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# Quality Analysis of Cotton/Polyester Yarn Blends Spun with the Use of a Rotor Spinning Frame

## Abstract

An analysis was carried out of parameters characterising fibres, half-finished products, cotton yarns and cotton/polyester yarn blends spun with the use of a R1 rotor spinning frame from Rieter. The influence of polyester fibres' share in the blends on their structural yarn parameters was analysed. Cotton yarns combed and carded with linear densities of 20 tex & 30 tex and with a constant twist factor of  $\alpha = 140$  were spun by means of the R1 spinning frame. A two-factor variance analysis was carried out which proved the significant influence of the blends' content on the basic quality yarn parameters.

**Key words:** cotton yarn, blended yarns, cotton/polyester blends, quality yarn parameters, rotor yarns, two-factor variance analysis.

## Introduction

Yarns spun with the use of modern, recently used rotor spinning machines are to a significant degree close in quality to ring-spun yarns. The increasing possibilities of rotor-yarn application for manufacturing various textile products have also broadened the application range of rotor spinning frames and increased demand for them. From the literature [1 - 4] it results that 20% of the world production of cotton and cotton-like yarns is manufactured by means of the rotor system. Their share on the Polish market is even as high as within a range of 40-50%.

It has recently become clear that the market is more interested in rotor yarns than ring-spun yarns. This is because rotor yarns are almost equal to ring-spun yarns in their structure and quality parameters, but at the same the production costs are smaller, and the spinning efficiency higher.

The main directions in which the latest models of rotor spinning frames have been developing are the continuing increase in the velocity of machine elements, full automation of machine operation together with supervision of the technological process, and an increase in the number of spinning points [2, 6].

Recently, more and more attention has been devoted to manufacturing rotor yarns from chemical fibres, even though these yarns have not been fully accepted as a substitute for ring-spun yarns, considering their worse strength properties when compared with ring-spun yarns. This is caused by the basic difference in their structure, and is mirrored in the properties of flat textile products.

Research works [6, 7] have indicated that better results might be achieved by manufacturing blended yarns with the content of cotton and chemical fibres.

## Aim of the investigation

The aim of our research work was to analyse the quality parameters of cotton/polyester rotor yarn blends with various contents of the components and different length distributions of the cotton fibres. We examined yarns with two linear densities of 20 tex and 30 tex, manufactured with an R1 rotor spinning frame from Rieter.

## Research method – plan of tests

The following fibres were used for our investigation:

- Cotton fibres of medium staple cotton with 32/33 mm length, linear density of 165 mtex, tenacity of 24.9 cN/tex, elongation of 7.7%; and
- polyester staple fibres of 38 mm length, linear density of 150 mtex, tenacity of 36.2 cN/tex, and elongation of 36.1%.

The raw material for manufacturing the yarns with linear densities of 20 tex and 30 tex was slivers with a linear density of 4.45 ktex. The slivers obtained from medium staple cotton fibres carded and combed, with a percentage share of noils of 24%, and of polyester fibres, were used to form the following yarn blends: carded cotton+polyester fibres, and combed cotton+polyester fibres. The blends were mixed with the use of a Globe 740 drawing frame. Next, the slivers were joined and drawn, which enabled 14 variants of

blends and 3 variants of one-component yarns to be obtained. The percentage share of both kinds of fibres in the blends changed in steps of 12.5% within the range from 100% cotton fibres to 100% polyester fibres.

In order to manufacture yarns with a preset linear density, the working parameters of the spinning machine were set so as to maintain the optimum work of the frame. The rotor velocity was set at 100,000 rpm at a rotor diameter of 300 mm. In relation to these settings, the rotational velocity of the opening rollers was set at the level of 7,000 rpm.

From the sliver prepared in the way described above, rotor-spun yarns with two linear densities were prepared, with a constant twist factor of  $\alpha = 140$ . Next, the yarns were analysed by laboratory tests, and the following quality parameters were assessed: linear density, number of twists, breaking force, elongation at break, work to break, tenacity, elasticity degree, linear density unevenness, hairiness, and faults. All measurements were carried out in the laboratory of the Department of Spinning Technology and Yarn Structure at the Technical University of Łódź in accordance with standards generally applied in textile laboratory practice.

