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Comparative Analysis of Ring Spinning for Both Classic and Compact Yarns. Part II: Verification of Models Created

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Abstract
The verification of models based on multiple regress servants for the assessment of the ring spinning process of classic as well as compact cotton yarns was carried out. The analysis of results obtained showed that the statistical models proposed were very useful in making a qualitative and productive comparison of the yarns considered. Decreasing the metric coefficient of the twist - α_m and percentage noils - p_w during the production of compact yarn makes possible the obtainment of significant productive effects and the lowering of the costs of producing the yarn without an excessive worsening of quality.

Key words: *ring classic yarn, compact yarn, percentage of noils, twist coefficient, spinning plan, total experiment, double classification, multiple regression.*

Introduction

In the 1st part of the article [1], a construction statistical model based on multiple regression was presented, designed for the execution of the comparative analysis of selected physical proprieties of both classic and compact cotton yarns of a nominal linear mass of about 20 tex, as well as the character of these changes.

Verification of the model

Step 1: *Realisation of the plan and execution of the investigative experiment*

According to the algorithm of modelling given, two series of experiments of the type 5 × 5 were conducted - 50 tests all together.

Step 2. *Creation of the database*

The database in the table of results of the measurements of selected physical proprieties of classic and compact cotton ring yarns was created according to the measurement methods described in the 1st part of the article.

Step 3. *Assessment of the influence of the parameters of the spinning process on the physical properties of yarns by means of test of variance analysis according to double classification*

In order to check if simultaneous changes in the metric coefficient of the twist - α_m and percentage of noils – p_w significantly influence the physical proprieties of classic and compact cotton yarns, statistical inference was conducted to investigative the procedure (***Figure 1***) using test of the variance analysis according to double classification. The results of the tests are given in ***Table 1***.

Step 4. *Assessment of the correlation between the physical proprieties of the yarns analyzed*

The assessment correlation between selected physical proprieties of the yarns analyzed is given in ***Tables 2*** and ***3***.

Step 5. *Assessment of the significance of the appointed regression functions and the analysis of superficial and contour graphs*

For the physical proprieties of the yarns, in which the significant influence was af-

Table 1. *Results of the test of the variance analysis according to double classification; Legend: - influence of parameter analysed is statistically significant (■) and not statistically significant (■).*

Parameter of yarn analysed	Classic ring frame G33			Compact ring frame K44		
	$F_{A,\alpha}$ α_m	$F_{B,\alpha}$ p_w	$F_{critical}$	$F_{A,\alpha}$ α_m	$F_{B,\alpha}$ p_w	$F_{critical}$
Coefficient of variation – CV_m	14.10	13.46	3.01	23.74	43.95	3.01
Number of thin places$_{-50\%}$	2.25	1.63	3.01	1.88	1.88	3.01
Number of thick places$_{+50\%}$	4.24	6.57	3.01	4.99	22.55	3.01
Number of neps$_{+200\%}$	5.43	18.67	3.01	14.36	44.69	3.01
Hairiness – H	23.53	1.14	3.01	625.64	38.17	3.01
Tenacity – R_H, cN/tex	81.21	0.94	3.01	116.15	5.38	3.01
Elongation – ε_r, %	45.13	0.38	3.01	4.57	0.39	3.01

Table 2. *Assessment of the correlation between the physical proprieties of cotton ring classic yarns; weak - 1, ordinary - 2, strong - 3, very strong - 4, almost full -5.*

Physical properties of yarns	CV_m	Thin$_{-50\%}$	Thick$_{+50\%}$	Neps$_{+200\%}$	H	R_H	ε_H
CV_m		+ 2	+ 4	+ 4	- 3	+ 3	+ 3
Thin$_{-50\%}$	+ 2		+ 1	+ 1	- 1	+ 1	+ 1
Thick$_{+50\%}$	+ 4	+ 1		+ 4	- 2	+ 2	+ 3
Neps$_{+200\%}$	+ 4	+ 1	+ 2		- 2	+ 2	+ 2
H	- 3	- 1	- 2	- 2		- 5	- 4
R_H	+ 3	+ 1	+ 2	+ 2	- 5		+ 4
ε_H	+ 3	+ 1	+ 3	+ 2	- 4	+ 4	

Table 3. *Assessment of the correlation between the physical proprieties of cotton compact yarns; faint - 0, weak - 1, ordinary - 2, strong - 3, very strong - 4, almost full -5.*

Physical properties of yarns	CV_m	Thin$_{-50\%}$	Thick$_{+50\%}$	Neps$_{+200\%}$	H	R_H	ε_H
CV_m		+ 2	+ 4	+ 5	- 1	+ 2	+ 1
Thin$_{-50\%}$	+ 2		+ 2	+ 2	- 0	+ 1	+ 1
Thick$_{+50\%}$	+ 4	+ 2		+ 5	- 1	+ 1	+ 1
Neps$_{+200\%}$	+ 5	+ 2	+ 5		- 1	+ 2	+ 1
H	- 2	- 0	- 1	- 1		- 5	- 3
R_H	+ 2	+ 1	+ 1	+ 2	- 5		+ 3
ε_H	+ 1	+ 1	+ 1	+ 1	- 3	+ 3	

Józkowicz I., Drobina R., Lewandowski S.; Comparative Analysis of Ring Spinning for Both Classic and Compact Yarns. Part II: Verification of Models Created.
FIBRES & TEXTILES in Eastern Europe 2010, Vol. 18, No. 5 (82) pp. 28-34.

