BASIC COMPARISON OF THE PROPERTIES OF THE LOOP AND FROTTE YARNS, WOVEN AND KNITTED FABRICS

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Abstract:
Both loop fancy yarns and frotte fancy yarns belong to the group of yarns with continuous effects. The difference between frotte and loop yarn relies on the fact that the loop yarn is constructed with two core yarns and the frotte yarn is constructed with only one core yarn. The differences are evident in the shape of these two types of fancy yarns. These shape differences are the functions of the tensions of component yarns during the twisting process. The shape and construction of the fancy yarn influence its properties. The properties of loop and frotte fancy yarns, woven and knitted fabrics are compared in this article in order to find out the optimal yarn’s and fabric’s production condition to satisfy the final user and maintain low production costs. In terms of economy aspects only, the frotte fancy yarns are believed to be cheaper in production due to lower quantity of components utilize for their production to compare with loop fancy yarns, under conditions of the same settings of ring twisting frame.

Keywords:
fancy yarn, loop yarn, frotte yarn, weaving and knitting with fancy yarns, fancy yarns’ properties

Introduction
The loop yarn is characterized by distinct, rounded loops that occur on the surface of the thread. The loop yarn is formed as a result of the large overfeed of the effect yarn in relation to two core component yarns. The twist and the structure of the loop yarn are fixed by the binding yarn. The binding yarn is twisted, using low value twist, with the loop yarn in opposite direction and then the loop yarn is twisted. Therefore, the loop yarn is composed of four-component yarns: two core yarns, one effect yarn and one binding yarn. The structure of the loop yarn is presented in Figure 1 [1,2].

The frotte yarn is composed with three component yarns: one core yarn, effect yarn and binding yarn. The frotte yarn is characterized with wavy arrangement of the effect yarn. The structure of the frotte yarn is presented in Figure 2.

Figure 1. The structure of the loop yarn: 1 – core yarns, 2 – effect yarn and 3 – binding yarn [2].

Figure 2. The structure of the frotte yarn: 1 – core yarn, 2 – effect yarn and 3 – binding yarn [3].
All types of fancy yarns can be produced by a ring twisting machine or by a hollow spindle machine. The different types of fancy yarns are produced using different types of component yarns and different settings on the twisting machine. The main difference between the hollow spindle machine and ring twisting machine relies on the efficiency of the production of the fancy yarns: the hollow spindle efficiency is near 70 m/min and the efficiency of the ring twisting machine is only 15 m/min. The differences in the efficiency of these two types of twisting machines result from the construction of the spindles and the system of the re-twisting process – in the case of hollow spindle machine, the twisting and re-twisting processes form one system; in the case of ring twisting machine, these processes are two different systems of twisting [3-6].

The differences in the shape of the loop yarn and frotte yarn are the result of the differences in the construction and laying of the component yarns in the guides during the twisting process. Laying of the component yarns on the ring-twisting machine in the case of the production of the loop yarn is shown in Figure 3. The two component yarns R1 and R2 (core) are delivered by guide PIII to the feed roller III. Next, the component core yarns are separated and introduced to the rocker arm shaft W, into two grooves on the pressure roller Nr and on this way they are twisted below guide Pn. The effect yarn Op is introduced (A) to the guide PII and to the slot guide S on the centre between the two grooves of the pressure roller Nr. Next, the effect yarn is introduced to the twisting zone through the guide Pn. In this manner, the effect yarn is introduced between two core yarns and using higher overfeed of the effect yarn, the regular loops are created on the core yarn. On the next stage and process, the loops are re-twisted with the binding yarn [1,3-6].

The settings of the component yarns in the case of the production of the frotte yarn on the ring-twisting machine are presented in Figure 4. The one core yarn R is introduced through the guide PIII, feed roller III and the rocker arm shaft W. Next, the core yarn R is carried through the pressure roller Nr on the one groove to the guide Pn. The effect yarn

Figure 3. The scheme of the production of fancy loop yarn on the ring twisting machine: R1, R2 – the core yarns, PII, PIII – guide, III – feed roller, W – rocker arm shaft, Nr – pressure roller, Pn – spindle guide, Op – effect yarn, S – slot guide [1].
The last process is the fixing of the effects by re-twisting the frotte yarn in opposite direction with the binding yarn [1,3-6].

**Experimental Part - Yarns**

Nine types of loop yarns and nine types of frotte yarns were produced on the ring twisting machine using the different settings on the machine: the crimp of the effect yarn and the twist. The plan of the experiment is presented in Table 1 (a and b).