## Research results

The average values of measurement results of the yarn's quality parameters are shown in Figures 1 – 7, whereas in Tables 1 – 3 the results of the statistical analysis are presented.

For the statistical analysis of results obtained by measuring such quantities as tenacity, elongation at break, the co-

**Table 1.** Results of the statistic analysis of the 1<sup>st</sup> system: a – linear density of yarn blends, b – length distribution of cotton fibres.

Parameter	Statistic parameter	linear density of yarns	length distribution of cotton	Interaction
Tenacity, W <sub>d</sub>	F-Snedocor statistic	1.209	0.046	0.017
	significance level, p	0.280	0.832	0.898
Elongation	F-Snedocor statistic	2.230	0.128	0.001
	significance level, p	0.145	0.723	0.977
linear density unevenness, CV	F-Snedocor statistic	<b>46.561</b>	0.015	0.033
	significance level, p	<b>0.000</b>	0.904	0.856
Hairiness – Uster, H	F-Snedocor statistic	3.899	0.030	0.101
	significance level, p	0.057	0.864	0.753
Thin places (-50%)	F-Snedocor statistic	<b>83.204</b>	0.123	0.038
	significance level, p	<b>0.000</b>	0.728	0.846
Thick places (+50%)	F-Snedocor statistic	<b>25.594</b>	0.396	0.603
	significance level, p	<b>0.000</b>	0.534	0.443
neps (+280%)	F-Snedocor statistic	<b>29.589</b>	4.401	2.033
	significance level, p	<b>0.000</b>	0.044	0.164

**Table 2.** Results of the statistic analysis of the 2<sup>nd</sup> system: a – linear density of blended yarns, b – content of cotton in the blends with polyester fibres.

Parameter	Statistic parameter	linear density of yarns	length distribution of cotton	Interaction
Tenacity, W <sub>d</sub>	F-Snedocor statistic	<b>91.441</b>	<b>293.997</b>	<b>6.972</b>
	significance level, p	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>
Elongation	F-Snedocor statistic	<b>119.997</b>	<b>208.233</b>	<b>5.582</b>
	significance level, p	<b>0.000</b>	<b>0.000</b>	<b>0.001</b>
linear density unevenness, CV	F-Snedocor statistic	<b>167.574</b>	<b>8.057</b>	<b>4.110</b>
	significance level, p	<b>0.000</b>	<b>0.000</b>	<b>0.006</b>
Hairiness – Uster, H	F-Snedocor statistic	<b>33.607</b>	<b>30.388</b>	<b>1.980</b>
	significance level, p	<b>0.000</b>	<b>0.000</b>	<b>0.109</b>
Thin places (-50%)	F-Snedocor statistic	<b>587.098</b>	<b>16.874</b>	<b>9.243</b>
	significance level, p	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>
Thick places (+50%)	F-Snedocor statistic	<b>79.842</b>	<b>4.699</b>	<b>5.919</b>
	significance level, p	<b>0.000</b>	<b>0.003</b>	<b>0.001</b>
neps (+280%)	F-Snedocor statistic	<b>79.842</b>	<b>4.699</b>	<b>5.919</b>
	significance level, p	<b>0.000</b>	<b>0.003</b>	<b>0.001</b>

**Table 3.** Results of the statistic analysis of the 3<sup>rd</sup> system: a – length distribution of cotton fibres, b – content of cotton in the blends with polyester fibres.

Parameter	Statistic parameter	linear density of yarns	length distribution of cotton	Interaction
Tenacity, W <sub>d</sub>	F-Snedocor statistic	0.406	<b>34.451</b>	0.119
	significance level, p	0.532	<b>0.000</b>	0.998
Elongation	F-Snedocor statistic	0.727	<b>21.940</b>	0.065
	significance level, p	0.405	<b>0.000</b>	1.000
linear density unevenness, CV	F-Snedocor statistic	0.005	0.698	0.116
	significance level, p	0.947	0.689	0.998
Hairiness – Uster, H	F-Snedocor statistic	0.088	<b>10.360</b>	0.613
	significance level, p	0.771	<b>0.000</b>	0.756
Thin places (-50%)	F-Snedocor statistic	0.023	0.453	0.027
	significance level, p	0.880	0.873	1.000
Thick places (+50%)	F-Snedocor statistic	0.163	0.621	0.126
	significance level, p	0.691	0.750	0.997
neps (+280%)	F-Snedocor statistic	1.828	0.884	0.171
	significance level, p	0.193	0.549	0.992

efficient of variation of linear density at short segments, hairiness as measured by an Uster tester, and the faults of the yarn, a two-factor variance analysis was applied [10] with the following factor systems:

