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KNITTING SHORT SOCKS WITH SIRO AND MODAL YARNS

Tea JOVANOVIĆ; Željka PAVLOVIĆ; Miloš LOZO & Zlatko VRLJIČAK

Abstract: Plain socks can be men’s, women’s or children’s. They are essentially made from three yarns. The base yarn is most often cotton or woollen, single or ply, or one of many other yarns with similar shape and fibre composition. Various plain socks which have special uses are developed using the same construction principles as classic plain socks. Therefore, socks for skiers, football, handball, basketball and tennis players are made according to predefined principles with some yarns that have special properties being knitted into certain sock parts. There is a continuous search for the most suitable yarns and yarn properties for all of the above mentioned and similar shapes of plain socks. The focus of this research is on the production of classic winter plain socks with viscose SIRO yarns and modal fibre yarns. Sock samples were made using hosiery machine with a cylinder-bed diameter of 95 mm (3 ¾ inches) which knitted with 108 needles, i.e. it had the E9 gauge. On this type of machine, up to five yarns with total yarn count of 50 to 100 tex are optimally knitted into a row. The described yarns were used to make three samples per each type of plain sock with different base and plated yarns. The base yarns had the yarn count of 20 and 25 tex, the plated PA 156 and 220 dtex and the elastane 54 tex. The masses of produced socks were 19.3 to 23.0 g/pc.

Keywords: classic winter plain socks, modal, viscose, SIRO, polyamide, cotton

1. Introduction

Plain socks can be men’s, women’s or children’s. They are essentially made from three yarns. The base yarn is most often cotton or woollen, single or ply, or one of many other yarns with similar shape and fibre composition. This yarn participates in the sock from 60 to 90%. It carries the sock structure and is inserted into almost all parts of the sock. Such base yarns have small breaking elongation, which is usually 3 to 10 %, and do not provide the necessary sock elasticity. To obtain the necessary sock elasticity or yarn contraction when the sock is pulled onto the leg and used, apart from the base yarn, polyamide multifilament yarn is inserted. This yarn is plated with the aim of reinforcing the structure, particularly yarn contraction. Polyamide multifilament yarns that are used in the production of plain socks have the breaking elongation of 25 to 35%. They are introduced into the knitting zone in the elongated state, but in the area of elastic recovery. After inserting the yarns into the knitted fabric and their removal from the needles, the yarns contract and achieve great contraction of the knitwear, which is desirable when putting on and using the sock. This kind of yarn participates in the sock from 8 to 30%. The third yarn used in the production of plain socks is elastane, usually monofilament, which is knitted into the sock cuff. It provides greater cuff compressibility on the leg and makes the sock stay up. The proportion of this yarn in the sock is from 2 to 10% [1,2].

Various plain socks which have special uses are developed using the same construction principles as classic plain socks. Therefore, socks for skiers, football, handball, basketball and tennis players are made according to predefined principles with some yarns that have special features being knitted into certain sock parts. In the case of the classic, or the so-called sports sock, elastane yarn is additionally knit into the body or one part of the foot, as necessary. Here, the proportion of elastane yarn is up to 30%. In the production of the ski sock, elastane yarn is partially knitted into certain rows while the polyamide yarn can be multiply or partially plated. Therapeutic socks used for medical purposes can be designed in two ways. One design has a compressive effect on healthy external leg tissue and is made almost exclusively from polyamide and elastane yarns. The latter sock design is put on a leg with active wounds. The wound is taken care of, protected by a bandage or swab, and a sock with mild compression is pulled over it. The leg is not dynamically active [3].

There is a continuous search for the most suitable yarns and yarn properties for all of the above mentioned and similar shapes of plain socks. The focus of this research is on the production of classic winter plain socks with viscose SIRO yarns and modal fibre yarns. [4,5].