Table 1. The Plan of The Experiment:

(a) Loop Yarn:

<table>
<thead>
<tr>
<th>NOMINAL TWIST (Z)</th>
<th>200 rpm</th>
<th>300 rpm</th>
<th>400 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect yarn nominal crimp [%]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td>a1</td>
<td>a2</td>
<td>A3</td>
</tr>
<tr>
<td>120%</td>
<td>B1</td>
<td>B2</td>
<td>B3</td>
</tr>
<tr>
<td>150%</td>
<td>C1</td>
<td>C2</td>
<td>C3</td>
</tr>
</tbody>
</table>

(b) Frotte Yarn:

<table>
<thead>
<tr>
<th>NOMINAL TWIST (Z)</th>
<th>200 rpm</th>
<th>300 rpm</th>
<th>400 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect yarn nominal crimp [%]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td>a1</td>
<td>a2</td>
<td>a3</td>
</tr>
<tr>
<td>120%</td>
<td>b1</td>
<td>b2</td>
<td>b3</td>
</tr>
<tr>
<td>150%</td>
<td>c1</td>
<td>c2</td>
<td>c3</td>
</tr>
</tbody>
</table>
The raw materials were as follows:
- Core yarn(s) – PET yarns, 24 tex.
- Effect yarn – PET 32x2 tex.
- Binding yarn – filament 22 tex.

For the statistical analysis of test hypotheses on the base parameters Student’s t-test was used. The aim of the tests was finding the source of the significance of differences between the height of loops in the case of two very similar types of fancy yarns: loop yarn and frotte yarns produced on the base the same raw materials and ring twisting machine settings. Also, we tried to answer what influences on the differences in yarns linear densities. The hypothesis zero was formulated as the lack of the significance differences between the chosen properties of loop and frotte yarns. Using the Shapiro–Wilk test, the normal distribution of the experiment data was proven. Using Student’s t-test, the essentiality of differences was proved. The analysis of the essentiality of the differences between the high of the loops in the case of loop and frotte yarns was performed on the basis of analysis of the images taken from the produced yarns. The images were transferred to the computer memory using scanning method and stored in the form of a bitmaps, which were then analysed using the image computer program. Measurement of linear mass of produced yarns was made based on the standard PN-83/P-04653.

The analysis of the essentiality of the differences between the linear densities of the loop yarn and frotte yarn

The difference between the average linear densities of loop and frotte fancy yarns produced on ring-twisting machine is statistically significant assuming a constant value of crimp and the number of twist for a given variant thread. These differences are more significant when the crimp increases.

Table 2. presents the results of carried out experiments on the linear densities of:

(a) Loop yarns:

<table>
<thead>
<tr>
<th>Yarn linear density Tt [ tex ]</th>
<th>Average value</th>
<th>Standard deviation</th>
<th>CV</th>
<th>Confidence interval for average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A&lt;sub&gt;1&lt;/sub&gt; 90% 200 rpm</td>
<td>169,600</td>
<td>4,949</td>
<td>1,49</td>
<td>167,180 , 172,020</td>
</tr>
<tr>
<td>A&lt;sub&gt;2&lt;/sub&gt; 90% 300 rpm</td>
<td>166,800</td>
<td>1,789</td>
<td>1,072</td>
<td>164,579 , 169,021</td>
</tr>
<tr>
<td>A&lt;sub&gt;3&lt;/sub&gt; 90% 400 rpm</td>
<td>161,000</td>
<td>2,000</td>
<td>1,242</td>
<td>158,517 , 163,483</td>
</tr>
<tr>
<td>B&lt;sub&gt;1&lt;/sub&gt; 120% 200 rpm</td>
<td>187,400</td>
<td>1,140</td>
<td>0,608</td>
<td>185,984 , 188,816</td>
</tr>
<tr>
<td>B&lt;sub&gt;2&lt;/sub&gt; 120% 300 rpm</td>
<td>184,400</td>
<td>2,881</td>
<td>1,562</td>
<td>180,823 , 187,977</td>
</tr>
<tr>
<td>B&lt;sub&gt;3&lt;/sub&gt; 120% 400 rpm</td>
<td>180,000</td>
<td>2,236</td>
<td>1,242</td>
<td>177,224 , 182,776</td>
</tr>
<tr>
<td>C&lt;sub&gt;1&lt;/sub&gt; 150% 200 rpm</td>
<td>230,000</td>
<td>2,236</td>
<td>0,972</td>
<td>227,224 , 232,776</td>
</tr>
<tr>
<td>C&lt;sub&gt;2&lt;/sub&gt; 150% 300 rpm</td>
<td>225,800</td>
<td>2,280</td>
<td>1,010</td>
<td>222,969 , 228,631</td>
</tr>
<tr>
<td>C&lt;sub&gt;3&lt;/sub&gt; 150% 400 rpm</td>
<td>218,400</td>
<td>4,159</td>
<td>1,904</td>
<td>213,236 , 223,564</td>
</tr>
</tbody>
</table>