1<sup>st</sup> system: a – linear density of blended yarns, b – length distribution of cotton fibres;

2<sup>nd</sup> system: a – linear density of blended

yarns, b – content of cotton in the blends with polyester fibres;

3<sup>rd</sup> system: a – length distribution of cotton fibres, b – content of cotton in the blends with polyester fibres;

where:

- linear density of yarns: 20 tex and 30 tex,

- length distribution of cotton fibres: medium staple cotton carded and combed,
- percentage content: change of the percentage share with steps of 12.5% within the range from 0% to 100%.

We assume that two factors (A and B) influence the given variable Y with normal distribution. The first factor occurs at c levels, whereas the second at r levels. This leads to the r × c populations being distinguished. Within each of these populations, n observations of the variable Y are carried out. The mechanism which generates the variable Y can be presented in the form of a mathematical model:

$$Y_{ijk} = m + a_i + b_j + ab_{ij} + e_{ijk}$$

$$I = 1, \dots, c; j = 1, \dots, r; k = 1, \dots, n;$$

where:

- m – the total average,
- a<sub>i</sub> and b<sub>j</sub> – effects of the factor's action,
- ab<sub>ij</sub> – effect of factor cooperation (combined effect of factors' action),
- e<sub>ijk</sub> – random effect.

On the basis of this model, three kinds of hypothesis are tested:

$$H_1 : a_i = 0, i = 1, \dots, c$$

$$H_2 : b_j = 0, j = 1, \dots, r$$

$$H_3 : ab_{ij} = 0, i = 1, \dots, c; j = 1, \dots, r$$

Next, the variances S<sup>2</sup><sub>A</sub>, S<sup>2</sup><sub>B</sub>, S<sup>2</sup><sub>AB</sub>, S<sup>2</sup><sub>E</sub> and the test statistics F<sub>a</sub>, F<sub>b</sub>, F<sub>ab</sub> are determined.

For each of the hypotheses, from the tables of F-Snedocore distribution we decode the critical values, for the given significance level p and the calculated degrees of freedom, and compare them with the calculated values of the test statistics.

If F<sub>A</sub> > F<sub>crA</sub>, the hypothesis H<sub>1</sub> is rejected, the effect of action of factor A is significant, and the variable Y depends on the factor A.

If F<sub>B</sub> > F<sub>crB</sub>, the hypothesis H<sub>2</sub> is rejected, the effect of action of factor B is significant, and the variable Y depends on the factor B.

If F<sub>AB</sub> > F<sub>crAB</sub>, the hypothesis H<sub>3</sub> is rejected, the effect of the common action of both factors is significant.

The significance level for our investigations was accepted within the range of p < 0.1. The **significant statistic results are marked by bold italic** in all tables.

The results obtained from the statistic analysis indicate that the linear density of the yarn manufactured and the percentage share of cotton fibres in the blends with polyester fibres have significant influence on the tenacity values. On the contrary, no significant influence of the combing process on the tenacity of the yarns tested was stated. The diagrams shown in Figure 1 indicate that thicker yarns with linear density of 30 tex have tenacity values slightly higher than those yarns with smaller linear density. The percentage share of polyester fibres in the blends determine the value of yarn strength, and with an increase in its share, the tenacity of yarns increases independently of the linear density.

The dependencies presented in Figure 2 indicate that yarns with 100% of cotton fibres are characterised by the smallest values of elongation at break, whereas yarns with 100% polyester fibres have the greatest values of elongation at break. Thinner yarns with smaller linear density are characterised by a smaller value of elongation at break while compared with thicker yarns. The tests of the two-factor statistic analysis which we carried out indicate that the share of cotton fibres in the blend with polyester fibres and the yarn's linear density have a significant influence on the level of elongation at break. The significance of the combing process was not stated.