2. Basic structures in sock production

Several types of plated knitted structures are used to make the classic unpatterned plain sock. The beginning of the sock is knitted in plain structure with a PA multifilament thread. After knitting ten rows of loops, base yarn is inserted along with it and the knitting is done in basic plated structure [6,7]. After base plating, another elastane yarn, but this time monofilament, is inserted after approximately ten rows to shape the cuff. Therefore,
the base sock cuff is manufactured using three significantly different yarns. After the cuff is made, the elastane thread is excluded and the knitting continues in base plated structure, i.e. this structure is used to knit the body, heel, foot and toes. In the manufacturing of a higher-quality sock, several yarns can be interlaced in one row, usually three or four, with differences in their fibre composition, structure and features, Figure 1.

Figure 1: Plated jersey structures used in the manufacturing of plain socks; a) plain plated structure - two yarns in a row, b) multiple plated structure – three threads in a row, c) multiple plated structure – four yarns in a row, d) four separated yarns from a row; PA – cotton, Ly - elastane

3. Yarns and the machine for manufacturing the samples

Seven yarns with different fibre composition, yarn counts, structures and tensile properties were used to manufacture the socks [4,5]. The main parameters of tensile properties of the analysed yarns are given in Table 1 with p=0.05.

Table 1: Labels and tensile properties of yarns used in the sock production

<table>
<thead>
<tr>
<th>Yarn</th>
<th>Breaking force, cN</th>
<th>Breaking elongation, %</th>
<th>Breaking load, cN/tex</th>
<th>Work to break, cN/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP20</td>
<td>393 ± 7</td>
<td>13.6 ± 0.3</td>
<td>19.7 ± 0.4</td>
<td>1700 ± 59</td>
</tr>
<tr>
<td>MR20</td>
<td>487 ± 10</td>
<td>10.2 ± 0.2</td>
<td>24.3 ± 0.5</td>
<td>1436 ± 47</td>
</tr>
<tr>
<td>MOE20</td>
<td>326 ± 9</td>
<td>7.2 ± 0.2</td>
<td>16.3 ± 0.5</td>
<td>738 ± 32</td>
</tr>
<tr>
<td>MAJ20</td>
<td>406 ± 10</td>
<td>9.0 ± 0.2</td>
<td>20.3 ± 0.5</td>
<td>1067 ± 42</td>
</tr>
<tr>
<td>PA156</td>
<td>985 ± 5</td>
<td>30.3 ± 0.3</td>
<td>63.1 ± 0.3</td>
<td>8314 ± 133</td>
</tr>
<tr>
<td>PA220</td>
<td>991 ± 4</td>
<td>28.5 ± 0.2</td>
<td>45.1 ± 0.2</td>
<td>7846 ± 81</td>
</tr>
<tr>
<td>PKKR25</td>
<td>325 ± 13</td>
<td>6.1 ± 0.2</td>
<td>13.6 ± 0.6</td>
<td>506 ± 31</td>
</tr>
</tbody>
</table>

where: SP20 – viscose yarn with a yarn count of 20 tex spun by SIRO spinning process, MR20 – modal yarn with a yarn count of 20 tex spun by ring spinning process, MOE20 – modal yarn with a yarn count of 20 tex spun by rotor spinning process, MAJ20 – modal yarn with a yarn count of 20 tex spun by air-jet spinning process, PA156 – polyamide multifilament yarn with a yarn count of 156 dtex, PA220 – polyamide multifilament yarn with a yarn count of 220 dtex, PKKR25 – cotton yarn with a yarn count of 25 tex spun by ring spinning process.

The smallest yarn breaking force was 325 ± 13 cN and was recorded in cotton yarn spun by ring spinning process. The largest yarn breaking force was 991 ± 4 cN, recorded in PA multifilament yarn with a yarn count of 220 dtex. The smallest breaking elongation was 6.1 ± 0.2 %, recorded in cotton yarn with a yarn count of 25 tex, while the largest was 30.3 ± 0.3 %, recorded in PA multifilament yarn with a yarn count of 156 dtex. The smallest work to break was also recorded in cotton yarn, and the largest in PA multifilament yarn with a yarn count of 156 dtex.