(b) Frotte yarns:

<table>
<thead>
<tr>
<th>Yarn linear density Tt [ tex ]</th>
<th>Average value</th>
<th>Standard deviation</th>
<th>CV</th>
<th>Confidence interval for average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>a&lt;sub&gt;1&lt;/sub&gt; 90% 200 rpm</td>
<td>143,600</td>
<td>1,140</td>
<td>0,794</td>
<td>142,184 , 145,016</td>
</tr>
<tr>
<td>a&lt;sub&gt;2&lt;/sub&gt; 90% 300 rpm</td>
<td>139,200</td>
<td>2,683</td>
<td>1,927</td>
<td>135,868 , 142,532</td>
</tr>
<tr>
<td>a&lt;sub&gt;3&lt;/sub&gt; 90% 400 rpm</td>
<td>136,400</td>
<td>1,949</td>
<td>0,696</td>
<td>133,980 , 138,820</td>
</tr>
<tr>
<td>b&lt;sub&gt;1&lt;/sub&gt; 120% 200 rpm</td>
<td>159,400</td>
<td>4,037</td>
<td>2,533</td>
<td>154,387 , 164,413</td>
</tr>
<tr>
<td>b&lt;sub&gt;2&lt;/sub&gt; 120% 300 rpm</td>
<td>158,600</td>
<td>1,140</td>
<td>0,719</td>
<td>157,184 , 160,016</td>
</tr>
<tr>
<td>b&lt;sub&gt;3&lt;/sub&gt; 120% 400 rpm</td>
<td>149,400</td>
<td>1,817</td>
<td>1,216</td>
<td>147,144 , 151,656</td>
</tr>
<tr>
<td>c&lt;sub&gt;1&lt;/sub&gt; 150% 200 rpm</td>
<td>169,800</td>
<td>1,483</td>
<td>0,873</td>
<td>167,958 , 171,642</td>
</tr>
<tr>
<td>c&lt;sub&gt;2&lt;/sub&gt; 150% 300 rpm</td>
<td>169,400</td>
<td>2,074</td>
<td>1,224</td>
<td>166,825 , 171,975</td>
</tr>
<tr>
<td>c&lt;sub&gt;3&lt;/sub&gt; 150% 400 rpm</td>
<td>167,400</td>
<td>1,817</td>
<td>1,085</td>
<td>165,144 , 169,656</td>
</tr>
</tbody>
</table>
The analysis of the essentiality of the differences between the altitudes of loops in the case of the loop yarn and frotte yarn

With increasing the twist, the reduction of the loop altitude occurs. The increase in crimp increases the loop altitude. This phenomenon occurs regardless of the type of yarn used in the experiment.

Table 5 presents the results of carried out Student’s t-statistics for the loop altitudes of loop and Frotte fancy yarn.

<table>
<thead>
<tr>
<th>Type of Fancy Yarn</th>
<th>Value of Student’s t statistics</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop</td>
<td>Frotte</td>
<td></td>
</tr>
<tr>
<td>90% 200 rpm</td>
<td>169,600</td>
<td>143,600</td>
</tr>
<tr>
<td>90% 300 rpm</td>
<td>166,800</td>
<td>139,200</td>
</tr>
<tr>
<td>90% 400 rpm</td>
<td>161,000</td>
<td>136,400</td>
</tr>
<tr>
<td>120% 200 rpm</td>
<td>187,400</td>
<td>159,400</td>
</tr>
<tr>
<td>120% 300 rpm</td>
<td>184,400</td>
<td>158,600</td>
</tr>
<tr>
<td>120% 400 rpm</td>
<td>180,000</td>
<td>149,400</td>
</tr>
<tr>
<td>150% 200 rpm</td>
<td>230,000</td>
<td>169,800</td>
</tr>
<tr>
<td>150% 300 rpm</td>
<td>225,000</td>
<td>169,400</td>
</tr>
<tr>
<td>150% 400 rpm</td>
<td>218,400</td>
<td>167,400</td>
</tr>
</tbody>
</table>

Table 4. presents the results of carried out experiments on the altitudes of loops in the case of:
(a) Loop yarns:

<table>
<thead>
<tr>
<th>Loop altitude [mm]</th>
<th>Average value</th>
<th>Standard deviation</th>
<th>CV</th>
<th>Confidence interval for average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>90% 200 rpm</td>
<td>2,000</td>
<td>0,429</td>
<td>21,450</td>
<td>1,468÷2,532</td>
</tr>
<tr>
<td>90% 300 rpm</td>
<td>1,484</td>
<td>0,305</td>
<td>20,580</td>
<td>1,104÷1,860</td>
</tr>
<tr>
<td>120% 200 rpm</td>
<td>1,860</td>
<td>0,415</td>
<td>22,312</td>
<td>1,345÷2,375</td>
</tr>
<tr>
<td>120% 300 rpm</td>
<td>1,524</td>
<td>0,290</td>
<td>19,094</td>
<td>1,163÷1,885</td>
</tr>
<tr>
<td>150% 200 rpm</td>
<td>2,694</td>
<td>0,334</td>
<td>12,398</td>
<td>2,279÷3,109</td>
</tr>
<tr>
<td>150% 300 rpm</td>
<td>1,496</td>
<td>0,216</td>
<td>14,438</td>
<td>1,228÷1,764</td>
</tr>
</tbody>
</table>

(b) Frotte yarns:

<table>
<thead>
<tr>
<th>Loop altitude [mm]</th>
<th>Average value</th>
<th>Standard deviation</th>
<th>CV</th>
<th>Confidence interval for average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>90% 200 rpm</td>
<td>2,488</td>
<td>0,379</td>
<td>15,233</td>
<td>2,017÷2,959</td>
</tr>
<tr>
<td>90% 300 rpm</td>
<td>1,640</td>
<td>0,204</td>
<td>12,439</td>
<td>1,386÷1,894</td>
</tr>
<tr>
<td>120% 200 rpm</td>
<td>2,872</td>
<td>0,359</td>
<td>12,500</td>
<td>2,426÷3,318</td>
</tr>
<tr>
<td>120% 300 rpm</td>
<td>1,624</td>
<td>0,285</td>
<td>17,549</td>
<td>1,271÷1,977</td>
</tr>
<tr>
<td>150% 200 rpm</td>
<td>3,254</td>
<td>0,297</td>
<td>9,127</td>
<td>2,885÷3,623</td>
</tr>
<tr>
<td>150% 300 rpm</td>
<td>1,928</td>
<td>0,238</td>
<td>12,344</td>
<td>1,633÷2,223</td>
</tr>
</tbody>
</table>

Table 5. Results of Student’s t statistics for detecting the differences between the loop altitudes in the case of loop and Frotte fancy yarn.

<table>
<thead>
<tr>
<th>Loop altitude [mm]</th>
<th>Type of Fancy Yarn</th>
<th>Value of Student’s t statistics</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop</td>
<td>Frotte</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90% 200 rpm</td>
<td>2,000</td>
<td>2,488</td>
<td>-1,906</td>
</tr>
<tr>
<td>90% 300 rpm</td>
<td>1,482</td>
<td>1,640</td>
<td>-0,963</td>
</tr>
<tr>
<td>120% 200 rpm</td>
<td>2,872</td>
<td>2,890</td>
<td>4,125</td>
</tr>
<tr>
<td>120% 300 rpm</td>
<td>1,624</td>
<td>1,63</td>
<td>0,550</td>
</tr>
<tr>
<td>150% 200 rpm</td>
<td>2,694</td>
<td>3,254</td>
<td>-2,798</td>
</tr>
<tr>
<td>150% 300 rpm</td>
<td>1,496</td>
<td>1,928</td>
<td>-3,009</td>
</tr>
</tbody>
</table>
The loops of Frotte Yarn are higher than those in the case of Loop yarn. It can be concluded that the differences between the mean values of loop altitude in the case of loop yarn and frotte yarns are becoming larger (statistically significant) with the escalation of the crimp and slightly decreasing with the accumulation of the number of turns.

**Experimental Part – Weaving Fabrics**

Two batches of fabrics were produced on the loom “The tread stretcher Control TC-1” with different kinds of yarns used as a weft – a total of 10 samples of weaving fabrics were produced. Five samples of fabrics involve loop yarns from pre-selected variants: A1 – 90% of the crimp and 200 rpm, A2 – 90%, 300 rpm, B2 – 120%, 300 rpm, C2 – 150%, 300 rpm, C3 – 150%, 400 rpm, and five samples of fabrics with frotte yarn types: a1, a2, b2, c2 and c3 with crimp and twist as above. For all fabrics, satin weave was used. The plan of experiment for weaving fabrics is presented in Table 6: variant A for loop yarns as the weft and variant b for frotte yarns as weft. As a warp PE 15’2 tex was used.

The aim of the analysis was the detection of the source of the differences of fabric thickness and surface mass. The fabric thickness was measured according to the standard PN-EN ISO 5084 and the fabric surface mass was measured according to PN/ISO 3801 standard. The statistical analysis used was Student's t-test.

The analysis of the essentiality of the differences between the fabric thickness with the weft of the loop yarn and frotte yarns

The summary of the results of carried out experiments on the fabric thickness in the case of the loop yarns (A) and frotte yarns (b) used as a weft is presented in Table 7.