Linear density of yarn is the factor which most significantly influences the level of unevenness of linear density at short segments. The diagrams in Figure 3 show significant differences between 20-tex and 30-tex yarns. Generally we can state that with the increase in linear density, the yarns' regularity improves. At the same time, the level of unevenness is the smallest for yarns with a 100% share of cotton fibres, and increases with the increase in the content of polyester fibres. No influence of the combing process was stated.

The results of the statistical analysis indicated that the influence of the percentage share of the fibre blend significantly influences the hairiness as measured by the Uster apparatus. The diagrams in Figure 4 demonstrate that yarns with 100% share of cotton fibres are characterised by the smallest hairiness, and the blends with the highest share of polyester fibres (12.5% of cotton, 87.5% of polyester) by the greatest. It should be

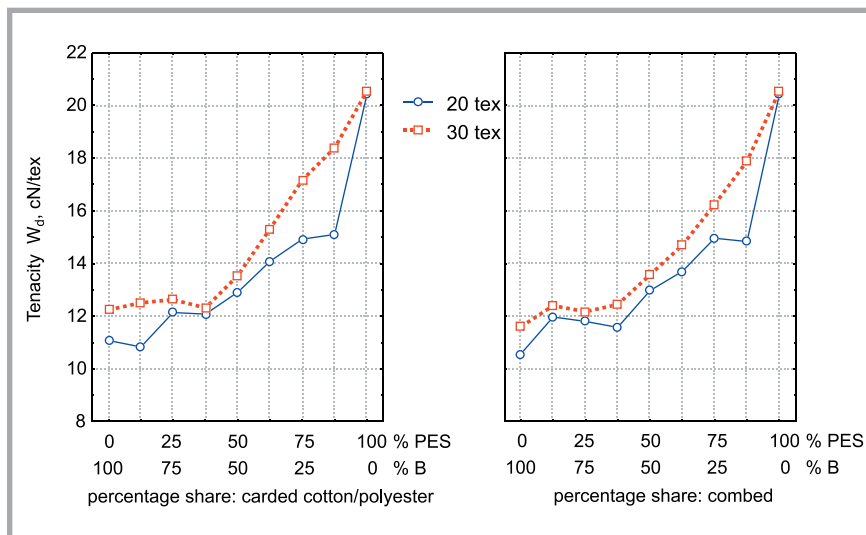


Figure 1. Influence of the linear density of yarn, length distribution of cotton fibres, and percentage share of cotton in the blend on tenacity.

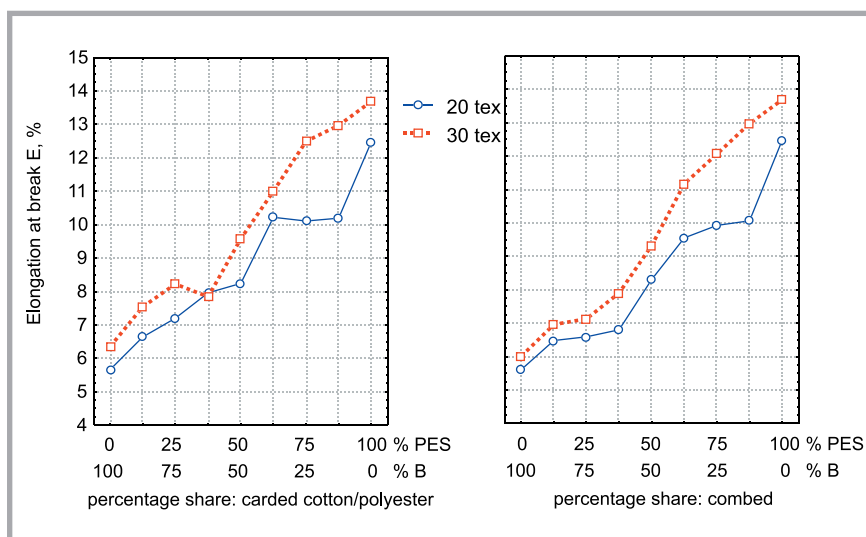


Figure 2. Influence of the linear density of yarn, length distribution of cotton fibres, and percentage share of cotton in the blend on elongation at break.