Based on the data obtained by measuring, it can be concluded that the analysed yarns differ significantly according to their tensile properties, and that cotton yarn has all the smallest recorded values of tensile properties. Sock samples were manufactured on a single-bed automatic hosiery machine with a cylinder diameter of 95 mm (3 ¾ inches) which used 108 needles and is used to manufacture winter plain socks. The machine uses the CAD/CAM system [8]. To manufacture the desired socks, a special computer control program was developed which controlled the knitting. The program contained all the important values for the manufacture of socks where four yarns are interlaced in a row. Loop sinking depth and knitting speed were defined for each sock row and section. The speed of feeding yarns from spools was adjusted to the knitting...
speed. The position of turning on/off the lead in/out of operation with certain yarns was also defined. According to the control program, the time to knit one sock was 178 ± 4 s.

4. Sock samples

Four main sample groups were manufactured with respect to fibre structure and yarn production process. In the first sock sample, the base yarn was viscose yarn made by SIRO spinning process (SP20). Three base and one polyamide yarn were inserted into one row. In the second sample, the base yarn consisted of modal fibres made by ring spinning process (MR20). The third group was also made from modal-fibre yarns, but by rotor spinning process (MOE20), while the fourth, also made from modal-fibre yarns, was made by air-jet spinning process (MAJ20). Each group had three subgroups. In the first subgroup, one row of loops was formed by three base yarns and one PA with a yarn count of 156 dtex. In the second group, PA yarn with a yarn count of 156 dtex was replaced by PA yarn with a yarn count of 220 dtex in order to obtain a fuller and less stretchable sock. In the third subgroup, one base yarn with a yarn count of 20 tex was replaced by cotton yarn with a yarn count of 25 tex, also to increase yarn fullness, and thereby also its thickness. All the socks were made using a single control program. The sock body, heel and foot were made in multiple plated structure and a single row was formed using four yarns. The socks were made for the leg with a foot length from 26 to 30 cm, which corresponds to the shoe size of 42 to 44 [9]. In total, 12 basic sock groups were manufactured.

5. Results of sock measurements

Considering the different structures and tensile properties of the yarns used, different measurements of certain major sock parts were expected, Tab. 2. The sock cuff width (B) is in the range between 83 and 86 mm or 84 ± 2 mm and can be considered uniform for practical use. The sock body width (B1) is somewhat greater and is in the range between 85 and 91 mm or 88 ± 3 mm. The body width is greater than the cuff width because an elastane thread was not inserted into the body. The sock foot width is even greater and is in the range between 89 and 95 mm or 93 ± 3 mm.

Table 2: Measurements of the projected manufactured socks

<table>
<thead>
<tr>
<th>Samples</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B, mm</td>
<td>B1, mm</td>
<td>B2, mm</td>
</tr>
<tr>
<td>SIRO</td>
<td>83±1</td>
<td>85±1</td>
<td>89±1</td>
</tr>
<tr>
<td>MR</td>
<td>84±1</td>
<td>85±1</td>
<td>90±1</td>
</tr>
<tr>
<td>MOE</td>
<td>84±0</td>
<td>87±1</td>
<td>93±1</td>
</tr>
<tr>
<td>MAJ</td>
<td>85±1</td>
<td>89±1</td>
<td>92±1</td>
</tr>
<tr>
<td>SIRO</td>
<td>84±1</td>
<td>88±1</td>
<td>91±0</td>
</tr>
<tr>
<td>MR</td>
<td>85±1</td>
<td>89±1</td>
<td>93±1</td>
</tr>
<tr>
<td>MOE</td>
<td>85±1</td>
<td>89±1</td>
<td>94±1</td>
</tr>
<tr>
<td>MAJ</td>
<td>85±0</td>
<td>90±1</td>
<td>94±1</td>
</tr>
<tr>
<td>SIRO</td>
<td>85±0</td>
<td>89±1</td>
<td>91±1</td>
</tr>
<tr>
<td>MR</td>
<td>86±1</td>
<td>90±0</td>
<td>95±1</td>
</tr>
<tr>
<td>MOE</td>
<td>86±1</td>
<td>90±2</td>
<td>95±1</td>
</tr>
<tr>
<td>MAJ</td>
<td>86±1</td>
<td>91±1</td>
<td>94±2</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>84±2</td>
<td>88±3</td>
<td>93±3</td>
</tr>
</tbody>
</table>