<table>
<thead>
<tr>
<th>Table 6. Plan of the experiments for weaving fabrics produced with loop (A) and frotte (b) yarn as a weft.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>YARN VARIANT</strong></td>
</tr>
<tr>
<td>A1 90% 200 rpm</td>
</tr>
<tr>
<td>Satin weave</td>
</tr>
<tr>
<td>Note: F, woven fabric; L, loop yarns; thus, e.g. FL2, woven fabric no. 2 made of loop yarn A2 (weft).</td>
</tr>
</tbody>
</table>

(b) frotte yarn as a weft:

<table>
<thead>
<tr>
<th>YARN VARIANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a1 90% 200 rpm</td>
</tr>
<tr>
<td>Satin weave</td>
</tr>
<tr>
<td>Note: F, woven fabric; f, frotte yarn; thus, e.g. Ff3, woven fabric no. 3 made of frotte yarn a2 (weft).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 7. The fabrics thickness in the case of the loop yarns (A) and frotte yarns (b) used as a weft.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average value</strong></td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
</tr>
<tr>
<td><strong>CV</strong></td>
</tr>
<tr>
<td><strong>Confidence interval for average value</strong></td>
</tr>
</tbody>
</table>

(a) Loop yarns as a weft:

<table>
<thead>
<tr>
<th>Fabric thickness [mm]</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL1 90% 200rpm</td>
<td>3,230</td>
<td>0,020</td>
<td>0,619</td>
<td>3,180÷3,280</td>
<td></td>
</tr>
<tr>
<td>FL2 90% 300rpm</td>
<td>2,860</td>
<td>0,026</td>
<td>0,909</td>
<td>2,794÷2,926</td>
<td></td>
</tr>
<tr>
<td>FL3 120% 300rpm</td>
<td>2,983</td>
<td>0,031</td>
<td>1,039</td>
<td>2,907÷3,059</td>
<td></td>
</tr>
<tr>
<td>FL4 150% 300rpm</td>
<td>3,007</td>
<td>0,090</td>
<td>2,925</td>
<td>2,853÷3,301</td>
<td></td>
</tr>
<tr>
<td>FL5 150% 400rpm</td>
<td>2,713</td>
<td>0,021</td>
<td>0,774</td>
<td>2,662÷2,765</td>
<td></td>
</tr>
</tbody>
</table>

(b) frotte yarns as a weft:

<table>
<thead>
<tr>
<th>Fabric thickness [mm]</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ff1 90% 200 rpm</td>
<td>3,067</td>
<td>0,351</td>
<td>11,444</td>
<td>2,979÷3,154</td>
<td></td>
</tr>
<tr>
<td>Ff2 90% 300 rpm</td>
<td>2,570</td>
<td>0,347</td>
<td>13,502</td>
<td>1,709÷3,431</td>
<td></td>
</tr>
<tr>
<td>Ff3 120% 300 rpm</td>
<td>2,740</td>
<td>0,010</td>
<td>0,365</td>
<td>2,715÷2,765</td>
<td></td>
</tr>
<tr>
<td>Ff4 150% 300 rpm</td>
<td>2,913</td>
<td>0,159</td>
<td>5,458</td>
<td>2,517÷3,309</td>
<td></td>
</tr>
<tr>
<td>Ff5 150% 400 rpm</td>
<td>2,613</td>
<td>0,040</td>
<td>1,531</td>
<td>2,513÷2,714</td>
<td></td>
</tr>
</tbody>
</table>
The analysis of the essentiality of the differences between the fabric surface mass with different wefts used – the loop yarn and frotte yarns.

The summary of the results of experiments carried out on the fabrics surface mass in the case of different wefts used – the loop yarns (A) and frotte yarns (b) – is presented in Table 9.

With the increase in yarn crimp, the mass surface of fabric increases. With increase in yarn twist, the mass surface of the fabric decreases. Table 10 presents the results of carried out Student's t statistics for the weaving fabric mass surface in the case of different wefts used: loop and frotte fancy yarns.

Fabrics with loop yarn as a weft are thicker than fabrics with frotte yarn used as a weft. With the increase in yarn twist and crimp, the differences in the thickness of the fabrics with used different yarns as a weft are less statistically significant.

Table 8. Results of Student's t-statistics for detecting the differences between the thicknesses of weaving fabrics with different wefts used – loop yarn and frotte yarn.

