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

Abstract
The verification of models based on multiple regression 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 - $\alpha_m$ and percentage noils - $p_w$ during the production of compact yarn makes possible the attainment 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.

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.

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

<table>
<thead>
<tr>
<th>Parameter of yarn analysed</th>
<th>Classic ring frame G33</th>
<th>Compact ring frame K44</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{A,\alpha}$</td>
<td>$F_{B,\alpha}$</td>
<td>$F_{critical}$</td>
</tr>
<tr>
<td>Coefficient of variation – $CV_m$</td>
<td>14.10</td>
<td>13.46</td>
</tr>
<tr>
<td>Number of thin places, $%$</td>
<td>2.25</td>
<td>1.63</td>
</tr>
<tr>
<td>Number of thick places, $%$</td>
<td>4.24</td>
<td>6.57</td>
</tr>
<tr>
<td>Number of neps+$200%$</td>
<td>5.43</td>
<td>18.67</td>
</tr>
<tr>
<td>Hairiness – $H$</td>
<td>23.53</td>
<td>1.14</td>
</tr>
<tr>
<td>Tenacity – $RH$, cN/tex</td>
<td>81.21</td>
<td>0.84</td>
</tr>
<tr>
<td>E elongation – $\varepsilon_H$, %</td>
<td>45.13</td>
<td>0.38</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Physical properties of yarns</th>
<th>$CV_m$</th>
<th>Thinn+$50%$</th>
<th>Thick+$50%$</th>
<th>Neps+$200%$</th>
<th>$H$</th>
<th>$RH$</th>
<th>$\varepsilon_H$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CV_m$</td>
<td>+2</td>
<td>+4</td>
<td>+4</td>
<td>-3</td>
<td>+3</td>
<td>+3</td>
<td></td>
</tr>
<tr>
<td>Thinn+$50%$</td>
<td>+2</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
<td>-1</td>
<td>+1</td>
<td></td>
</tr>
<tr>
<td>Thick+$50%$</td>
<td>+4</td>
<td>+1</td>
<td>+4</td>
<td>+4</td>
<td>-2</td>
<td>+2</td>
<td>+3</td>
</tr>
<tr>
<td>Neps+$200%$</td>
<td>+4</td>
<td>+1</td>
<td>+2</td>
<td>-2</td>
<td>+2</td>
<td>+2</td>
<td></td>
</tr>
<tr>
<td>$H$</td>
<td>-3</td>
<td>-1</td>
<td>-2</td>
<td>-2</td>
<td>-5</td>
<td>-4</td>
<td></td>
</tr>
<tr>
<td>$RH$</td>
<td>+3</td>
<td>+1</td>
<td>+2</td>
<td>+2</td>
<td>+4</td>
<td>+4</td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_H$</td>
<td>+3</td>
<td>+3</td>
<td>+3</td>
<td>+2</td>
<td>-4</td>
<td>+4</td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Physical properties of yarns</th>
<th>$CV_m$</th>
<th>Thinn+$50%$</th>
<th>Thick+$50%$</th>
<th>Neps+$200%$</th>
<th>$H$</th>
<th>$RH$</th>
<th>$\varepsilon_H$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CV_m$</td>
<td>+2</td>
<td>+4</td>
<td>+5</td>
<td>-1</td>
<td>+2</td>
<td>+1</td>
<td></td>
</tr>
<tr>
<td>Thinn+$50%$</td>
<td>+2</td>
<td>+2</td>
<td>+5</td>
<td>0</td>
<td>+1</td>
<td>+1</td>
<td></td>
</tr>
<tr>
<td>Thick+$50%$</td>
<td>+4</td>
<td>+2</td>
<td>+5</td>
<td>-1</td>
<td>+1</td>
<td>+1</td>
<td></td>
</tr>
<tr>
<td>Neps+$200%$</td>
<td>+5</td>
<td>+2</td>
<td>+5</td>
<td>-1</td>
<td>+2</td>
<td>+1</td>
<td></td>
</tr>
<tr>
<td>$H$</td>
<td>+2</td>
<td>+0</td>
<td>-1</td>
<td>+1</td>
<td>-3</td>
<td>-5</td>
<td></td>
</tr>
<tr>
<td>$RH$</td>
<td>+2</td>
<td>+1</td>
<td>+1</td>
<td>+2</td>
<td>-5</td>
<td>+3</td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_H$</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
<td>-3</td>
<td>+3</td>
<td></td>
</tr>
</tbody>
</table>

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 $\alpha_m$ and $p_w$ on the number of thick places+50% are presented in Figures 5 and 6 (see page 30).

Comparison of the coefficient of variation -CVm

Comparative assessment of in the data given in Figure 1 shows that in the majority of cases the coefficient – CVm 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 $\alpha_m$ and $p_w$ on the coefficient – CVm for both yarns analysed is presented in Figures 2 and 3. Hence the character of changes in the coefficient - CVm of both yarns analysed yarns is brought nearer.