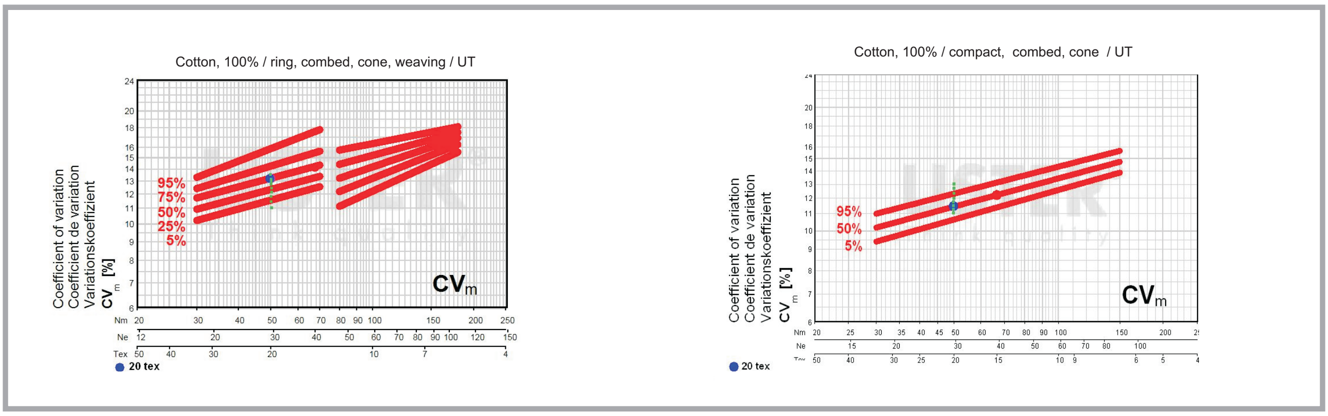

Figure 1. *USTER STATISTICS for the coefficient of variation – CV_m*

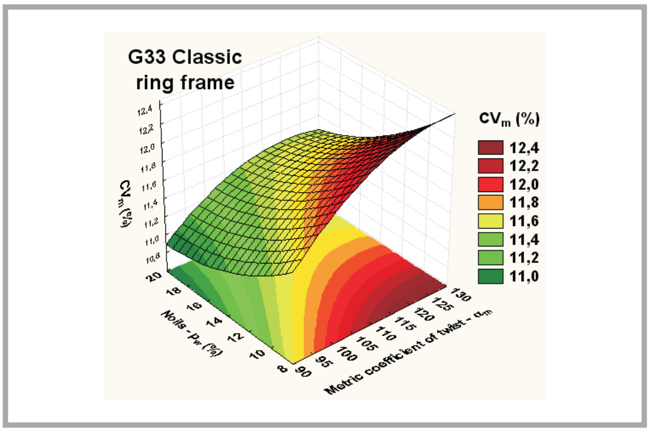

Figure 2. *Diagram of CV_m for cotton classic yarn; R = 0.900; F_{calc} = 16.28, F^5_{19} = 2.74.*

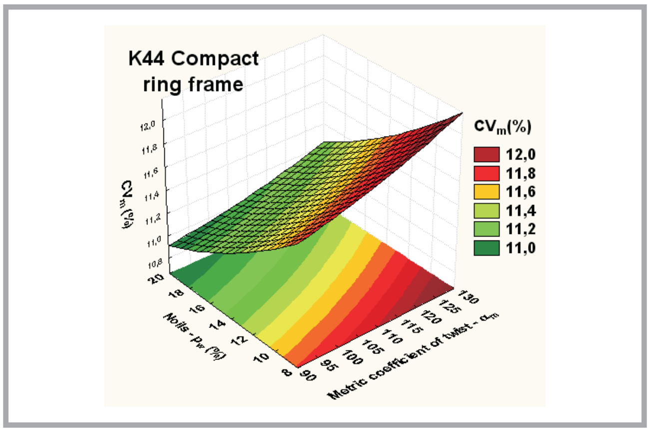

Figure 3. *Diagram of CV_m for cotton compact yarn; R = 0.932; F_{calc} = 25.19; F^5_{19} = 2.74.*

firmed for at least one parameter of the spinning process analysed, further analysis was carried out by way of calculation of the regression function together with an assessment of their significance and the qualitative character of changes in the drawing ahead near the help of the layer and surface graphs of the regression functions.

Comparison of the coefficient of variation -CV_m

Comparative assessment of in the data given in ***Figure 1*** shows that in the majority of cases the coefficient – CV_m of cotton ring yarns, both classic and compact, is shaped at an approximate level, and hence the compacting process of the yarn neither improves nor worsens the quality. A graphic image of the simultaneous influence of parameters α_m and p_w on the coefficient – CV_m for both yarns analysed is presented in ***Figures 2*** and ***3***. Hence the character of changes in the coefficient - CV_m of both yarns analysed yarns is brought nearer.

Both parameters of the spinning process (α_m and p_w) influence the coefficient of variation - CV_m with similar intensity. Together with an increase in coefficient - α_m and decrease in the percentage of noils - p_w, the coefficient - CV_m of both of the cotton yarns analysed grows. In the case of ring classic yarn (***Figure 2***), the influence of coefficient – CV_m is differentiated. Near the value $\alpha_m \approx 90$, the value of CV_m has a larger influence on changes in the percentage of noils - p_w. In the range of the value - $\alpha_m = 95 \div 105$, the parameters. α_m and p_w affect the value of CV_m with similar intensity. When $\alpha_m \geq 105$, then the value of CV_m mainly influences parameter – α_m only. In the case of ring compact yarn (***Figure 3***), changes in p_w have a larger influence on the value of coefficient – CV_m in the whole range of α_m analysed.

Comparison of the number of thick places -$z_{T,\,1000}$

There is a relationship between thick and thin places of yarn and yarn evenness. Because thin and thick places are a considerable part of the entire evenness of yarn, it has to be expected that the evenness for a given yarn count will increase with the number and size of thick and thin places or vice versa (Furter R., Physical properties of spun yarns. The standard from fibre to fabric. Application report., SE586, USTER Think quality, USTER TECHNOLOGY AG, 2004). Comparative assessment of the data in ***Figure 4*** (see page 30) shows that in the majority of cases, the number of thick places$_{+50\%}$ in ring compact yarns are larger than in ring classic ones, although one can find cases where the thick$_{+50\%}$ is the same or even smaller than in ring classic yarn. Generally, the compacting process unfavorably influences the value of thick$_{+50\%}$. Graphic images of the simultaneous influence of parameters α_m and p_w on the number of thick places$_{+50\%}$ are presented in ***Figures 5*** and ***6*** (see page 30).