<table>
<thead>
<tr>
<th>Yarn variant (used as a weft)</th>
<th>Value of Student's t statistics t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabric thickness [mm]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loop yarn</td>
<td>Frotte yarn</td>
<td></td>
</tr>
<tr>
<td>90% 200rpm</td>
<td>3,230</td>
<td>3,067</td>
</tr>
<tr>
<td>90% 300rpm</td>
<td>2,860</td>
<td>2,740</td>
</tr>
<tr>
<td>120% 300rpm</td>
<td>3,077</td>
<td>2,570</td>
</tr>
<tr>
<td>150% 300rpm</td>
<td>2,983</td>
<td>2,913</td>
</tr>
<tr>
<td>150% 400rpm</td>
<td>2,713</td>
<td>2,613</td>
</tr>
</tbody>
</table>

Table 9. The fabrics surface mass in the case of the loop yarns (a) and frotte yarns (b) used as a weft. (a) Loop yarns as a weft:

<table>
<thead>
<tr>
<th>Fabric mass surface [g/m²]</th>
<th>Average value</th>
<th>Standard deviation</th>
<th>CV</th>
<th>Confidence interval for average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL1 90% 200rpm</td>
<td>419,667</td>
<td>4,623</td>
<td>1,102</td>
<td>408,182÷ 431,151</td>
</tr>
<tr>
<td>FL2 90% 300rpm</td>
<td>402,867</td>
<td>6,765</td>
<td>1,679</td>
<td>386,060÷ 419,673</td>
</tr>
<tr>
<td>FL3 120% 300rpm</td>
<td>412,800</td>
<td>2,663</td>
<td>0,645</td>
<td>406,185÷ 419,415</td>
</tr>
<tr>
<td>FL4 150% 300rpm</td>
<td>438,800</td>
<td>3,700</td>
<td>0,843</td>
<td>429,609÷ 447,997</td>
</tr>
<tr>
<td>FL5 150% 400rpm</td>
<td>434,367</td>
<td>4,050</td>
<td>0,932</td>
<td>424,306÷ 444,428</td>
</tr>
</tbody>
</table>

(b) Frotte yarn used as a weft:

<table>
<thead>
<tr>
<th>Fabric mass surface [g/m²]</th>
<th>Average value</th>
<th>Standard deviation</th>
<th>CV</th>
<th>Confidence interval for average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ff1 90% 200rpm</td>
<td>412,633</td>
<td>2,902</td>
<td>0,703</td>
<td>405,424÷ 419,843</td>
</tr>
<tr>
<td>Ff2 90% 300rpm</td>
<td>371,433</td>
<td>4,136</td>
<td>1,113</td>
<td>361,160÷ 381,707</td>
</tr>
<tr>
<td>Ff3 120% 300rpm</td>
<td>394,633</td>
<td>3,053</td>
<td>0,774</td>
<td>387,048÷ 402,218</td>
</tr>
<tr>
<td>Ff4 150% 300rpm</td>
<td>409,867</td>
<td>4,600</td>
<td>1,122</td>
<td>398,439÷ 405,300</td>
</tr>
<tr>
<td>Ff5 150% 400rpm</td>
<td>401,433</td>
<td>5,870</td>
<td>1,462</td>
<td>386,850÷ 416,017</td>
</tr>
</tbody>
</table>
Table 10. Results of Student’s t statistics for detecting the differences between the mass surfaces of weaving fabrics with different wefts used – loop yarn and frotte yarn.

<table>
<thead>
<tr>
<th>Fabric mass surface [g/m²]</th>
<th>Yarn variant</th>
<th>Value of Student’s t statistics</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loop</td>
<td>Frotte</td>
<td></td>
</tr>
<tr>
<td>90%, 200rpm</td>
<td>419,667</td>
<td>412,633</td>
<td>2.232</td>
</tr>
<tr>
<td>90%, 300rpm</td>
<td>402,867</td>
<td>371,433</td>
<td>6.866</td>
</tr>
<tr>
<td>120%, 300rpm</td>
<td>412,800</td>
<td>394,633</td>
<td>7.767</td>
</tr>
<tr>
<td>150%, 300rpm</td>
<td>438,800</td>
<td>394,100</td>
<td>14.145</td>
</tr>
<tr>
<td>150%, 400rpm</td>
<td>434,367</td>
<td>401,433</td>
<td>7.998</td>
</tr>
</tbody>
</table>

The fabric mass surface is different in the case of used weft. The fabrics with loop weft are heavier than fabrics with frotte weft. The essentiality of these differences increases with the increase in yarn crimp and twist.

Experimental Part – Knitted Fabrics

The single jersey flat knitting machine was used for the production of two batches knitted fabrics with different kinds of yarn used – a total of 10 samples of knitted fabrics were produced – five samples involving selected variants of different loop yarns: A1 – 90% of crimp and number-of-turn 200 rpm, A2 – 90%, 300 rpm, B2 – 120%, 300 rpm, C2 – 150%, 300 rot/m, C3 – 150%, 400 rot/m, and five samples involving forte yarns: a1, a2, c2 and c3 with the number-of-turns and crimp as above. For all knitted fabrics, the plain stitch was used. The Plan of Experiment for Knitted Fabrics with Loop Yarn (A) and Frotte Yarn (b) is presented in Table 11.