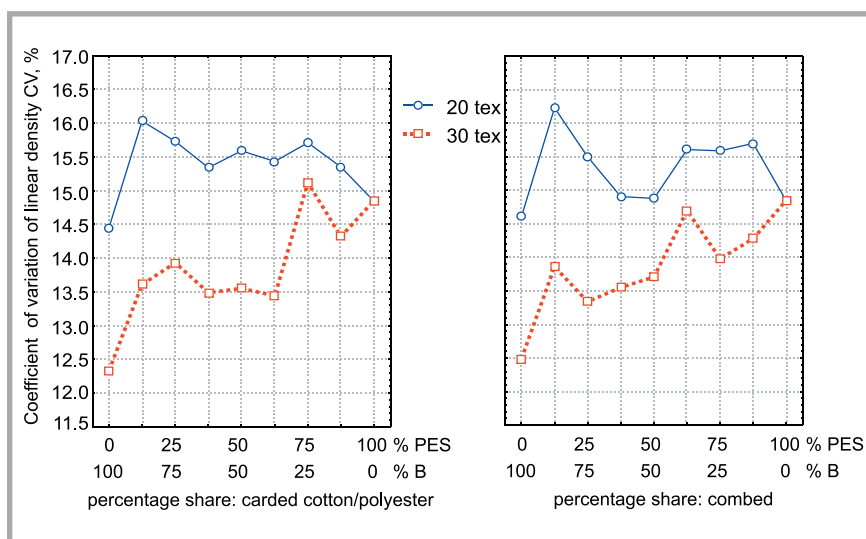
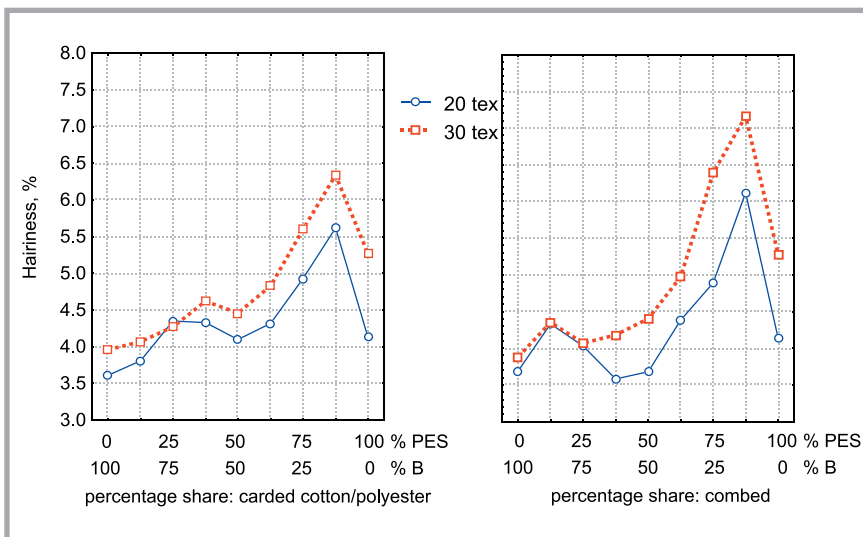
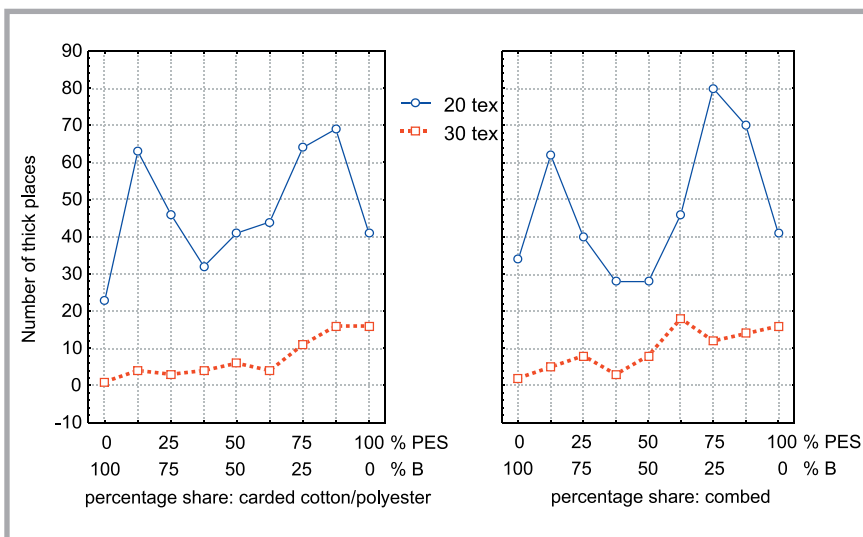