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

Comparison of the number of thick places -ZT, 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 $\alpha_m$ 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
diverse. In the range $\alpha_m = 90 \div 95$ and $p_w = 12 \div 20\%$, the number of thick places in the larger rank the parameter $\alpha_m$. In the range $\alpha_m = 90 \div 100$ and $p_w = 8 \div 12\%$, both parameters affect the number of thick places $+50\%$ with almost equal intensity. The number of thick places $+50\%$ is primarily dependent on changes in $p_w$ beyond distinguished areas. Together with an increase in $p_w$, for the whole range of $\alpha_m$ analysed, the number of neps $+200\%$ decreases. Reducing $\alpha_m$ 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 $\alpha_m$ 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 $\alpha_m$ analysed, the number of neps $+200\%$ of both yarns decreases. Reducing the value of $\alpha_m$ 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 given 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 $\alpha_m$ 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 $\alpha_m$. 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 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 $-\alpha_m = 90 - 110$ 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 $\alpha_m = 90$ and very small value $p_w = 8\%$. Hence the compacting process significantly enlarges the tenacity of...
Figure 7. USTER STATISTICS for the number of nep$^+200\%$.

Figure 8. Diagram of nep$^+200\%$ for cotton classic yarn, where $R = 0.937$, $F_{\text{calc}} = 27.48$, and $F_{519} = 2.74$.

Figure 9. Diagram of nep$^+200\%$ for cotton compact yarn, where $R = 0.964$, $F_{\text{calc}} = 49.42$, and $F_{519} = 2.74$.

Figure 10. USTER STATISTICS for the hairiness - $H$.

Figure 11. Diagram of $H$ for cotton classic yarn $R = 0.909$; $F_{\text{calc}} = 18.16$, $F_{519} = 2.74$.

Figure 12. Diagram of $H$ for cotton compact yarn $R = 0.992$; $F_{\text{calc}} = 245.24$, $F_{519} = 2.74$. 
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 $\alpha_m$ and $p_w$ on values of $R_H$ are presented in Figures 14 and 15. The changes in metric $\alpha_m$ have a decidedly larger influence on $R_H$. Together with an increasing $\alpha_m$, 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 – $\varepsilon_{H}$

Comparative assessment of the data given in Figure 16 shows that for all the cases analyzed the breaking elongation – $\varepsilon_{H}$ of compact yarn is considerably larger than the classic one. In the majority of cases, by partly using classic yarn of $\alpha_m = 90 - 110$ 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. $\alpha_m = 90$ 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 $\alpha_m$ and $p_w$ on the value of $\varepsilon_{H}$ are introduced in Figures 17 and 18. Changes in $\alpha_m$ have a larger influence on the $\varepsilon_{H}$ of cotton classic yarn.

To the line of bending - $\alpha_m = 120.56 + 0.35.p_w$, the influence of $\alpha_m$ and $p_w$ is similar, with the quite considerable domination of $\alpha_m$. After the crossing of this line $\alpha_m$ mainly influences the value of $\varepsilon_{H}$ only. Together with an increase in $\alpha_m$, for the whole range of $p_w$ analysed, the breaking elongation – $\varepsilon_{H}$ of cotton classic yarn decreases to the value $\alpha_m = 120.56 - 0.35.p_w$ and rises after its crossing. Together with an increase in $p_w$, for the whole range of $\alpha_m$ analysed, the breaking elongation – $\varepsilon_{E}$ of cotton classic yarn rises imperceptibly. A somewhat different course of variation has the graph of the regression function - $\varepsilon_{H} = f(\alpha_m, p_w)$ prepared for cotton compact ring yarn - Figure 18. Together with an increase in $\alpha_m$, for the whole range of $p_w$ analysed, the breaking elongation – $\varepsilon_{H}$ rises. This yarn achieves the largest value of $\varepsilon_{H}$ in the range of $\alpha_m = 120 \div 130$ and $p_w = 8 \div 16\%$.

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 page 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 ($\alpha_m$ and $p_w$) assuring the obtainment of cotton ring classic yarns for which the General Index of Quality fulfils the equation - $G_{QG3} = R + \{0.5\}$ are introduced in Figure 21 (see page 34). These parameters were calculated using the result of the analysis of the regression function:

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

\[
\alpha_m = \{99 \lor 128\} \land p_w = \{12 \lor 20\}.
\]

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 - \(\alpha_m\) 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 - \(G_{QG3} = R + \{0.5\}\) are introduced in Figure 22 (see page 34). These parameters were calculated using the result of the analysis of the regression function:

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

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:

\[
\alpha_m = \{92 \lor 128\} \land p_w = \{9 \lor 20\}.
\]

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

### Conclusions

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-
plied in the production process of classic yarn of a coefficient of the twist in the range of $\alpha_m = 90 - 110$, 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 $\varepsilon_1$ significantly, which is also a very important feature.

7. The lowering of the coefficient of twist $\alpha_m$ and percentage of noils $p_w$ during the production of compact yarn makes possible the obtaining 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 $\alpha_m$ 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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