanical condensing of the fibre stream in the drawing zone. This latter was obtained by using a Solospun-type device. Thanks the reconstruction carried out, a modified drawing apparatus was obtained suitable for compact spinning of wool-type yarns.

Key words: *ring spinning machine, Duo-Roth-type drawing apparatus, Solospun-type compact drawing apparatus, wool, polyester fibres, fibre blending, yarn, quality parameters.*

■ Introduction

The demands for textile products have been rising continuously. The most significant requirements are the product quality, the use comfort, the products' aesthetics, and the hygienic properties, and decisive about all them is mainly the yarn quality. Yarns of the highest quality are characterised by small unevenness of the linear density, high strength, high elasticity, softness, and smoothness.

The problem of the increasing demand for high quality domestic yarns in Poland may be solute by increasing the quality of ring-spun yarns. A significant increase can be obtained by using the compact spinning system which was confirmed by many research works and industrial practice. The system consists in inserting a pneumatic condensing zone at the output of the drawing apparatus [8, 10, 28] resulting in liquidation or a significantly decrease of the twisting angle which is the main cause of yarn breakage.

Compact spinning creates new possibilities for ring spinning and improve the quality of the yarns manufactured [4, 5, 12, 28]. As have indicated Artz [1] and others [3, 8, 9, 14, 18, 20, 22, 24, 26, 27, 36], compact spinning is a real innovation in spinning staple fibres. Compact spinning allows us to manufacture yarns of decreased hairiness and increased strength, and therefore compact yarns are generally used for manufacturing high quality woven and knitted products.

■ The principle of compact spinning

Investigations into compact yarns are carried out since 1991 [2, 4, 7, 15 – 17, 19, 21, 23, 25, 26, 29 –33], whereas the first industrial compact spinning frame was build in 1995.

In classical ring spinning, a twisting angle is formed while yarn is spun (Figure 1.a). A fibre stream of a given width is led to the delivery rollers [26]. This width depends on many factors, such as linear density, roving twist, and drawing ratio of the drawing apparatus. After leaving the delivery rollers, the fibres are condensing in the twisting triangle, and next screwed into the twisted fibre stream. During twisting, the fibres, which lay around the symmetry axis of the stream, are arranged in the middle part of the stream, and the border fibres form the outer layer which insert a pressure on the remaining fibres [10]. The fibres, which lay in the twisting angle, are affect by different tensions. The highest tensions are inserted on the fibres positioned at the triangle boundaries, the smallest those which are in the middle. Therefore, over further processes, while yarns or the products manufactured from yarns are affected by tensions, the fibres, which are placed in the yarn cross-section, do not break at the same time. First break the fibres which are affected by the highest tensions in the twisting angle. This explains why the yarn tenacity is smaller than the tenacity of singular fibres [31]. The twisting angle cannot gather all fibres. Many of the border fibres remains free, forming the spinning fly, or are twisted into the yarn in a fully not controlled process, increasing the yarn hairiness (Figure 1.b). In a spinning frame with a compact drawing apparatus, the twisting angle is eliminated or minimised. The fibre stream is

condensing after it left the main drawing zone [26, 35, 37, 40, 41] as the result of the negative pressure existing in the condensing elements.

Air in the condensing elements causes fibre rotation around its own axis and condensing of the fibres' stream. The twisting angle decreases, so that all fibres, which are placed in the fibre stream, can be gathered and twisted into the yarn (Figure 1.b). The formed yarn has a circular cross-section, is stronger and smoother (Figure 1.c).

Another method of elimination the twist angle was developed by research centres in the UK. This method consists in a mechanical condensing of the fibre stream and eliminating the harmful twisting angle. This spinning method is the subject of our considerations.

■ Compact spinning with the use of RoCoS and Solospun drawing apparatuses and mechanical condensing of the fibre stream

Compact spinning with the use of a Rotorcraft Compact Spinning (RoCoS) drawing apparatus

Figure 2 presents the design of compact spinning proposed by Rotorcraft Co. [34, 38]. The compact yarn is obtained by joining the fibre stream in a condensation zone mounted after the drawing apparatus in such a way that the creation of a spinning balloon is prevented while the fibres are twisted into the yarn.

