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COMPARATIVE STUDY BETWEEN POLYAMIDE/ELASTANE AND COTTON/POLYAMIDE/ELASTANE SOCKS

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Abstract: *The paper presents a comparative study of the behaviour of 97% polyamide/3% elastane socks, named functional socks, and of 70% cotton/27% polyamide/3% elastane socks, called classic socks, both type used for moderate-intensity physical activity. Nowadays, the question always arises about what socks to wear: classic 100% cotton socks, cotton/polyamide/elastane socks, or polyamide/elastane socks. The wearing comfort of the socks is the determining factor in choosing the optimal variant. The functional socks are made of 100% synthetic yarns and are appreciated due to the properties of absorption and rapid transfer of moisture from the body to the environment. The classic socks are made of cotton or cotton yarns mixed with synthetic yarns, giving better wearing comfort compared to functional socks through the high moisture absorption capacity. But due to the small capacity to transfer moisture from the body to the outside environment, wearing for a long time can produce discomfort as a result of the humid environment that is created. The two types of socks were evaluated through a series of analyses as follows: weight per piece, optical microscopy, hygroscopicity, hydrophilicity, elasticity in the direction of stitches' rows and degree of compression. The analysed data led to the conclusion that functional socks have superior elasticity and comfort properties compared to the classical ones.*

Key words: *functional socks, classic socks, knitted structure, degree of compression, wearing comfort*

1. INTRODUCTION

Nowadays, the question always arises about what socks to wear: polyamide/elastane (functional socks) or cotton/polyamide/elastane blended yarns socks (classic socks). The wearing comfort of the socks is the determining factor in choosing the optimal variant. Wearing comfort is ensured by the raw material from which the socks are made and by the structure of the knit [1-3].

Without performing an initial analysis, the 100 % cotton socks would be the optimal option, but there is the problem of high hygroscopicity of cotton, around 8.5 %, which in the case of moderate physical activity leads to the absorption and maintenance of moisture, a situation that

creates discomfort and even irritation if the wear is for a long time [4]. To reduce the hygroscopicity, a variant of 70 % cotton + 27 % polyamide + 3 % elastane socks is proposed, elastane being used only for the ankle fixation garniture. Using this composition, the hygroscopicity of the socks reaches values around 4 %. This value is lower than that of cotton, but still during wearing can create discomfort due to the relatively high moisture absorption capacity. For moderate physical activity, using socks with a composition of 97 % polyamide + 3 % elastane and structures with transferred stitches elements will allow the foot to breathe and to rapid elimination of moisture, hygroscopicity being around 3 %.

The rib 1:1 knitted structures with transferred stitches, due to their architecture allows high deformability compared to classic jersey structures. The structures used in the production of socks are based on the knitting technique with transferred stitches or transferred stitches elements. The final product, the sock, is spatially contoured with different properties and homogeneities on the surface, with a positive influence on wearing comfort. By knitting and spatial contouring, articles with various shapes and perfectly adapted to the foot are obtained. Also, these structures have dimensional stability and good shape, the basic rib 1:1 bond being stable and balanced in terms of internal energies. This is due to the arrangement of the structure's elements. The thickness of the rib 1:1 structure with transferred platinum loops will be higher than that of the jersey structure made in similar conditions, the thermal insulation capacity and air permeability being better. The structures have low desirability and do not run at the edges. The high elasticity in the transverse direction positively influences the wearing comfort [5, 6].

For all the presented situations, the same type of "air cool" or "respira" sports shoes will be worn, which allows the foot to breathe during the physical activity.

2. EXPERIMENTAL PART

The socks were made of yarns of the same fineness, Ne 40/1, with the same size group, 39-41, on the same type of circular knitting machines with a small diameter for socks, Merz. The structures of the socks were manufactured differently, the ones made of 97 % polyamide + 3 % elastane yarns (functional socks) having a 1:1 rib structure with transferred stitches for the opposite side of the sole and jersey structure for the areas of the sole, heel and toe. For better fixation, on the hollow portion of the foot, the socks were knitted in the 2:1 rib structure.

The 70 % cotton + 27 % polyamide + 3 % elastane socks (classic socks) were manufactured in jersey structure and 2:1 rib structure for ankle fixation garniture. For both types of socks, the percentage of elastane was 3 % and was used for the 2:1 rib structure. The socks were knitted on a circular socks machine with a small diameter, Merz CC4 II.

The technical characteristics of the Merz CC4 II knitting machine are presented in Table 1.

Table 1*.The technical specifications of the Merz CC4 II knitting machine*

Technical specifications	Technical data
Needle dial diameter [inch]	4 ¾
Pitch [E]	E 24
Number of needles	360
Number of cam systems	4
Number of threads guides	10 guides on system 1, and 8 on systems 2-3-4
Needle bad rotation speed [rpm]	Variable working speed (90 rpm. - 320 rpm), optimum 240 rpm.
Engine power [Watt]	400
Power frequency [Hz]	50-60
Overall dimensions	270 cm height, 90 cm length, 68 cm width and 133 cm of yarn package ring diameter

The functional and classic socks were evaluated through a series of analyses as follows: weight per piece, optical microscopy, hygroscopicity, hydrophilicity, elasticity in the direction of stitches' rows, and degree of compression.