Of the parameters of the spinning process considered, changes in p_w have a considerably larger influence on the number of thick places$_{+50\%}$ in cotton ring classic yarn (***Figure 5,*** see page 30). The course of changes in the function Thich$_{+50\%}$ = $f(\alpha_m;\ p_w)$ is very

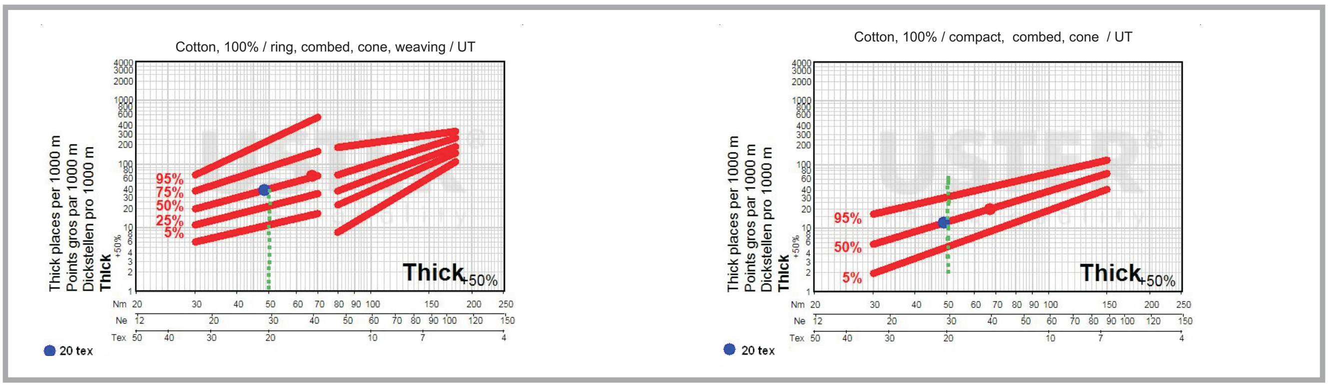

Figure 4. USTER STATISTICS for the number of thick places$_{+50\%}$.

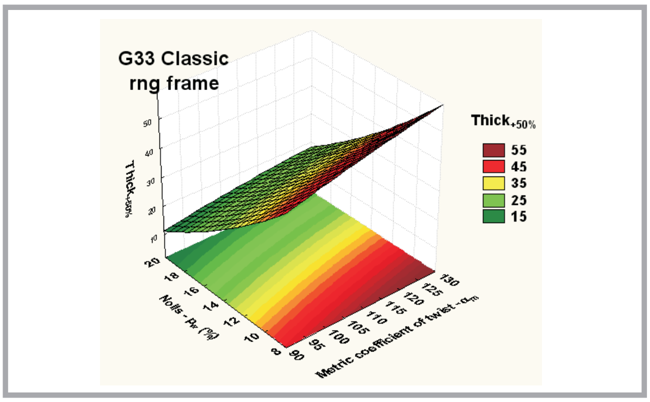

***Figure 5.** Diagram of thick places (+50%) for cotton classic yarn, where R = 0.861, F_{calc} = 10.89, and $F5_{19}$ = 2.74.*

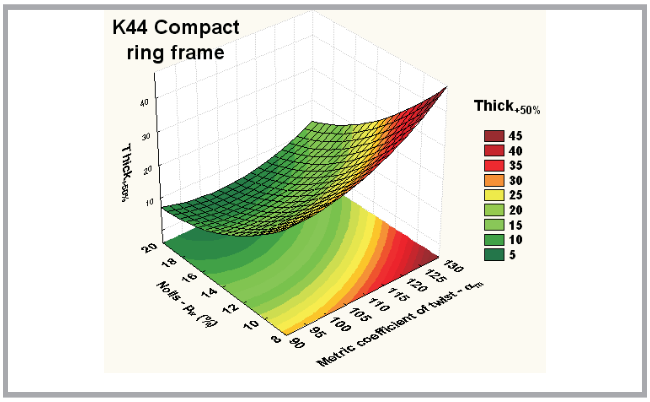

***Figure 6.** Diagram of thick places (+50%) for cotton compact yarn, where R = 0.884, F_{calc} = 13.63, and $F5_{19}$ = 2.74.*

diverse. In the range α_m = 90 ÷ 95 and p_w = 12 ÷ 20%, the number of thick places in the larger rank the parameter - α_m. In the range α_m = 90 ÷ 100 and p_w = 8 ÷ 12 %, both parameters affect the number of thick places$_{+50\%}$ with almost equal intensity. The number of thick placeds$_{+50\%}$ is primarily dependent on changes in p_w beyond distinguished areas. Together with an increase in p_w, for the whole range of α_m analysed, the number of thick places$_{+50\%}$ decreases. Reducing α_m also contributes to reducing the number of thick places$_{+50\%}$ in the yarn. The character of changes in this parameter for compact yarns (***Figure 6***) is similar.

Comparison of the number of neps$_{+200\%}$

The comparative assessment data given in ***Figure 7*** shows that in the majority of cases the number neps$_{+200\%}$ in compact yarns are imperceptibly larger than in classic ones, although cases can be found where the number of neps$_{+200\%}$ in the compact yarn is the same, or even smaller than in classic yarn. Generally, the compacting process imperceptibly worsens the quality of the yarn with respect to the number of neps$_{+200\%}$.

Graphic images of the simultaneous influence of parameters α_m and p_w on the number of neps$_{+200\%}$ are shown in ***Figures 8*** and ***9***.

The character of changes in both the yarns analysed is similar. p_w has a larger influence on the number neps$_{+200\%}$. Together with an increase in p_w, for the whole range of α_m analysed, the number of neps$_{+200\%}$ of both yarns decreases. Reducing the value of α_m also contributes to reducing the number of neps$_{+200\%}$ in the yarn.