The RoCoS solution is more economic in comparison to the conventional fibre condensation method in the drawing field (this is by the sucked air, which pressure must be high and at the same the costs
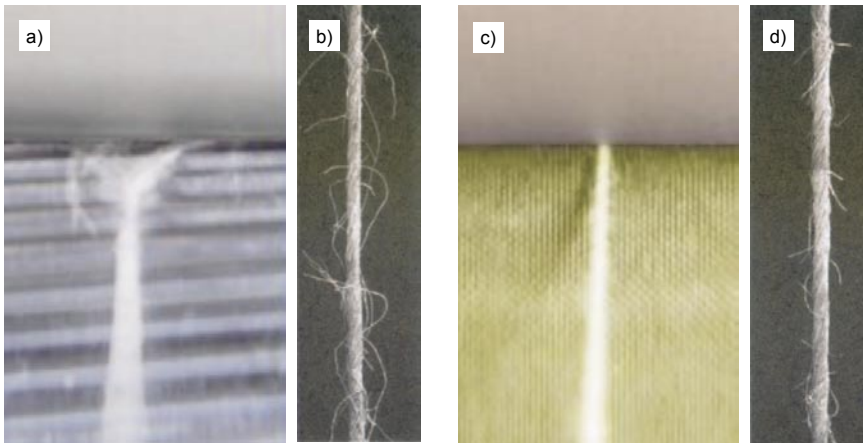
Figure 1. *Classical and compact spinning; a) twisting triangle in classical ring spinning, b) classical ring-spun yarn, c) compact spinning, d) compact yarn [37, 40].*
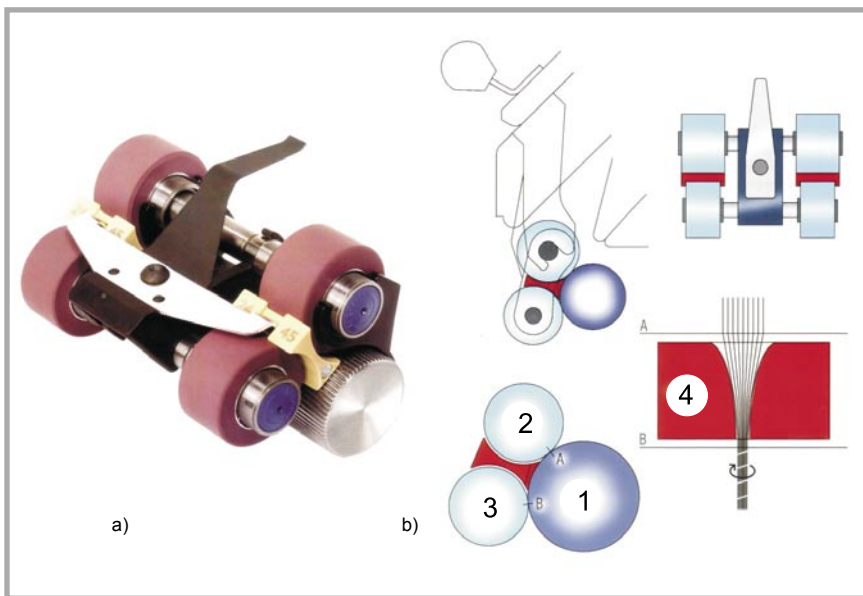

Figure 2. *View (a) and scheme (b) of installation of the Rotorcraft Compact Spinning magnetic rollers to the ring spinning machine [34]; 1 - lower delivery roller of the drawing apparatus, 2 - top roller, 3 - delivery roller, 4 - ceramic thickening funnel.*

of the compact device high), as its works without pressure air, basing only on magnetic and mechanical properties.

Principle of action of the RoCoS compact drawing apparatus

The lower roller (1) is equipped with precise furrows, and its diameter is equal to the radius of the ceramic thickening funnel (4) which fit the roller (1), and support the top roller (2) and the delivery roller (3). The condensation zone is between the lines A and B.

The ceramic thickening funnel (4) is pressed by magnets to the roller (1), and forms together with the lower roller (1) a closed thickening chamber, which lower edge formed on the surface of the roller (1) shifts the fibre stream and conveys

it through the ceramic funnel (compact effect). A partially thickening of the fibre stream takes place in the funnel, and at the same a partial elimination of the twisting angle occurs.

The RoCoS assures an optimum condensation, is simple in design and reliable in action. Using the RoCoS apparatus allows us to manufacture high quality yarns without increasing production costs.