The weight per piece was measured with an analytical balance Kern ABT 220-4M. The images of the knitted fabric structures of the two types of socks were captured with stereomicroscope Zeiss Stemi 2000 with AxioCam. The Sartorius MA 100 balance at 105 ^{0}C was used for hygroscopicity determination. Evaluation of the hydrophilic properties of the analysed socks was carried out according to the AATTCC Test Method 79-2007.

To determine the elasticity for the two socks variants the EN ISO 14704-3/2007 was followed. The socks from which the specimens were taken were conditioned for 12 hours in air-conditioned rooms with the parameters of the standard atmosphere: T = 20 ± 2 ^{0}C, p = 760 mm colHg = 1 atm, φ 65 ± 5%. Three specimens with the size of 50 mm x 50 mm from each type of socks were taken from the stitches' rows direction and analysed with an EMI dynamometer. The working parameters were: the gauge length of 100 mm ± 1 mm, a speed rate of 100 mm/min, and a tensile force of 100 cN.

The degree of compression was measured with a dynamometer according to NFG 30 102 - Textiles - Knitted goods - Determination of restraining force. The speed rate was set to 100 mm/min and values in the minimum, average and maximum points at the ankle were considered. Each sample was subjected to 6 elongations, the pressure being calculated with the force recorded during the sixth cycle. Before analysis, the samples were washed and dried, after which they were kept for 8 hours in air-conditioned rooms with a standard atmosphere.

3. RESULTS AND DISCUSSIONS

The values for the weight per piece, hygroscopicity and hydrophilicity of the two types of analysed socks are presented in Table 2. Because functional socks were made of different structures (1:1 rib structure with transferred stitches, jersey structure and 2:1 rib structure), the hydrophilicity evaluation was performed in each area.

Table 2. *The weight per piece, hygroscopicity and hydrophilicity of functional and classic socks*

Sample	Weight per piece [g]	Hygroscopicity [%]	Hydrophilicity [sec.]
97 % polyamide + 3 % elastan (functional socks) - 1:1 rib structure with transferred stitches area	6.631	3	3
97 % polyamide + 3 % elastan (functional socks) - jersey structure area			50
97 % polyamide + 3 % elastan (functional socks) - 2:1 rib structure			40
70 % cotton + 27 % polyamide + 3 % elastane (classic socks) - 1:1 rib structure	9.318	4	1

As can be seen from Table 2, for the classic socks that have in their composition predominantly cotton, the hygroscopicity is higher than that of functional socks where the percentage of polyamide is 97 %. The hydrophilicity values were around 1 second for classic socks due to the high moisture absorption capacity of the cotton fibres. Functional socks showed different values of hydrophilicity, these being around 3 seconds for the 1:1 rib structure with transferred stitches area and 40 - 50 seconds for the jersey and 2:1 rib structures areas. This is due to the lower absorption capacity of polyamide fibres and different structures of the socks.

The knitted structure images of the classic and functional socks are shown in Figures 1 to 4.

***Fig. 1**. 1:1 rib structure of the classic socks*

***Fig. 2**. Jersey structure of the functional socks*

***Fig. 3**. 1:1 rib structure with transferred stitches of the functional socks*

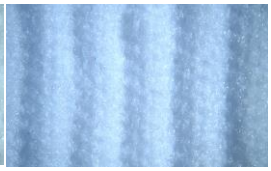

***Fig. 4**. 2:1 rib structure of the functional socks*

To study the behaviour during wearing, both types of socks have been subjected to the stretching solicitation in the direction of the stitches' rows. By stretching, the diameter of the yarn is reduced, the rows of stitches arranged face-to-back are flattened and amounts of threads migrate from the needle and platinum loops into the flanks leading to yarn to yarn friction forces at the points of contact, forces that oppose to elongation and the rows of stitches it's getting close to tangency. To evaluate the behaviour at stretching solicitation, three types of quota were considered as shown in Figure 5.

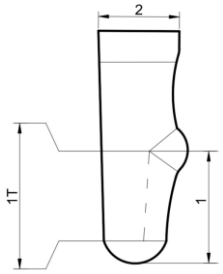

***Fig. 5**. The quotas in the initial state and after elongation of the analysed socks*

Where: 1 - distance from the top of the sock to the middle of the heel, in a relaxed state;
2 – width on the gasket finish line, in a relaxed state;
1T - elongation at traction.

For each sample, 3 tests were performed, and the average values of the considered quotas are presented in Table 3.

***Table 3**: The average values of the considered quotas for stretching evaluation of functional and classic socks*

Sample	Quota 1 [mm]	Quota 2 [mm]	Quota 1T [mm]
97 % polyamide + 3 % elastin (functional socks)	205	85	424
70 % cotton + 27 % polyamide + 3 % elastane (classic socks)	190	80	342

The obtained results are summarized in Table 4 and were calculated according to equation **(1)**.

$$F[cN/cm] = \frac{F_{device}[cN] \cdot 100}{l[cm]} \quad \textbf{(1)}$$

Where: F - the resulted force per cm [cN/cm];
F_{device} - force indicated by the device [cN];
A - test sample width [5 cm].