Comparison of hairiness - H

Yarn hairiness has a considerable influence on the appearance and handle of fabric, as well as on the formation of pilling (Furter, 2004). Comparative assessment of the data shown in ***Figure 10*** shows that for all the cases analysed, the hairiness H of compact yarn is essentially smaller than that of the classic variety; hence the compacting process significantly reduces the hairiness of yarn, which is a very important feature from the point of view of the appearance and handle of the finished article.

A graphic image of the simultaneous influence of parameters α_m and p_w on the hairiness H is presented in ***Figures 11*** and ***12***. The character of the changes in H of both yarns analysed is similar. The hairiness of the yarn is almost exclusively dependent on changes in α_m. And together with this increase, the value of H decreases p_w for the whole range of p_w analysed

Comparison of the tenacity – R_H

Comparative assessment of the data given in in ***Figure 13*** (see page 32) shows that for all the cases analysed, the tenacity – R_H of compact yarns is significantly larger than classic ones. In the majority of cases, the use of classic yarn of a metric coefficient of the twist -α_m = 90 - 110 in the production process, regardless of the percentage of noils -p_w applied, one obtains – $R_H \geq$ 15.5 cN/tex. One even achieves this tenacity for compact yarns near the small value of α_m = 90 and very small value p_w = 8%. Hence the compacting process significantly enlarges the tenacity of

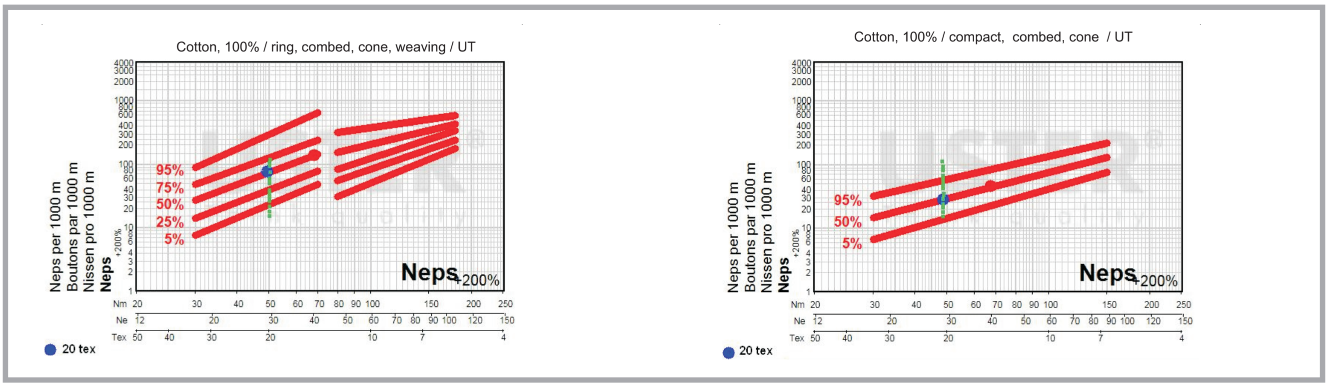

Figure 7. USTER STATISTICS for the number of neps+200%.

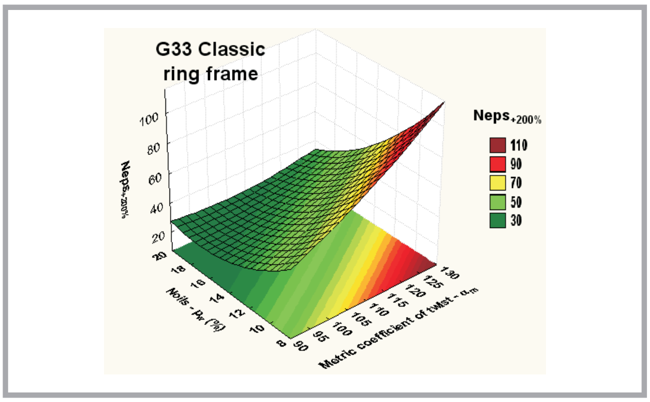

Figure 8. Diagram of neps (+200%) for cotton classic yarn, where R = 0.937, F_{calc} = 27.48, and $F5_{19}$ = 2.74.

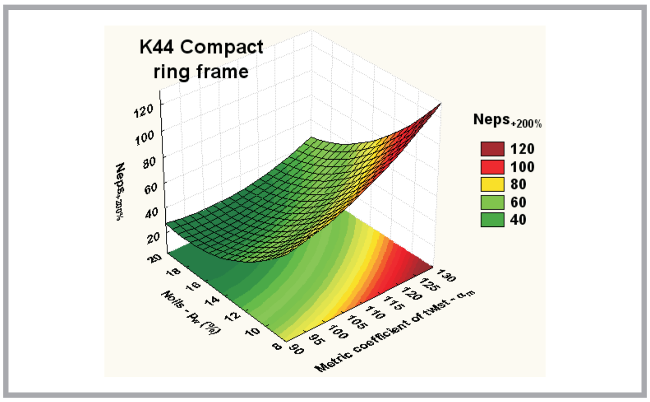

Figure 9. The diagram of neps (+200%) for cotton compact yarn, where R = 0.964, F_{calc} = 49.42, and $F5_{19}$ = 2.74.