The aim of the analysis was the detection of the source of the differences in knitting fabric thickness and surface mass. The fabric thickness was measured according to the standard PN-EN ISO 5084, and the fabric surface mass was measured according to PN/ISO 3801 standard. The statistical analysis used was –Student’s t-test.

Table 11. The Plan of Experiment for Knitted Fabrics produced with:
(a) Loop Yarn:

<table>
<thead>
<tr>
<th>Yarn Variant</th>
<th>A₁ 90%, 200 rpm</th>
<th>A₂ 90%, 300 rpm</th>
<th>B₂ 120%, 300 rpm</th>
<th>C₂ 150%, 300 rpm</th>
<th>C₃ 150%, 400 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain Stitch</td>
<td>KL₁</td>
<td>KL₂</td>
<td>KL₃</td>
<td>KL₄</td>
<td>KL₅</td>
</tr>
</tbody>
</table>

Note: K, knit fabric; L, loop yarns; thus, e.g. KL2, knit fabric no. 2 made of loop yarn A2.

(b) Frotte yarn:

<table>
<thead>
<tr>
<th>Yarn Variant</th>
<th>a₁ 90%, 200 rpm</th>
<th>a₂ 90%, 300 rpm</th>
<th>a₃ 120%, 300 rpm</th>
<th>c₂ 150%, 300 rpm</th>
<th>c₃ 150%, 400 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain Stitch</td>
<td>KF₁</td>
<td>KF₂</td>
<td>KF₃</td>
<td>KF₄</td>
<td>KF₅</td>
</tr>
</tbody>
</table>

Note: K, knit fabric; F, frotte yarns; thus, e.g. KF3, knit fabric no. 3 made of frotte yarn a2.
Table 12. The knitted fabrics thickness in the case of the loop yarns (a) and frotte yarns (b) used.

(a) Loop yarns:

<table>
<thead>
<tr>
<th>Knitting Fabric thickness [mm]</th>
<th>Average value</th>
<th>Standard deviation</th>
<th>CV</th>
<th>Confidence interval for average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>KL1 90%, 200 rpm</td>
<td>2,910</td>
<td>0,219</td>
<td>7,526</td>
<td>2,365÷3,455</td>
</tr>
<tr>
<td>KL2 90%, 300 rpm</td>
<td>2,603</td>
<td>0,145</td>
<td>5,570</td>
<td>2,224÷2,963</td>
</tr>
<tr>
<td>KL3 120%, 300 rpm</td>
<td>2,950</td>
<td>0,020</td>
<td>0,678</td>
<td>2,900÷3,000</td>
</tr>
<tr>
<td>KL4 150%, 300 rpm</td>
<td>3,340</td>
<td>0,040</td>
<td>1,198</td>
<td>3,439÷3,300</td>
</tr>
<tr>
<td>KL5 150%, 400 rpm</td>
<td>2,870</td>
<td>0,026</td>
<td>0,906</td>
<td>2,804÷2,936</td>
</tr>
</tbody>
</table>

(b) Frotte yarns:

<table>
<thead>
<tr>
<th>Knitting Fabric thickness [mm]</th>
<th>Average value</th>
<th>Standard deviation</th>
<th>CV</th>
<th>Confidence interval for average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>KF1 90%, 200 skr/m</td>
<td>2,580</td>
<td>0,026</td>
<td>1,008</td>
<td>2,514÷2,646</td>
</tr>
<tr>
<td>KF2 90%, 300 skr/m</td>
<td>2,537</td>
<td>0,111</td>
<td>4,375</td>
<td>2,262÷2,811</td>
</tr>
<tr>
<td>KF3 120%, 300 skr/m</td>
<td>2,887</td>
<td>0,075</td>
<td>2,598</td>
<td>2,700÷3,073</td>
</tr>
<tr>
<td>KF4 150%, 300 skr/m</td>
<td>3,327</td>
<td>0,108</td>
<td>3,246</td>
<td>3,059÷3,595</td>
</tr>
<tr>
<td>KF5 150%, 400 skr/m</td>
<td>3,237</td>
<td>0,057</td>
<td>2,009</td>
<td>2,695÷2,978</td>
</tr>
</tbody>
</table>

Table 13. Results of Student’s t statistics for detecting the differences between the thicknesses of the knitted fabrics with different yarns used – loop yarn and frotte yarn.