Table 4: *The parameters and test results for stretching solicitation of functional and classic socks*

Sample	Sample width [cm]	Deformation size 1 [mm]	Deformation size 2 [mm]	Deformation force 1 [N]	Deformation force 2 [N]	Elongation 1 [cN/cm]	Elongation 2 [cN/cm]
Functional socks	5	30	60	0.7545	1.240	15.09	24.80
Classic socks	5	30	60	0.6997	1.387	13.99	27.74

The graphical representations of the deformation dependency [%] under the traction force action of the two types of analysed samples are represented in Figures 6 and 7.

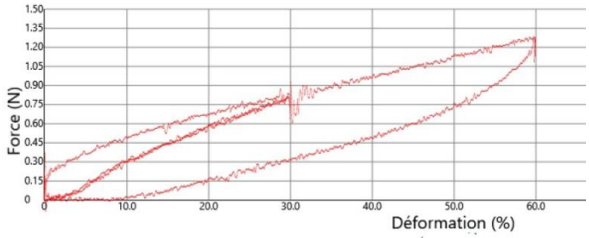

Fig. 6. *Elongation for functional socks*

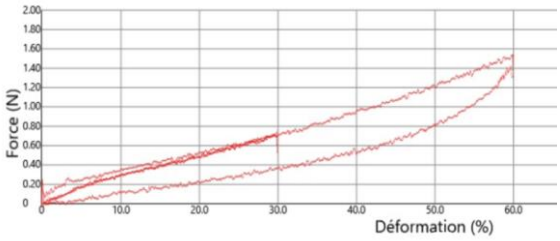

Fig. 7. *Elongation for classic socks*

For practice, the final values are of interest (those for deformations of 60 %). By analysing figures 6 and 7 it results that for 60 % deformations, lower tensile forces are applied and smaller deformations result for functional socks than for the classic ones. This leads to the conclusion that functional socks are more dimensionally stable than the classic ones due to the deformability properties of knit structures.

To evaluate the compression of the socks, the values in the minimum, average and maximum points at the ankle level were determined as shown in Figure 8, the pressure being calculated with the force registered during the sixth cycle, in point a.

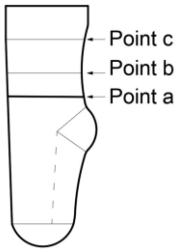

Fig. 8. *The compression lines*

The parameters and test results for compression solicitation are presented in Table 5 and the degrees of compression for functional and classic socks are shown in Figures 9 and 10.

By analysing Figures 9 and 10 it results that the compression degree is 17.03 hPa for the functional socks and 14.81 hPa for the classic ones. A higher degree of compression for the functional socks leads to a better fixation on the foot and implicitly to a superior comfort to wearing

compared to classic socks. Because the classic socks have a lower degree of compression they can easily slip on the leg, twist in a spiral and create discomfort when wearing. Both types of socks correspond to degree 1 of compression.

Table 5. *The parameters and test results for compression solicitation of functional and classic socks*

Sample	First cycle force [N]	Last cycle force [N]	Pressure/cycle [hPa]	Last cycle pressure [hPa]		Final pressure [hPa]
Functional socks	4.103	4.070	17.17	Upper limit	48	17.03
				Lower limit	13	
Classic socks	3.520	3.538	14.73	Upper limit	48	14.81
				Lower limit	13	

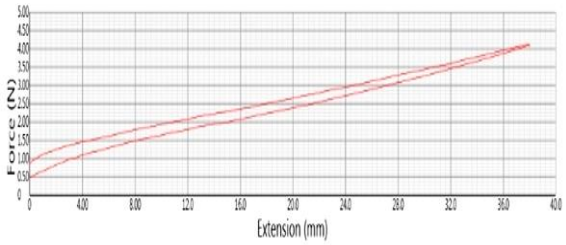

Fig. 9. *Degree of compression for functional socks*

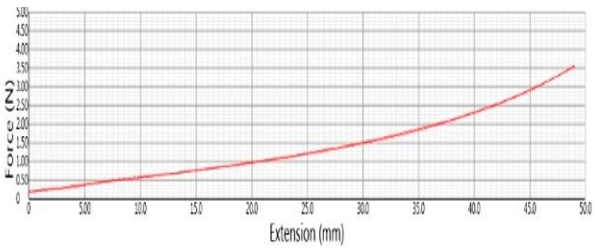

Fig. 10. *Degree of compression for classic socks*

5. CONCLUSIONS

The lower hygroscopicity of the functional socks led to superior wearing comfort and a higher moisture transfer capacity compared to the classic ones. The 1:1 rib structures with transferred stitches and the 2:1 rib structures in the hollow area of the sole used to produce functional socks give a lower elongation to traction and implicitly superior dimensional stability compared to classic socks with jersey structure. Both types of socks correspond to degree 1 of compression. Functional socks have a higher degree of compression and ensure a better fit on the foot compared to the classic ones. The analysed data lead to the conclusion of better elasticity and comfort properties for functional socks compared to the classic ones.

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