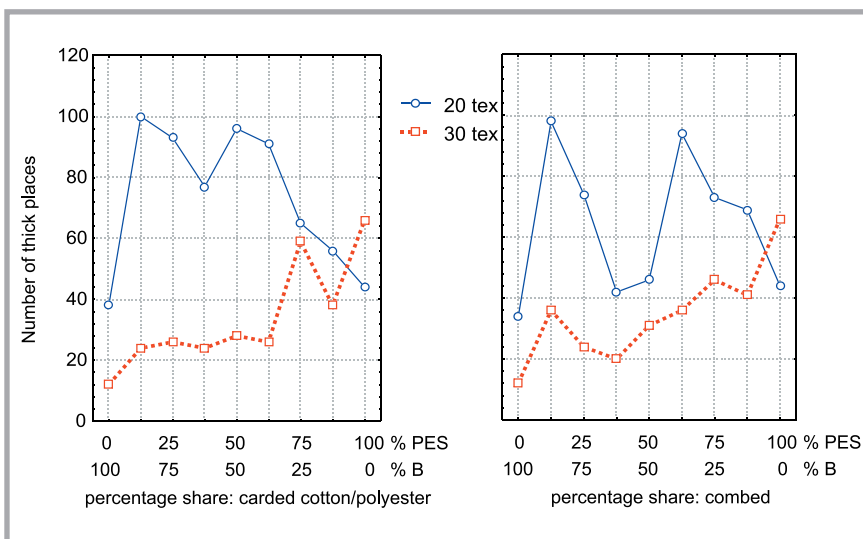
Figure 3. Influence of the linear density of yarn, length distribution of cotton fibres, and percentage share of cotton in the blend on coefficient of variation of linear density CV.



**Figure 4.** Influence of the linear density of yarn, length distribution of cotton fibres, and percentage share of cotton in the blend on hairiness as measured by an Uster tester.



**Figure 5.** Influence of the linear density of yarn, length distribution of cotton fibres, and percentage share of cotton in the blend on the number of thin places.



**Figure 6.** Influence of the linear density of yarn, length distribution of cotton fibres, and percentage share of cotton in the blend on the number of thick places.

emphasised that yarns with a 100% share of polyester fibres have a lower hairiness compared with the latter kind of blend. No influence of the combing process was confirmed, and the significance of the influence of linear density on the hairiness value is small.

The statistic analysis carried out indicates the significant influence of the linear density on the number of faults which appear in yarn. It was stated that for thinner yarns (Figure 5), the numbers of thin places indicated demonstrate a random character for different percentage shares of the blends. In the case of thicker yarns with a linear density of 30 tex, the number of thin places is at the same level as that found in the blend variant of 50% cotton/50% polyester fibres. The subsequent blend variants demonstrate a slight increase in the number of thin places. The influence of the combing process on the number of thin places is not significant.

The statistical tests of the number of thick places highlighted the significant influence of the linear density on this number. The diagrams presented in Figure 6 demonstrate that for thinner yarns, the number of thick places has a random character, whereas for thicker yarns an increasing tendency in the number of thick places was observed, dependent on the percentage share of cotton fibres in the blend. No significance of the combing process was stated.

The statistical analysis of the number of neps indicated the significant influence of the linear density on the number of neps. In the diagrams presented in Figure 7, it may be clearly seen that the thicker yarns are characterised by a flat distribution of the number of neps (at almost the same level for all blends), whereas thinner yarns are characterised by the random character in which the neps appear in dependence on the blend variant applied. The combing process is also not significant in this case.

Comparing the 100% carded cotton yarn and the blend variant yarn of 50% carded cotton/50% polyester with the Uster statistics allowed us to establish the quality of the yarns tested in comparison to the world production. This quality is at the level of 5% of world production, which means that only 5% of all spinning machines working in the world are able to manufacture yarns of similar quality.