Rotorcraft Co. presents the two following solutions: RoCoS 1 for cotton-type spinning machines, and RoCoS 2 for wool-type spinning machines. Both devices can be used with new spinning machines, as well as with already used. A change of the drawing apparatus of a standard ring-spinning frame may be realised each time without long-lasting modifications and at low cost.

Solospun compact spinning

A different method than the well known methods of manufacturing compact yarns is a wool spinning method called Solospun [39] developed together by the four institution: CSIRO, WRONZ, Woolmark Comp, and the Wool Institute in Ilkley. It consists on a suitable modification of the drawing apparatus of the ring spinning frame, which change the yarn structure in such a way that the yarn is more similar to the yarn doubled and plied. The abrasion resistance of such yarn is comparable to doubled yarn.

■ Aim of work

The aim of our work was to modify the Duo-Roth-type drawing apparatus of a PH 12 ring spinning frame and comparing the yarns obtained by them with yarns manufactured by the classical ring-spinning machine. As result of the modification we obtained a Solspun-type apparatus dedicated to manufacture of compact yarns. With the use of a spinning machine equipped with a compact-type modified drawing apparatus of the Solospun-type and a classical Duo-Roth-type apparatus yarns were manufactured with various linear densities from blends of wool and polyester fibres with a content of 55% PES and 45% wool. Next the measurement results of the quality parameters of both types of yarns were compared and analysed.

Modification of the Duo-Roth-type drawing apparatus

Figure 3 presents a simplified scheme of the action of a Solospun-type apparatus. An additional device for spinning by the Solospun method with the use of a conventional ring-spinning machine, which was equipped with two rollers, was mounted by a spring holder to the fastening cage of the spinning machine's pressure roller (Figure 3). The surfaces of the Solospun pressure rollers are equipped with furrows with dimensions of 1.7×26 mm (Figure 3.b). These rollers mates with the furrowed lower metal delivery roller of the apparatus.

While the machine is working, at the moment when the arm of the drawing apparatus is pressed down, the Solospun roller is pressed to the lower metal delivery roller. The Solospun roller is placed directly behind the delivery-pressing roller of the drawing apparatus. The distance between the surface of the So-

lospun roller and the surface of the upper delivery roller may be 2, 5, or 7 mm.

The Solospun rollers work in such a way that they take over feeding the drawn fibre stream which is delivered from the pair of drawing rollers and press the stream to the surface of the lower delivery roller. This prevents at the same time that the twist is shifted to this yarn segment.

The Solospun roller does not press the drawn fibres at their whole length but only in several points which results from the shape of the roller's surface. The depth of the roller's furrows is 1 mm, whereas the thickness of the matter which forms the furrows only 0.5 mm.

The width of the fibre band drawn in the drawing apparatus amounts about 5 mm. On this band-width occurs the division of the fibre layer into smaller elements in such a way that a part of microbands with the width of 1.7 mm is pressed to the surface, whereas at the width of 0.5 mm the fibres are not pressed but only guided along an arc of 26 mm; next the place of jamming changes on the band's width. This results in a division of the whole band by each 26 mm into new 2-3 microbands.

Transversal vibrations in relation to the direction of the fibre movement occur at the place of the division of the band into microbands, this is every each 26 mm. These vibrations cause a decrease in the twisting angle, which as is already known, is formed at the place where the twisting of the drawn fibre band into yarn begins.

Assuming that the spinning velocity of the spinning machine amounts 18 m/min, we obtain about 700 vibrations of the yarn per minute. The yarn vibrations cause a facilitation of passing the twist to all fibres, and thanks them a uniform arrangement of the twist along the yarn.

