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THE INFLUENCE OF THE PROCESS OF FRICTION - ABRASION ON THE AIR PERMEABILITY AND APPEARANCE OF CLASSIC COTTON-TYPE SOCKS

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Abstract

Socks are included in the group of everyday (indispensable) items of clothing. They should absolutely be comfortable, long-lasting and affordable. In this research were analyzed three types of socks that differ in raw material composition (mixture of Co, PA and Lycra fibers) and structure (loop density). All socks are made of knitwear in right-left interlacing. The basic characteristics of knitwear from feet, heels and toes were checked: longitudinal mass of yarn, density, loop length, surface mass, thickness. The samples were then subjected to measurements of air permeability and resistance to friction (abrasion) using methods according to ISO and EN ISO standards. After the friction process, the air permeability decreased thanks to the felting, i.e. rubbing the fibers in the structure of the knitwear, making it denser (regardless of the fact that protruding fibers fall out, they create piles of them). The visual assessment of appearance in the sock sections also changed with increasing number of friction cycles.

Keywords: socks, knitwear, air permeability, friction resistance.

INTRODUCTION

Textile materials and products play an important role in the daily life of man. Depending on their purpose, they are subject to increasing requirements for functional properties and comfort. More and more products are made from fibers of different origins, so one must know which fiber will provide the required properties [1,2,3]. Durability, good looks and comfort (the hem of the sock does not constrict the leg, a pleasant feeling when wearing) are important factors when wearing socks [4,5]. Another important feature is that they let air and sweat through [6]. Resistance to friction and pressure due to wear and maintenance (washing) is also an important characteristic because first the deformation of the surface and then the deformation of internal structure occurs, the shape is lost, the socks taer out (wear out), the fibers are pulled out due to friction, piles are formed [7,8,9].

All these characteristics depend on the type of yarn used (single - threaded, double - threaded), raw material composition, interweaving, structure [1,2,3].

After checking the basic characteristics of the knitwear in the sock parts, the knitwear samples were then subjected to the friction process, measurements of air permeability and thickness, as well as a visual assessment of friction resistance.

MATERIAL AND METHODS

The basic technical characteristics of the socks (intended for wide use) taken for this experiment are:

- raw material composition of socks 1 i 2 is 85/12/3 % Co/PA/Lycra, and sock 3 are 70/28/2 % Co/PA-regenerated/Lycra,
- yarn for production of sock 1 is linear density 15x2 tex, and socks 2 i 3 is 17x2 tex.

The socks are produced on single-cylinder machines Lonati 462C6P fineness 14E in right-left interlacing.

The methods used to check the characteristics of knitwears in parts of socks (foot, toes, heel) as well as to test the performance properties are in accordance with the standards:

EN 14970:2006 Textiles - Knitwears - Determination of stitch length and yarn linear density in weft knitwears [10],

EN 14971:2006 Textiles - Knitwears - Determination of number of stitches per unit length and unit area [11],

ISO 5084:1996 Textiles - Determination of thickness of textiles and textile products [12],

EN 12127:1997 Textiles - Fabrics - Determination of mass per unit area using small samples [13],

ISO 9237:1995 Textiles - Determination of permeability of fabrics to air [14],

ISO 12947-1:1998 Textiles - Determination of the abrasion resistance of fabrics by the Martindale method - Part 1: Martindale abrasion testing apparatus [15],

ISO 12945-1:2020 Textiles - Determination of fabric propensity to surface pilling, fuzzing or matting - Part 1: Pilling box method [16],

ISO 12945-2:2020 Textiles - Determination of fabric propensity to surface pilling, fuzzing or matting - Part 2: Modified Martindale method [17],

ISO 105-X12:2016 Textiles - Tests for colour fastness - Part X12: Colour fastness to rubbing [18].

The following devices and apparatus were used to test individual characteristics of the sock parts: analytical balance AA-160 Rusty′s, thickness gauge INSIZE 2364-10 (pressure between plates 0.5 kPa), device for measuring air permeability SDL Atlas M021A (air pressure 100 Pa, clamp size 5 cm^2), James Heal 900 friction tester (weight pressure 9 kPa).

RESULTS AND DISCUSSION

Loop length (l) represents the length of yarn needed to form one loop [1,2]. It depends on loop width (A), loop height (B) and yarn diameter (d):

$$l = xA + yB + zd \text{ (mm)} \qquad (1)$$

where x, y and z are coefficients that depend on the type of interlacing.

The horizontal density represents the number of loops in one row on a width of 1 cm of knitwear [1,2].

Vertical density represents the number of loops in one row on a length of 1 cm of knitwear [1,2].

Total density is the product of horizontal and vertical density and indicates the number of loops per 1 cm^2 of knitwear [2].

The thickness of the knitwear represents the distance between the tiles of the measuring device between which the knitwear is placed [13].

The surface mass represents the mass of 1 m^2 of knitwear [1,2].

Air permeability is one of the key factors to which great importance is attached, which affects the quality and comfort of knitwear, and therefore must be carefully monitored and examined. The air permeability of the face of the knitwear reflects the ability of the knitwear to bring air from the environment into the space between the material and the body and ventilate it for a comfortable feeling on the human skin. Also, the air permeability of the back of the knitwear reflects the ability of the knitwear to absorb and remove moisture (sweat) to the environment [1,2,5,6].

The results of testing the basic characteristics of knitwear in different parts of socks are shown in table 1.

The knits in the sock parts have the approximate values of the above characteristics, except for the surface masses of sock 1, thanks to the smaller longitudinal mass of yarn used for its production. Also, these socks have a higher air permeability compared to the other two, thanks to the yarn with lower linear density and lower surface mass. This means there is more air space between the fibers and yarns in the knit structure. It is noticeable that the air permeability of knitwear is higher in the foot compared to the toes and heel because they have a higher density of loops.