<table>
<thead>
<tr>
<th>Yarn variant</th>
<th>Value of Student’s t statistics</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knitting Fabric Thickness [mm]</td>
<td>Loop</td>
<td>Frotte</td>
</tr>
<tr>
<td>90%, 200 rpm</td>
<td>2,910</td>
<td>2,537</td>
</tr>
<tr>
<td>90%, 300 rpm</td>
<td>2,603</td>
<td>2,580</td>
</tr>
<tr>
<td>120%, 300 rpm</td>
<td>2,950</td>
<td>2,887</td>
</tr>
<tr>
<td>150%, 300 rpm</td>
<td>3,340</td>
<td>3,327</td>
</tr>
<tr>
<td>150%, 400 rpm</td>
<td>2,870</td>
<td>2,837</td>
</tr>
</tbody>
</table>

Table 14. The knitted fabrics mass surface in the case of the loop yarns (a) and frotte yarns (b) used.

(a) Loop yarns:

<table>
<thead>
<tr>
<th>Knitting Fabric mass surface [g/m²]</th>
<th>Average value</th>
<th>Standard deviation</th>
<th>CV</th>
<th>Confidence interval for average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>KL1 90%, 20 rot/m</td>
<td>253,167</td>
<td>3,253</td>
<td>1,285</td>
<td>245,085÷ 261,248</td>
</tr>
<tr>
<td>KL2 90%, 300 rpm</td>
<td>236,167</td>
<td>8,501</td>
<td>3,599</td>
<td>215,050÷ 257,284</td>
</tr>
<tr>
<td>KL3 120%, 300 rpm</td>
<td>278,667</td>
<td>4,424</td>
<td>1,587</td>
<td>267,376÷ 289,657</td>
</tr>
<tr>
<td>KL4 150%, 300 rpm</td>
<td>337,667</td>
<td>3,431</td>
<td>1,016</td>
<td>329,143÷ 346,190</td>
</tr>
<tr>
<td>KL5 150%, 400 rpm</td>
<td>336,568</td>
<td>9,745</td>
<td>2,895</td>
<td>312,359÷ 360,774</td>
</tr>
</tbody>
</table>

(b) Frotte Yarns:

<table>
<thead>
<tr>
<th>Knitting Fabric mass surface [g/m²]</th>
<th>Average value</th>
<th>Standard deviation</th>
<th>CV</th>
<th>Confidence interval for average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>KF1 90%, 200 rpm</td>
<td>203,967</td>
<td>9,103</td>
<td>4,463</td>
<td>181,354÷ 226,580</td>
</tr>
<tr>
<td>KF2 90%, 300 rpm</td>
<td>198,833</td>
<td>4,452</td>
<td>2,238</td>
<td>187,773+ 209,894</td>
</tr>
<tr>
<td>KF3 120%, 300 rpm</td>
<td>236,100</td>
<td>7,333</td>
<td>3,106</td>
<td>217,884+ 254,316</td>
</tr>
<tr>
<td>KF4 150%, 300 rpm</td>
<td>303,933</td>
<td>4,544</td>
<td>1,495</td>
<td>292,644+ 315,223</td>
</tr>
<tr>
<td>KF5 150%, 400 skr/m</td>
<td>299,267</td>
<td>4,729</td>
<td>1,580</td>
<td>287,519+ 311,014</td>
</tr>
</tbody>
</table>
Conclusions

The list of observations and conclusions made after analysis of all the samples ranges from very obvious to interesting. The selected conclusions concerning comparison of loop and frotte fancy yarns and both woven and knit fabrics made of these yarns are as follows:

Not only the linear density of the introduced yarns impact the mass density of the fabric but also the crimp of the component yarns constituting the final fancy yarn.

The yarn's linear density is higher if the crimp is higher due to wedge, jam of the greater quantity of component yarns in the architecture of the final yarn. This phenomenon occurs regardless of the type of yarn used in the experiment.

The loop size is reduced by the increased twist per meter and on the contrary, the loop size increases, when the crimp of the component yarns increases (in case of loop yarns).

The differences between the mean values of loop altitude in the case of loop yarn and frotte yarns are becoming larger (statistically significant) with the escalation of the crimp and slightly decreasing with the accumulation of the number of twists per meter.

In terms of economy aspects only, the frotte fancy yarns are believed to be cheaper in production due to lower quantity of components utilize for their production to compare with loop fancy yarns, under conditions of the same settings of ring twisting frame.

Acknowledgement

We acknowledge funding provided by Polish National Science Centre for "Electromagnetic induction in the yarns with carbon nanotubes as an effective method for suppressing the electromagnetic fields", ST8, OPUS III, ID: 183626, No.: 2012/05/B/ST8/01528, contract no.: UMO-2012/05/B/ST8/01528 and express gratitude to European Commission for Marie Curie International Outgoing Fellowship – Project Acronym: Magnum Bonum.

References