The new method of spinning modifies the yarn structure in such a way that the fibres are arranged not only in parallel regular helixes, but continuously oscillate between the outer surface and the yarn axis. This causes that each fibre is alternately joined with other fibres in several points along its length in different layers of the yarn. Such fibre arrangement is similar to the arrangement in plied yarns, but an additional advantage
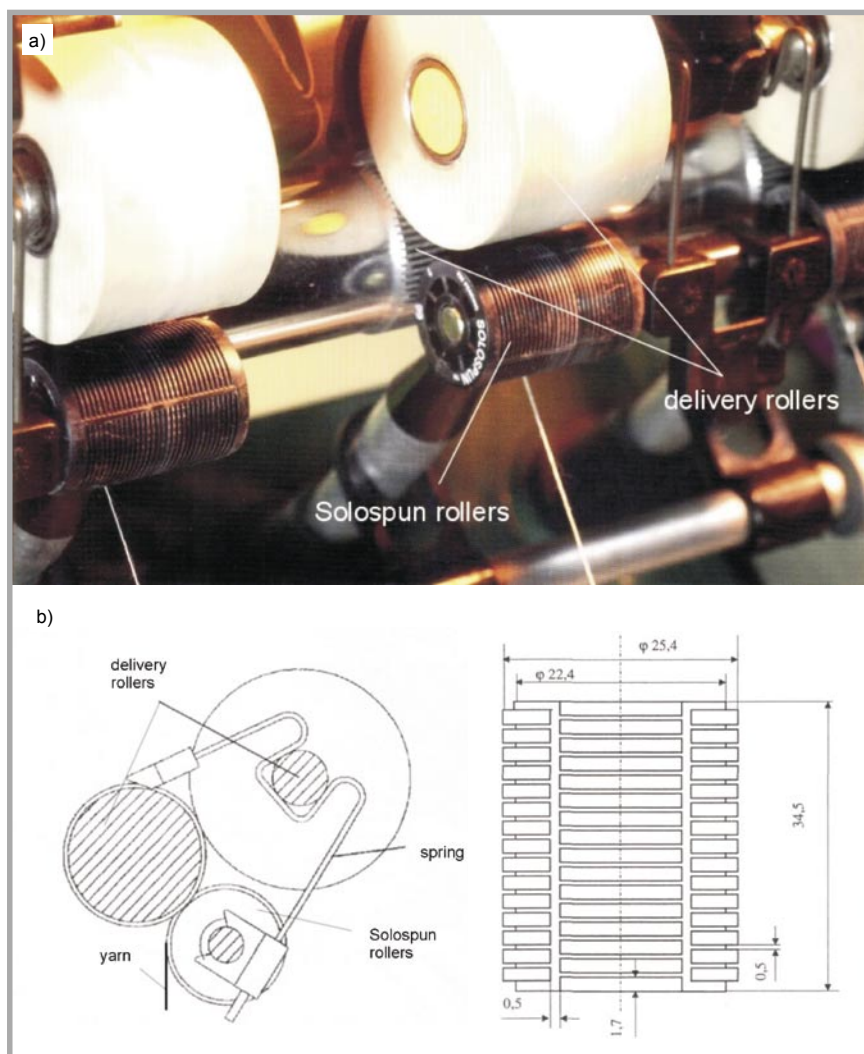

Figure 3. Solospun-type rollers; a) view of a Solospun-type roller; b) scheme of fastening the rollers on ring spinning machine, furrow dimensions: length – 26.0 mm, width – 0.5 mm, depth – 1.5 mm; number of furrows: on the roller's length – 15, on the roller's circumference – 4.

also occurs which does not exist in plied yarns. The fibre migration through the yarn cross-section indicate a degree of internal working-in which impedes the degree of yarn stretching at the moment while the yarn is guided through friction barriers.

As a possibility exists of manufacture and apply coarser singular yarns instead of plied double yarns, we can use coarser wool, which decreases the raw material costs. In this case applying thicker wool enables obtaining an effect connected with the yarn appearance and handle which differ from the standard for fine wool. Yarn assortments exist for which applying coarser wool is fully acceptable. The savings originated in using single yarns instead of doubled amounts about 20%, even taken into consideration the use of wool with the same thickness as raw material.

Research results and their analysis

Research tests aimed at manufacturing wool/polyester fibres blend yarns were carried out with the use of a PH 12 ring-spinning machine. The linear densities obtained were; 16.4 tex, 20 tex, 25 tex, 29 tex, and 30 tex.

The evaluation of the yarns obtained were carried out on the basis of the following parameters:
a) linear density,
b) coefficient of variation of linear density,
c) tenacity,
d) elongation at break,
e) number of twists,
f) number of faults (thin and thick places, neps), and
g) hairiness.

The measurement results of the average values of the quality parameters of yarns manufactured with the use of the classical ring spinning frame and the compact ring spinning machine equipped with the Solospun-type drawing apparatus are presented in Figures 4 – 10. Table 1 presents the results of a statistic analysis.