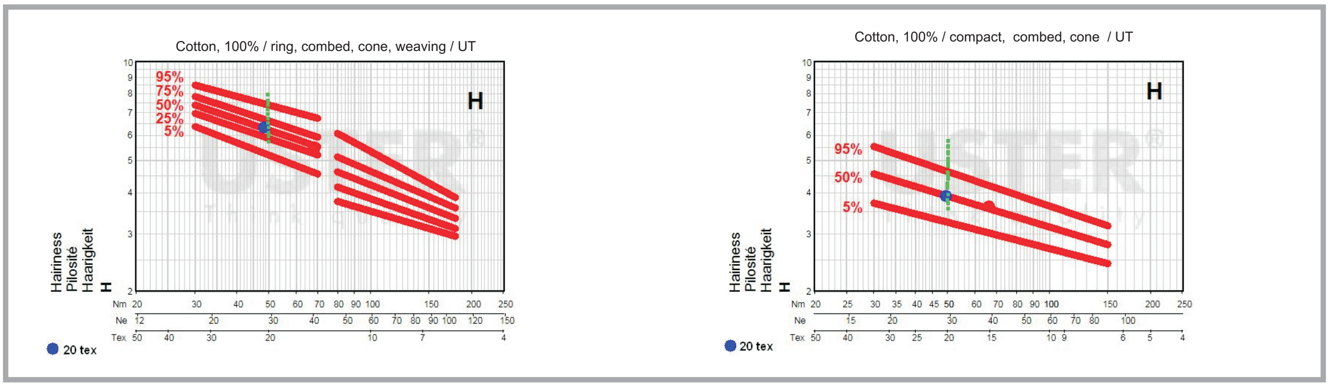

Figure 10. USTER STATISTICS for the hairiness - H.

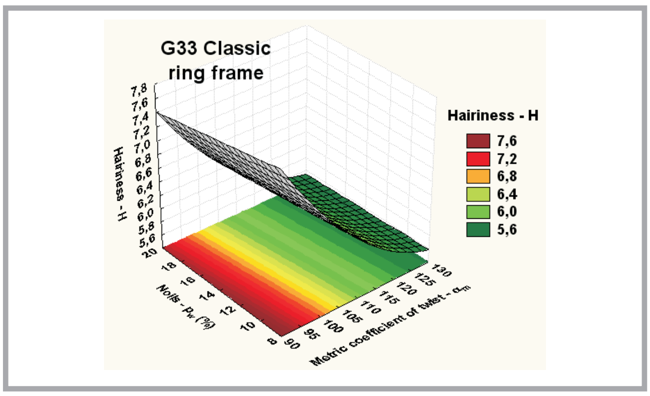

Figure 11. Diagram of H for cotton classic yarn R = 0.909; F_{calc} = 18.16, $F5_{19}$ = 2.74.

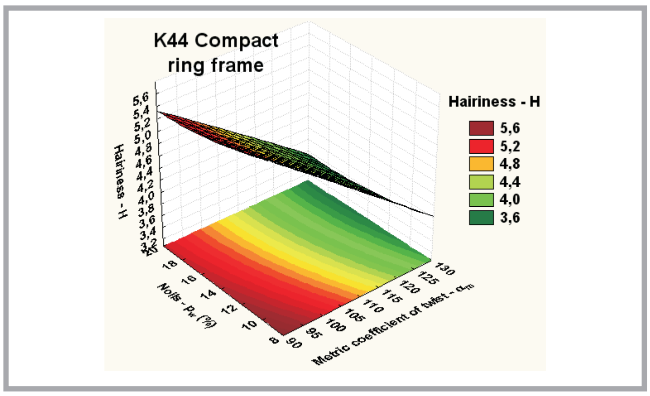

Figure 12. Diagram of H for cotton compact yarn R = 0.992; F_{calc} = 245.24, $F5_{19}$ = 2.74

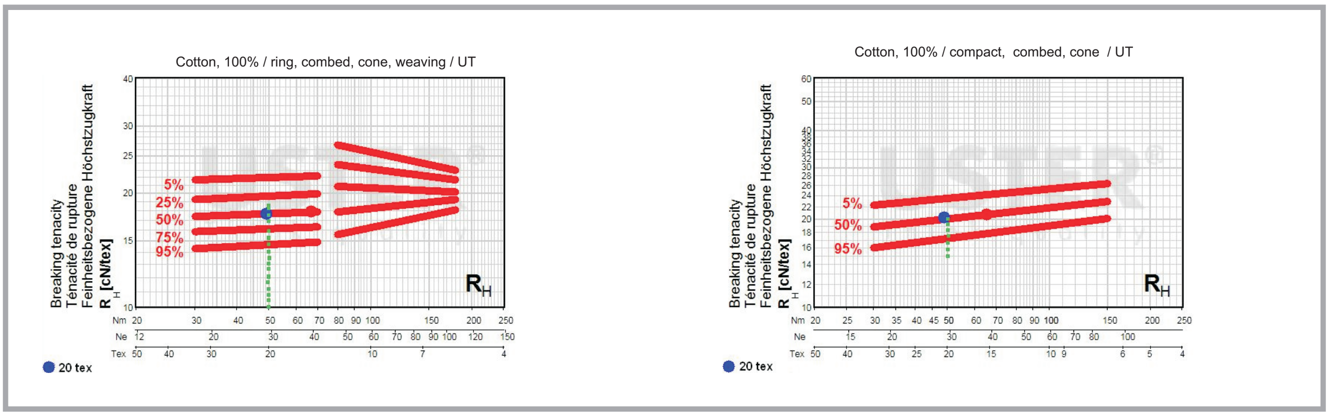

Figure 13. *USTER STATISTICS for the tenacity - R_H.*

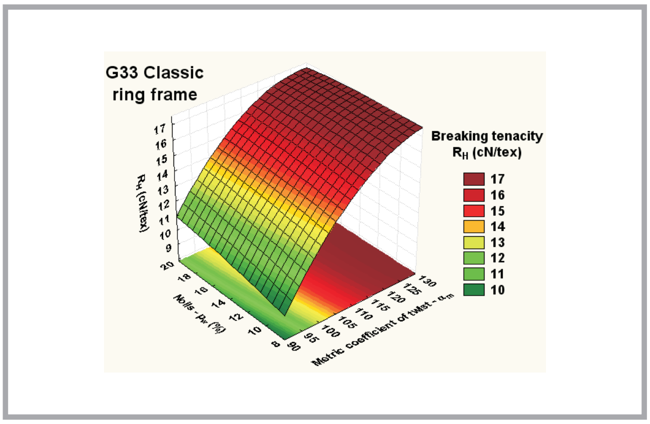

Figure 14. *Diagram of R_H for cotton classic yarn, where R = 0.982, F_{calc} = 101.84, and $F^5{}_{19}$ = 2.74.*