Sock height (H) is recommended, not defined, and depends on fashion trends or purpose. In the production of classic socks, it is recommended that the length be nearly the same as the foot length. In the samples it ranges between 229 and 255 mm or 240 ± 10 mm, while the foot length (H1) ranges between 269 and 280 mm or 275 ± 5 mm. The size of a plain sock is determined according to the foot length with the allowed deviations of ±10 mm [9]. According to the analysed measurements, all the manufactured and analysed socks can be classified into one size.
6. Results of the sock structure parameters

All the parameters of yarn structure are best reflected in the sock mass. The first group of samples had the average mass of 19.3 ± 0.1, the second 21.5 ± 0.1 and the third 23.0 ± 0.1 g/pc, Tab. 3. The first group of socks was produced in a way that one row was made using three base yarns with a yarn count of 20 tex and one PA multifilament with a yarn count 156 dtex. The second group was also made from three base yarns, as the first sample, but the PA multifilament yarn with a yarn count of 156 dtex was replaced with a coarser yarn with a yarn count of 220 dtex. The obtained sock mass was therefore greater. The third group has the greatest mass since one base thread with a yarn count of 20 tex is replaced by cotton yarn with a yarn count of 25 tex.

As the sock mass increased with the change in yarn counts, yarn thickness in the socks also increased and was 1.24 ± 0.02, 1.32 ± 0.03 and 1.41 ± 0.02 mm. Since the manufactured socks were winter plain socks, sock thickness is an important parameter in determining thermophysiological yarn features when evaluating sock comfort [10-12]. In such research, apart from sock thickness, data about fibre structure of yarn in a sock row is also important, Tab. 4. In the lightest socks, or the socks in Group A, the average share of the base yarn is 79 ± 1% and PA yarn 21 ± 1%; in Group B, the average share of the base yarn is 71 ± 1% and PA yarn 29 ± 1%. In the third sample group, the average share of the base yarn is 44 ± 0%, PA yarn 28 ± 1% and cotton yarn 28 ± 1%.

Table 3: Masses and thicknesses of the sock knit

<table>
<thead>
<tr>
<th>Samples</th>
<th>Sock mass, g/pc</th>
<th>Sock thickness, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group A</td>
<td>Group B</td>
</tr>
<tr>
<td>SIRO</td>
<td>19.9±0.0</td>
<td>21.1±0.0</td>
</tr>
<tr>
<td>MR</td>
<td>19.0±0.0</td>
<td>21.4±0.0</td>
</tr>
<tr>
<td>MOE</td>
<td>19.2±0.0</td>
<td>21.4±0.0</td>
</tr>
<tr>
<td>MAJ</td>
<td>19.4±0.1</td>
<td>21.7±0.1</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>19.3±0.1</td>
<td>21.5±0.1</td>
</tr>
</tbody>
</table>

Table 4: Fibre composition in a row of the sock body

<table>
<thead>
<tr>
<th>Yarn</th>
<th>A_u, %</th>
<th>B_u, %</th>
<th>C_u, %</th>
<th>Yarn</th>
<th>A_u, %</th>
<th>B_u, %</th>
<th>C_u, %</th>
<th>Yarn</th>
<th>C_u, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIRO</td>
<td>79</td>
<td>70</td>
<td>44</td>
<td>PA</td>
<td>21</td>
<td>30</td>
<td>28</td>
<td>PKKR</td>
<td>28</td>
</tr>
<tr>
<td>MR</td>
<td>78</td>
<td>71</td>
<td>44</td>
<td>PA</td>
<td>22</td>
<td>29</td>
<td>27</td>
<td>PKKR</td>
<td>29</td>
</tr>
<tr>
<td>MOE</td>
<td>78</td>
<td>71</td>
<td>44</td>
<td>PA</td>
<td>22</td>
<td>29</td>
<td>28</td>
<td>PKKR</td>
<td>28</td>
</tr>
<tr>
<td>MAJ</td>
<td>79</td>
<td>70</td>
<td>44</td>
<td>PA</td>
<td>21</td>
<td>30</td>
<td>28</td>
<td>PKKR</td>
<td>28</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>79±1</td>
<td>71±1</td>
<td>44±0</td>
<td></td>
<td>21±1</td>
<td>29±1</td>
<td>28±1</td>
<td></td>
<td>28±1</td>
</tr>
</tbody>
</table>