The F-Fisher-Snedocore statistical test was applied in order to perform the statistical analysis of the results obtained. The aim was to determine the significance of the divergence between the variances S^2_1 and S^2_2 obtained from two research series using the F-Fisher-Snedocore test on the basis of variable F distribution:

$$F = S^2_1 / S^2_2$$

where: S^2_1 and S^2_2 are variances of the features of the classical and the compact Solospun-type yarn.

As the tables for the variable F are arranged so that the values F are all the time greater than 1, the greater variances should be placed in the numerator while calculating F. The value F is a random variable for which the probability density depends on the number of the degree of freedom $k_1 = n_1 - 1$ and $k_2 = n_2 - 1$, where n_1 and n_2 are the number of measurements carried out for the calculation of S^2_1 and S^2_2. The boundary values of F related to the number of the degrees of freedom k_1 and k_2 for the probability values P = 0.95 and P = 0.99 are listed in tables and designated as $F_{0.95}$ and $F_{0.99}$. In order to check the significance of the divergence between the variances S^2_1 and S^2_2, the value of F_{total} is compared with the values of $F_{0.95}$ and $F_{0.99}$, and dependent on the comparison result, the divergence is accepted as significant or not.

On the basis of the procedure described, the following variances were determined:
- of the coefficient of variation CV of linear density,
- of the tenacity W_d,
- of the elongation at break,
- of the hairiness H, and
- of the twist.

The divergence significance between the variances of the above-mentioned parameters was checked. The results are listed in Table 1.

From the data listed in Table 1 results that the parameters, such as tenacity, hairiness, and the coefficient of variation of the twist of yarn manufactured with the use of the ring spinning machine equipped with the modified Solospun-type drawing apparatus differ significantly from the parameters of those yarns which were manufactured using the ring spinning machine equipped with a classical drawing apparatus.

As from the F-Fisher-Snedocore test could not be explicitly determined if the Solospun-type apparatus influences yarn parameters, such as the yarn unevenness of linear density (measured by CV) and elongation at break, we used for our further analysis the t-Student's parametrical significance test for the difference of two means in the case of different variances and equal sample sizes of research tests. On the basis of the statistical analysis results, we indicated that at the significance level of $\alpha = 0.05$ any grounds exist to determine that significant differences occur between the values of elongation at break and the yarn unevenness of linear density of yarns manufactured with the use of a ring spinning frame equipped with a modified Solospun-type drawing

apparatus and of a ring spinning frame with a classical drawing apparatus.

From the results presented in Figure 4 we can see that the tenacity of yarns manufactured from twisted and rubbed roving with the use of the ring spinning frame equipped with the Solospun-type drawing apparatus is higher than of those which are manufactured with use of the classical ring spinning frame, whereas the elongation at break (Figure 5) remains at the same level or its changes are insignificant. The tenacity of yarns manufactured from rubbed roving is higher than that obtained from twisted roving. With the increase in linear density the tenacity of both types of yarns, manufactured from twisted and rubbed roving, also increases.

From Figure 6 we can state that the additional Solospun rollers raise insignificantly the value of the coefficient of variation of the linear density and slightly worsen the yarn quality, as the numbers of faults (Figures 7 and 8) are lower than those for classical yarn. With the increase in the linear density of both kinds of yarns (from the twisted and rubbed roving), the unevenness of the linear density, as well as the number of faults decreases.

In Figure 9 is visible that the hairiness of yarns and the standard deviation of hairiness decrease while using the Solospun-type method of spinning, especially for yarns manufactured from rubbed roving. With increase in the linear density of yarns manufactured from twisted and rubbed roving the hairiness of yarn and the value of its standard deviation also decrease.