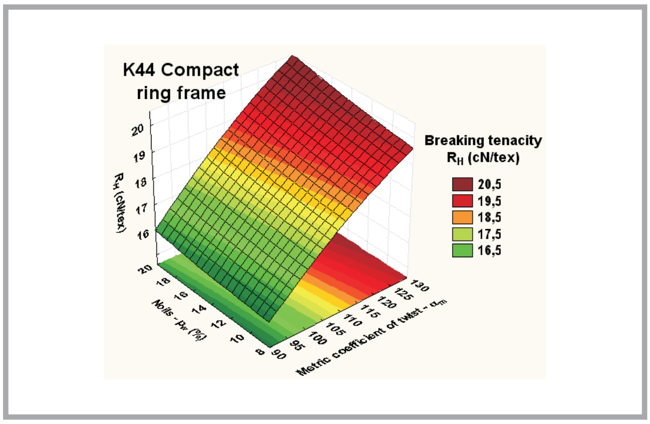

Figure 15. *Diagram of R_H for cotton compact yarn, whre R = 0.945, F_{calc} = 31.49, and $F^5{}_{19}$ = 2.74.*

yarns, which is a very important feature from the point of view of both the quality of the yarn and the efficiency of the spinning process.

A graphic image of the simultaneous influence of parameters α_m and p_w on values of R_H are presented in ***Figures 14*** and ***15***. The character of changes in the R_H of all the yarns analysed is similar. The changes in metric α_m have a decidedly larger influence on R_H. Together with an increasing α_m, for the whole range of p_w analysed, the tenacity – R_H increases. The growth of p_w also contributes to the insignificant enlargement of R_H.

Comparison of the breaking elongation – ε_H

Comparative assessment of the data given in ***Figure 16*** shows that for all the cases analyzed the breaking elongation – ε_H of compact yarn is considerably larger than the classic one. In the majority of cases, by partly using classic yarn of α_m = 90 - 110 in the production process, regardless of the p_w applied, one does not obtain a breaking elongation – $\varepsilon_H \geq 5.5$ %. It is possible to achieve this aspect ratio for compact yarns with a small value of approx. α_m = 90 and very small value of p_w = 8%. Hence the compacting process significantly enlarges the breaking elongation of yarns. Graphic images of the simultaneous influence of parameters α_m and p_w on the value of ε_H are introduced in ***Figures 17*** and ***18***. Changes in α_m have a larger influence on the ε_H of cotton classic yarn .

To the line of bending - α_m = 120.56 + - 0.35·p_w, the influence of α_m and p_w is similar, with the quite considerable domination of α_m. After the crossing of this line α_m mainly influences the value of ε_H only. Together with an increase in α_m, for the whole range of p_w analysed, the breaking elongation – ε_H of cotton classic yarn decreases to the value α_m = 120.56 - 0.35·p_w and rises after its crossing.

Together with an increase in p_w, for the whole range of α_m analysed, the breaking elongation – ε_H of cotton classic yarn rises imperceptibly. A somewhat different course of variation has the graph of the regression function - $\hat{\varepsilon}_H$ = f(α_m; p_w) prepared for cotton compact ring yarn - ***Figure 18***. Together with an increase in α_m, for the whole range of p_w anlaysed, the breaking elongation – ε_H rises. This yarn achieves the largest value of ε_H in the range of α_m = 120 ÷ 130 and p_w = 8 ÷ 16%.

Step 6. *Selection of technologically useful parameters for the spinning process by means of the General Index of Quality - G_Q*

The General Index of quality, G_Q, (***Figure 19*** and ***20,*** see pasge 34) was used to select parameters for the spinning process that are technologically useful in the way described in the first part of the article. The parameters of the spinning process (α_m and p_w) assuring the obtainment of cotton ring classic yarns for which the General Index of Quality fulfils the equation - $G_{QG3} = R^+ \cup \{0.5\}$ are introduced in ***Figure 21*** (see page 34). These parameters were calculated using the result of the analysis of the regression function:

$$G_{QG3} = -5.622 + 0.107 \cdot \alpha_m + - 0.00053 \cdot \alpha_m^2 - 0.00257 \cdot p_w^2 + + 0.00088 \cdot \alpha_m \cdot p_w \geq 0.5$$