where: A_u – share of the base yarn mass in a sock row, %, B_u – share of the PA multifilament yarn mass in a sock row, %, C_u – share of the cotton yarn mass in a sock row, %

7. Results of sock compression measurements

Compression of the sock body and cuff was measured in all the manufactured sock samples. Six wooden cylinders and the PicoPress device were used to measure compression, Fig. 2, [13,14]. The cylinders had the length of 200 mm and diameter/perimeter: 80/250, 90/283, 100/315, 110/345, 120/377 and 130/408 mm which mimicked the leg perimeter under the calf, i.e. place where the sock lies. The lowest compression of the sock body was measured on the smallest cylinder which had the measurements of 80/250 mm and it was 6.3 hPa. The highest compression was measured on the biggest cylinder, with the measurements of 130/408 mm and it was 23.9 hPa. The cuff compression was significantly higher and was in the range between 13.3 and 38.6 hPa.
Viscose yarn spun by SIRO spinning process was used to knit three groups of sock samples. The first group was made from the finest yarns, which resulted in the lightest sock. The third group was made from the coarsest yarns, which resulted in the greatest sock mass. By stretching all three sock groups on a cylinder of the diameter/perimeter of 80/250 mm, the compression of 6.7 to 9.3 hPa was recorded, Fig. 3a. The greatest elongation was achieved on the 130/408 mm cylinder, while the recorded sock compression was from 18.6 to 23.9 hPa. Average compression results of all the sock samples and groups are somewhat smaller and range from 6.3 to 17.3 hPa, Fig. 3b. The recorded results of compression in the body of socks made from viscose SIRO yarns in Group B are 9.3 to 23.4 hPa, and the cuff 17.3 to 38.6 hPa, Fig. 4a.

**Figure 2:** Wooden cylinders with diameters of 80 to 130 mm and PicoPress device for measuring sock compression

**Figure 3:** Recordings of the sock body compression on a wooden cylinder; a) socks made from viscose yarns by SIRO spinning process, b) average values of all the measured samples classified into three major groups

**Figure 4:** Recordings of the body and cuff compression of socks; a) made from viscose yarns by SIRO spinning process, Group B, b) recording compression of the sock body
8. Conclusion

Twelve groups of plain socks were designed, manufactured and analysed. They were produced from viscose and modal yarns made by different spinning processes. Based on the manufactured and analysed socks, the following can be concluded. Using different yarn combinations, three groups of socks with different masses were made in one size. The first group has the mass of 19.3 ± 0.1 g/pc, the second 21.5 ± 0.1 g/pc and the third 23.0 ± 0.1 g/pc. Compression of the sock body was measured on stiff cylinders with different diameters and it depends on the fibre structure and yarn structure, as well as inserting yarns into a row. The compression is from 6.3 hPa to 23.9 hPa. Elastane yarn was interlaced into the sock cuff. Therefore, the compression in the cuff is significantly higher than in the body or foot and ranges from 13.3 to 38.6 hPa. The socks were made for temperatures between -10 and +5°C. Due to the insertion of four high-quality yarns into a knit wale, the socks are considered quite a remarkable product. The main purpose of this paper is to explore the yarn usage from the newest fibres to make a quality classic winter short socks with four knitted yarns in one row.

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References


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