On the basis of the twist measurements presented in Figure 10 we could indi-

***Table 1.** Results of the statistic analysis.*

| Parameter	Number of degrees of freedom		Relation of variances of tested features of classical yarn and compact Solospun-type yarn Value F_{total}		Boundary value F				Testing result	Discussion Differences between compact and classical yarn
	k_1	k_2			Roving twisted		Roving rubbed			
	Roving twisted	Roving rubbed	Roving twisted	Roving rubbed	$F_{0.95}$	$F_{0.99}$	$F_{0.95}$	$F_{0.99}$		
Coefficient of variation CV of linear density, %	59	39	1.10	1.20	1.64	2.02	1.96	2.11	$F_{cal} < F_{0.95}$	not significant
Tenacity W_d, cN/tex	59	49	1.89	1.97	1.64	2.02	1.60	1.95	$F_{cal} > F_{0.95}$	significant
Elongation at break, %	59	49	1.36	1.52	1.64	2.02	1.60	1.95	$F_{cal} < F_{0.95}$	not significant
Hairiness (Uster) H, -	59	19	1.85	2.99	1.64	2.02	2.12	2.94	$F_{cal} > F_{0.95}$	significant
Coefficient of variation of twist, %	99	99	1.74	1.98	1.64	2.02	1.28	1.43	$F_{cal} > F_{0.95}$	significant
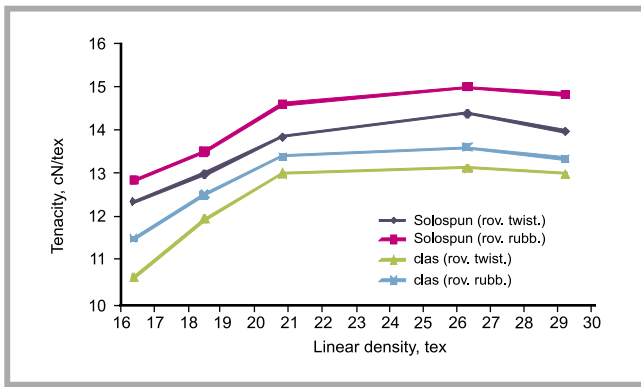
Figure 4. *Tenacity of Solospun-type and classical ring-spun yarns as a function of their linear density.*
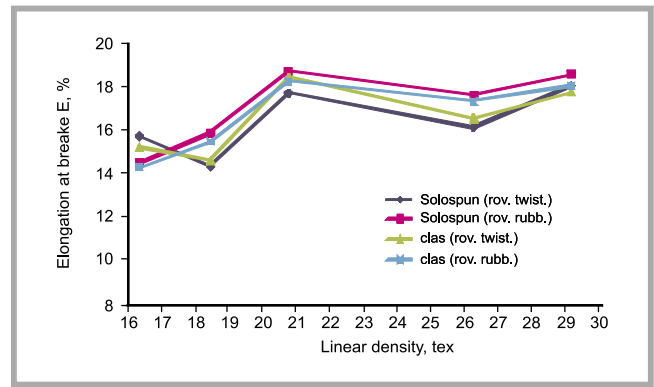

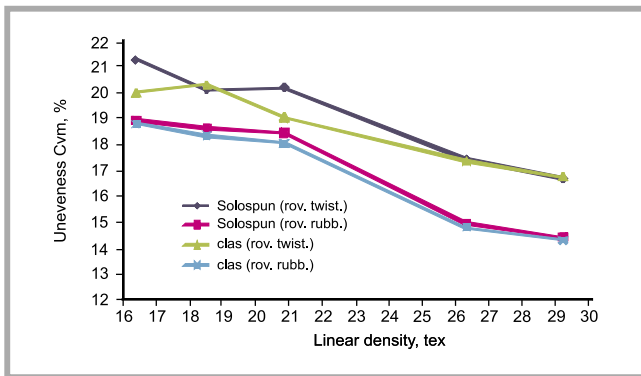**Figure 5.** *Elongation at break of Solospun-type and classical ring-spun yarns as a function of their linear density.*

Figure 6. *Uneveness of linear density of Solospun-type and classical ring-spun yarns as a function of their linear density.*
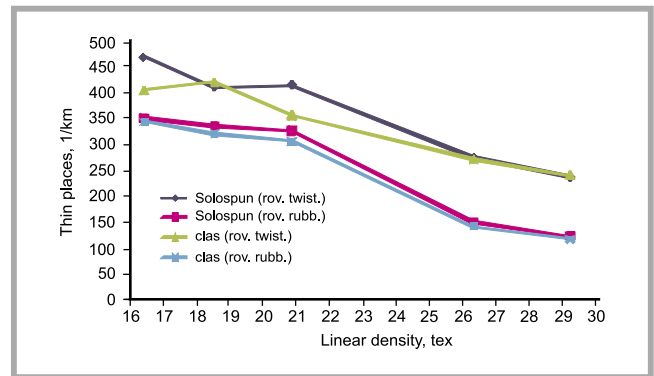