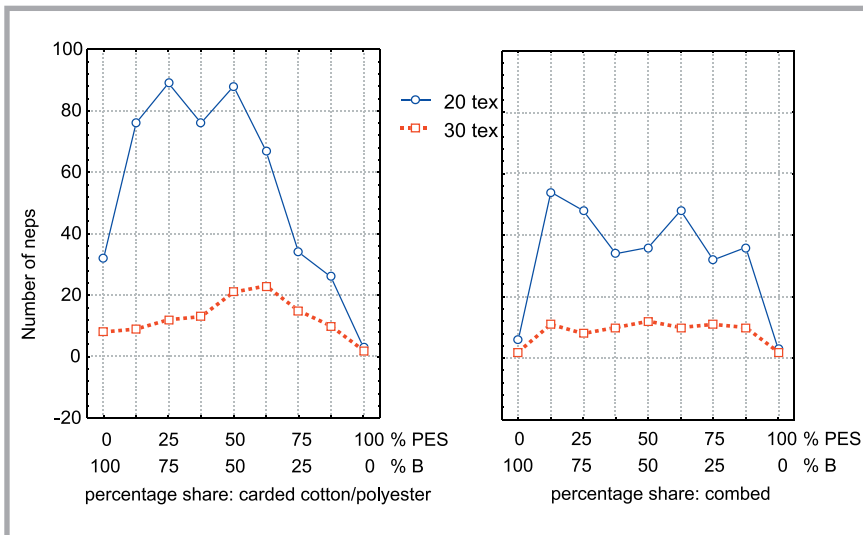


Figure 7. Influence of the linear density of yarn, length distribution of cotton fibres, and percentage share of cotton in the blend on the number of neps.

## Conclusions

The analysis of the quality parameters of slivers and yarns, as well as the statistic analysis, enabled us to make the following statements:

1. The percentage share of the particular fibres in the blends has the greatest influence on the yarn parameters of all blend variants. The quality parameters change in dependence on the percentage of cotton fibre in the blend. The two-factor variance analysis carried out confirmed the significant influence of the blend composition on the yarns' basic quality parameters.
2. An analysis of the strength parameters of the yarns manufactured demonstrates a gradual increase in the quality parameters with an increase in the percentage share of polyester fibres.
3. The statistical analysis of the linear density unevenness at short segments indicates the significant influence of yarns' linear density on the level of unevenness. Generally, we can state that the greater is the linear density, the better the regularity of their linear density.
4. The greatest values of parameter dispersion was observed for blend yarns of 50% cotton/50% polyester, i.e. in these yarns where no component predominated.
5. A comparison of the 100% cotton yarn and 50% carded cotton/50% polyester

yarn with the Uster statistics enabled us to determine the quality of the yarns tested in relation to the world production. The quality may be related to the level of about 5% of world production, which means that only 5% of all spinning machines working in the world are able to manufacture yarns of similar quality.

6. An interpretation of the statistic analysis of yarn faults enabled us to determine the significant influence of the yarns' linear density on the number of thin & thick places and neps observed in the yarns. The yarn with the linear density of 30 tex is characterised by an even distribution of the number of faults in dependence on the blend variant. In the case of the thinner yarn with linear density of 20 tex, the occurrence of faults has a random character. At the same time, a comparison with Uster characteristics enables us to determine, from the point of view of its quality, the yarn manufactured at the level of 5% of world production.
7. Estimating the hairiness measured by the Uster-Tester III apparatus by means of the two-factor variance analysis, we have established the significant influence of the blend variant on the hairiness degree. Generally, an tendency in the hairiness degree to increase was observed with the increase in the content of polyester fibres in the blend.. Furthermore, the highest hairiness value was obtained for the blend variant of 12.5% carded cotton/87.5% polyester. Yarns manufactured of

100% polyester fibres were characterised by smaller hairiness than that of the above-mentioned variant.

8. None of the investigations into the quality parameters of the yarns manufactured indicate the significant influence of the combing process. This means that introducing the combing process in order to improve the yarns' quality parameters in the case of spinning it by the rotor system is not recommended.

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