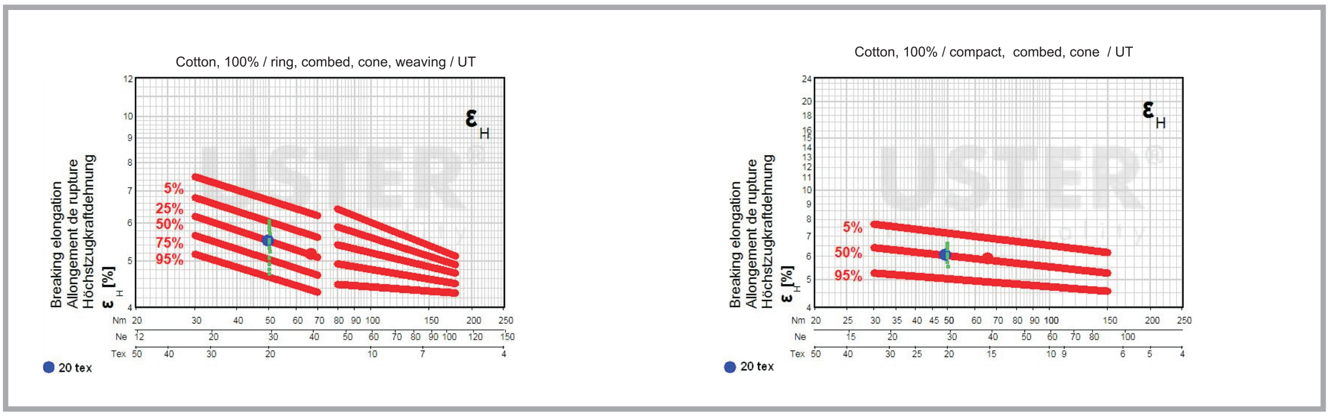

Figure 16. *USTER STATISTICS for the breaking elongation -* ε_H*.*

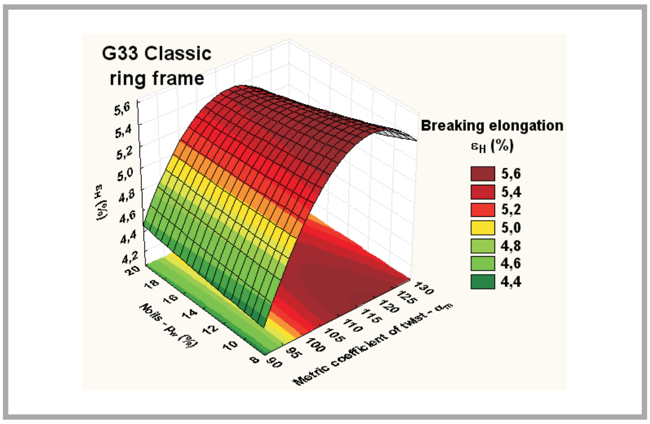

Figure 17. *Diagram of* ε_H *for cotton classic yarn;* $R = 0.956$*;* $F_{calc} = 40.64$*,* $F^5_{19} = 2.74$*.*

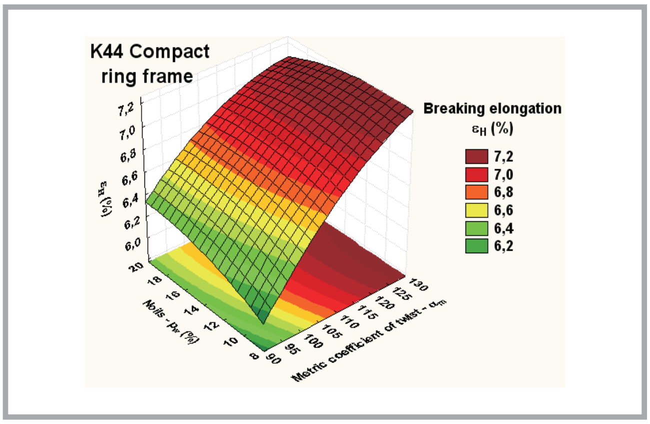

Figure 18. *Diagram of* ε_H *for cotton compact yarn;* $R = 0.932$*;* $F_{calc} = 25.19$*;* $F^5_{19} = 2.74$*.*

In the case of the production of cotton ring classic yarns with a linear mass of about 20 tex on a ring spinning frame of the type G33, made by the Rieter firm, the assurance of quality guaranteeing the obtainment of suitable technological usefulness is possible, when the following condition is fulfilled:

$$\alpha_m = \{99 \vee 128\} \wedge p_w = \{12 \vee 20\}.$$

This means that you should apply the metric coefficient of the twist $\alpha_m \geq 99$ and the percentage of noils - $p_w \geq 12\%$ for the assurance of the sufficient quality of the yarns analysed.

The parameters of the spinning process represented by the metric coefficient of the twist - α_m and percentage of noils - p_w, assuring the obtainment of cotton ring compact yarns for which the General Index of the Quality fulfils the equation - $G_{QG3} = R^+ \cup \{0.5\}$ are introduced in ***Figure 22*** (see page 34). These parameters were calculated using the result of the analysis of the regression function :

$$G_{QG3} = -4.149 + 0.077 \cdot \alpha_m + \\ - 0.00037 \cdot \alpha_m^2 - 0.00195 \cdot p_w^2 + \\ + 0.0007 \cdot \alpha_m \cdot p_w \geq 0.5$$

In turn, in the case of the production of cotton ring compact yarns with a linear mass of about 20 tex on a ring spinning frame of the type K44, made by the Rieter firm, the assurance of quality guaranteeing the obtainment of suitable technological usefulness is possible when the following condition is fulfilled:

$$\alpha_m = \{92 \vee 128\} \wedge p_w = \{9 \vee 20\}.$$

This also means that one can already apply a metric coefficient of twist – α_m of about 92 and a percentage of noils – p_w of about 9% for the production of these yarns.

Conlusions

On the basis of the investigations conducted and an analysis of the review of the literature, it can be concluded that:

1. The coefficient of variation – CV_m in % of cotton ring yarns, both classic and compact, is maintained at an approximate equal level, hence the compacting process of the yarn does not worsen this index of the quality.
2. The compacting process of the yarn does not influence any decrease nor enlargement in the number thin places$_{-50\%}$.
3. In the majority of cases, the number of thick places$_{+50\%}$ and neps$_{+200\%}$ in compact yarns are larger than the analogical number of thick places and neps in classic yarns; although this number does not increase, it becomes more visible under the influence of the consolidation of fibres in the compacting zone.
4. The hairiness - H of compact yarn is significantly smaller than the that of classic yarn, which is a very important feature from the point of view of the appearance and handle of the finished article.
5. The tenacity – R_H of compact yarn is indeed larger than the tenacity of classic yarn. In the majority of cases ap-

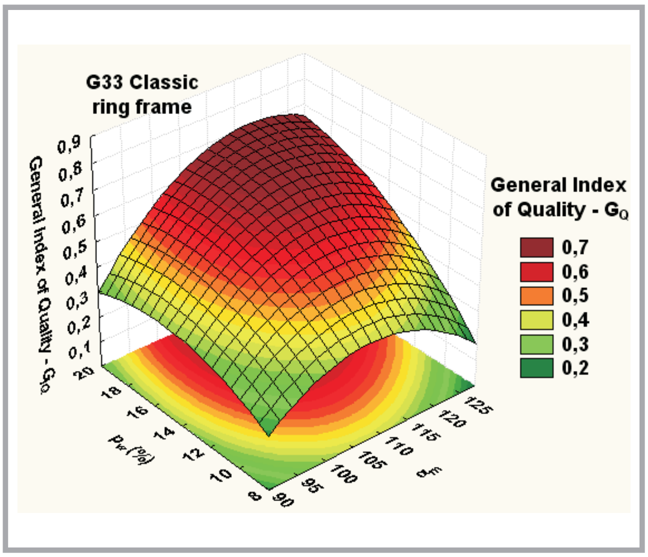

Figure 19. *The diagram of G_Q for cotton classic yarn $R = 0.929$; $F_{calc} = 27.64$; $F^5_{19} = 2.87$.*