Figure 7. *Thin places of Solospun-type and classical ring-spun yarns as a function of their linear density.*
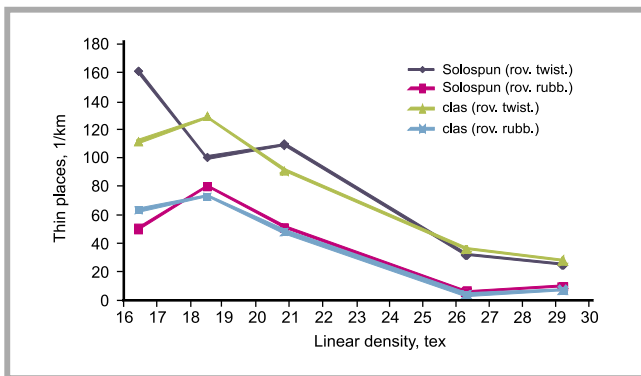

Figure 8. *Thick places of Solospun-type and classical ring-spun yarns as a function of their linear density.*
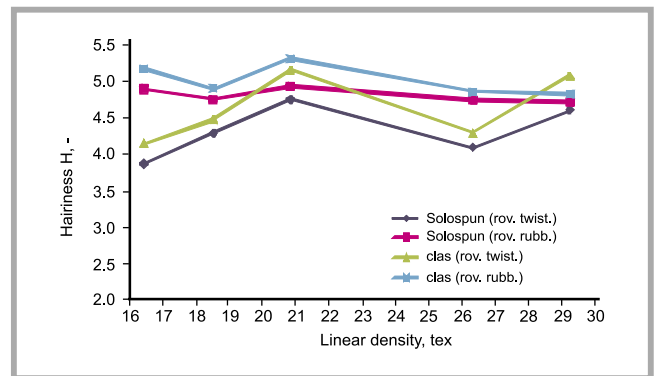

Figure 9. *Hairiness of Solospun-type and classical ring-spun yarns as a function of their linear density.*
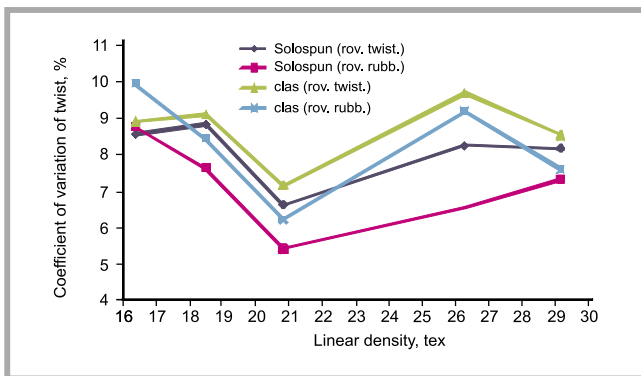

Figure 10. *Coefficient of variation of twist of Solospun-type and classical ring-spun yarns as a function of their linear density.*

Figures 4 - 10. *Partienlar quantities determined as functions of the linear density of yarn.*

Table 2. Evaluation of the measurement results for yarns manufactured from twisted and rubbed roving.

Type of rowing	Linear density, tex	coefficient of variation of tenacity CV_W, %		coefficient of variation of linear density on short segments CV_m, %		Thin places (-50%), %		Thick places (+50%), %		Standard deviation of hairiness sh, %	
		classical	Solospun type	classical	Solospun type	classical	Solospun type	classical	Solospun type	Classical	Solospun type
Roving twisted	16.6	50	50	50	50	50	50	50-95	95	5-50	50
	17.2	5-50	50	50-95	50-95	50-95	50-95	50-95	50-95	50-95	50-95
	18.5	50-95	50-95	50-95	50-95	50-95	50-95	50-95	50	50-95	50-95
	19.0	50	50-95	50	50	5-50	95	50	50-95	95	50-95
	20.8	50-95	95	50-95	50	50-95	50-95	50	50	5-50	5
	25.0	50	50	50	50	95	95	95	95	5-50	5
	29.0	50	95	95	95	50-95	50-95	50-95	50-95	5-50	5-50
	30.0	95	95	95	95	50-95	50-95	50-95	50-95	95	50-95
Roving rubbed	16.4	5	5	5	5	5	5	5	5	95	50
	18.5	5	5	5-50	5-50	5-50	5-50	5-50	5-50	5-50	5-50
	21.5	5	5	50	50	5-50	5-50	5-50	5-50	5-50	5-50
	26.3	5-50	5-50	5	5	5	5	5	5	5-50	5-50
	29.2	50-95	50-95	5	5	5	5	5	5	5-50	5-50

cate that the yarns manufactured by the Solospun-type method are characterised by a smaller coefficient of variation of the twist.