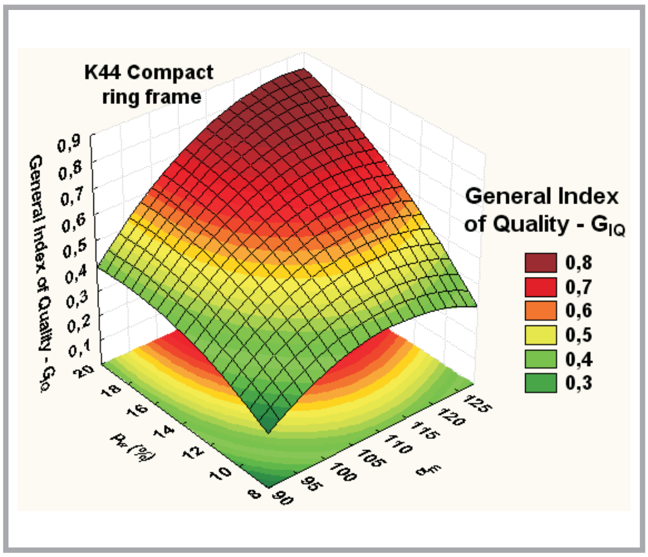

Figure 20. *The diagram of G_Q for cotton compact yarn $R = 0.942$; $F_{calc} = 39.50$; $F^5_{19} = 2.87$.*

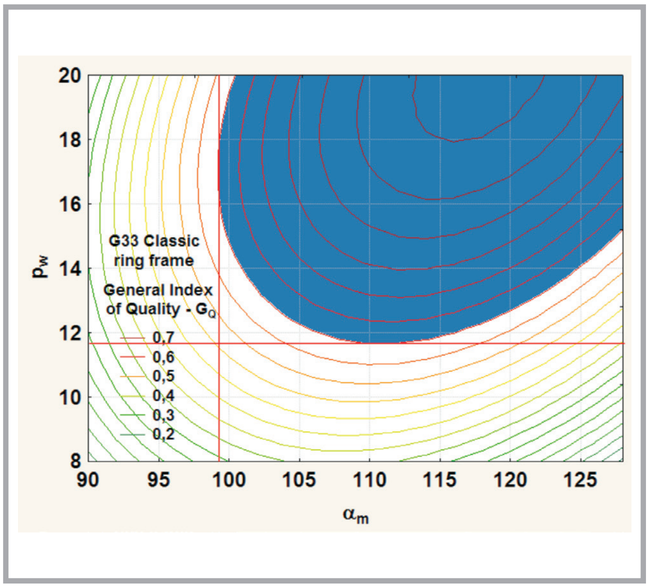

Figure 21. *Diagram of G_Q for cotton classic yarn.*

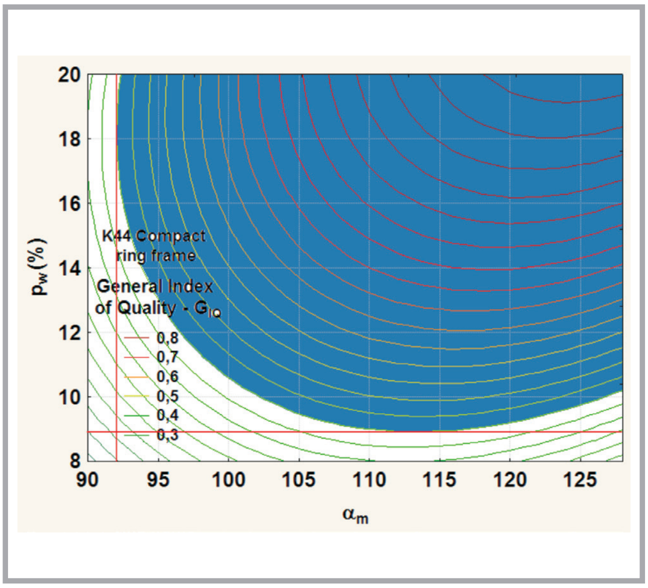

Figure 22. *Diagram of G_Q for cotton compact yarn.*

plied in the production process of classic yarn of a coefficient of the twist in the rangeof - $\alpha_m = 90 - 110$, regardless of the percentage of noils - p_w applied, one cannot obtain a tenacity $R_H \geq 15.5$ cN/tex. This the tenacity – R_H one already achieves for compact yarns near the border bottom parameters of the spinning process assumed in the investigations, and now near the coefficient of the twist - $\alpha_m = 90$ and the percentage of noils - $p_w = 8\%$. Hence the compacting process significantly enlarges the value of R_H, which is a very important feature from the point of view of both the quality of the yarn and the efficiency of the spinning process.

6. The compacting process influences the growth of the breaking elongation of the yarn - ε_H significantly, which is also a very important feature.

7. The lowering of the coefficient of twist - α_m and percentage of noils - p_w during the production of compact yarn makes possible the obtainment of significant productive effects and a decrease in the cost of producing yarn without worsening its quality.

8. For the production of ring classic cotton yarns it is necessary to apply a coefficient of twist α_m of at least 99 and a percentage of noils of at least 12%; although it is already possible to apply a metric coefficient of the twist $\alpha_m = 92$ and percentage of noils - $p_w = 9\%$ for the production of cotton ring compact yarns.

Reference

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Received 30.11.2009 Reviewed 07.06.2010