Evaluation of selected yarn parameters using Uster-statistics

The Uster-statistics are a set of data gathered by this enterprise thanks co-operation with the most spinning mills all over the world. They are devoted to compare the yarn parameters assessed with the use of Uster devises. In our work we applied the 2001 statistics for wool and polyester yarns.

The evaluation of yarns manufactured by us according to the Uster-characteristics are presented in Table 2

By comparing the yarn parameters of yarns manufactured by us with those of the Uster-statictics, the following statements can be drawn:
- the quality of yarns manufactured from twisted roving is satisfying,
- the quality of yarns manufactured from rubbed roving is good or very good.

Analysing the Table 2 we can also draw the conclusion that the Solospun-type method do not decrease, as well as do not increase explicitly such parameters as unevenness of linear density and the number of all faults.

■ Conclusions

On the basis of the results of our investigation carried out we can state that a modification of the drawing apparatus of a classical ring spinning frame similar to the Solospun drawing apparatus has an essential influence on some quality parameters and the tensile strength properties of polyester 55% / wool 45% blend yarns. The following statements can be drawn:

1. The tenacity of Solospun-type yarns is higher than that of classical ring spun yarns, especially of yarns with linear density above 21 tex. In the case of yarns manufactured from rubbed roving, the tenacity differences reach even 1 cN/tex and are statistically significant.

2. The elongation at break of Solospun-type yarns manufactured from twisted and rubbed roving is greater than that of classical yarns.

3. Compact spinning of the Solospun-type does not have an essential influence on the unevenness of linear density measured by the CV_m Uster factor. For the yarns tested, great differences could be indicated between yarns manufactured from rubbed and twisted roving.

4. The compact Solospun-type yarns are characterised by a slightly higher level of faults (thin and thick places) than the classical yarns. However these differences are not important and do not influence the quality of yarn.

5. The application of a mechanical fibre condensing by a Solospun-type apparatus decreases significantly the yarn hairiness and its coefficient of variation.

6. Solospun-type compact spinning has an essential influence on the value of the coefficient of variation of the yarn twist.

Summarising, we can state that in the case of polyester 55% / wool 45% blend yarns, compact spinning of the Solospun-type increases tenacity and twist evenness, as well as decreases the hairiness of yarn.

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will be held on 6-7 September 2007 in Gdynia, Poland

Organisers:
- **The Gdynia Cotton Association (GCA)**
- **The Department of Spinning Technology and Yarn Structure, and the Department of Clothing Technology, Technical University of Łódź**

The **International Cotton Conference in Gdynia** has been organised bi-annually since 1988, in alternation with the cotton conferences in Bremen organised by the Faserinstitut Bremen & the Bremen Cotton Exchange. The Conference topic is always devoted to selected problems of testing, turnover and processing of cotton and cotton-like fibres.

We hope that as in previous years, **the 9th International Cotton Conference** in Gdynia will bring together numerous participants from international business and science as well as representatives of R&D centres and companies active in the cotton sector.

The dynamic globalisation of this sector is changing development trends in the European textile industry to a considerable extent, and has increased the need for the creation and efficient implementation of new-generation materials and technologies. The **leading topic of the scientific-technical part of the Conference will be cellulose fibres, their application and development prospects. The topic of the Conference will also cover issues of the prospects for the textile-apparel sector** which has recently been undergoing drastic changes, such as the liberalisation of turnover, the rapid development of emerging economies, the breakdown of the multilateral Doha talks, allocation of industrial production, and problems in removing access barriers to the markets of third countries for goods from developed countries. The question of the future and economic perspectives of the European and world industries is now the most important one asked by the international trade and industry groups.

Presentation of companies: We invite companies to present their technical achievements; interested parties are asked to contact the conference organisers.

You are welcome to participate.

Chairman of the Organising Committee:
Ignacy Józkowicz, President of GCA

Chairman of the Scientific Committee:
Professor Tadeusz Jackowski

For more information, please contact:

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