Socks that are often worn are subject to friction - abrasion on various surfaces, which leads to gradual friction of their surface and changes in structure. The area exposed to friction gradually loses fibers, protruding fibers appear and form bumps on the surface.

Table 1. Characteristics of knitwear incorporated in different parts of socks

Characteristics of knitwear	Foot	Toes	Heel
Sock 1			
loop length, mm	5.1	4.72	4.78
horizontal loop density, cm^{-1}	8.2	8.5	8.5
vertical loop density, cm^{-1}	10.4	11.3	11.2
total loop density, cm^{-2}	85.3	96	95.2
thickness of the knitwear, mm	0.84	0.77	0.74
surface mass, $g \cdot cm^{-2}$	130.5	135.9	136.5
Air permeability, $cm^3 \cdot cm^{-2} \cdot s^{-1}$			
- on the face	64.1	57.6	70.5
- on the back	56.4	53.7	69.3
- mean value	60.2	55.6	69.9
Sock 2			
loop length, mm	5.17	4.85	4.93
horizontal loop density, cm^{-1}	8.3	9	9
vertical loop density, cm^{-1}	11.7	12.3	12.2
total loop density, cm^{-2}	97.1	110.7	109.8
thickness of the knitwear, mm	0.83	0.78	0.8
surface mass, $g \cdot cm^{-2}$	170.7	182.5	184
Air permeability, $cm^3 \cdot cm^{-2} \cdot s^{-1}$			
- on the face	50.8	50	53.7
- on the back	46.5	53.7	55.7
- mean value	48.6	51.8	54.7
Sock 3			
loop length, mm	5.3	5.17	5.1
horizontal loop density, cm^{-1}	8.4	8.8	8.9
vertical loop density, cm^{-1}	11.4	11.7	11.7
total loop density, cm^{-2}	95.8	103	104.1
thickness of the knitwear, mm	0.83	0.84	0.84
surface mass, $g \cdot cm^{-2}$	172.6	181.1	180.5
Air permeability, $cm^3 \cdot cm^{-2} \cdot s^{-1}$			
- on the face	50.9	55.4	44.7
- on the back	48.6	58.5	42.3
- mean value	49.8	59.9	43.5

For the purposes of this research, samples of sock parts were exposed to friction against standard felt for up to 5000 cycles. After each friction cycle (1000, 2000 and 5000), air permeability was measured on the face and back, the results are given in table 2, and their change trends are shown in figures 1 to 6. Table 3 also provides a visual assessment of friction resistance. The number of friction cycles of 10,000 and more caused considerable damage to all samples of sock parts, so the results for this number of cycles are not presented.

Table 2. The results of the air permeability test in the sock parts before and after the friction process

Air permeability, $cm^3 \cdot cm^{-2} \cdot s^{-1}$		Foot	Toes	Heel
Sock 1				
before friction	face	64.1	57.6	70.5
	back	56.4	53.7	69.3
after 1000 cycles	face	37.4	44.3	40.6
	back	36	51	48.2
after 2000 cycles	face	31.7	43.1	35.9
	back	30.2	49.5	43
after 5000 cycles	face	19	38.2	26.1
	back	18.5	44.6	34.1
Sock 2				
before friction	face	50.8	50	53.7
	back	46.5	53.7	55.7
after 1000 cycles	face	43.8	35	29.3
	back	42.6	43	38.5
after 2000 cycles	face	41.1	30.7	26.9
	back	39.9	38	35.1
after 5000 cycles	face	28.7	20.1	13.5
	back	26.3	28.8	24.4
Sock 3				
before friction	face	50.9	55.4	44.7
	back	48.6	58.5	42.3
after 1000 cycles	face	36.1	33.5	34.3
	back	42.7	39.9	30.5
after 2000 cycles	face	30.1	28.5	29.9
	back	36.1	34.8	22.3
after 5000 cycles	face	17.7	14.7	15.7
	back	23.6	20.5	14.3

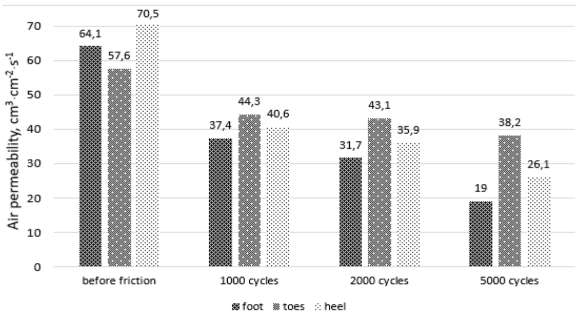


Figure 1. *Change of air permeability on the face of parts of socks 1 depending on the number of friction cycles*

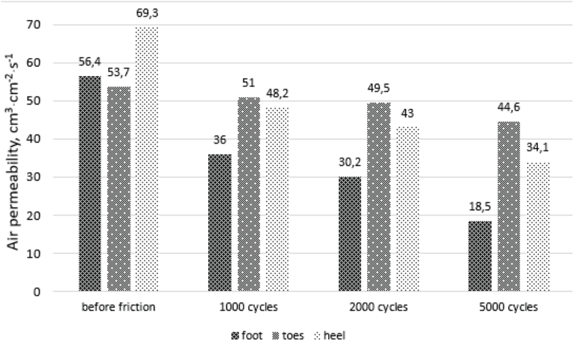


Figure 2. *Change of air permeability on the back of parts of socks 1 depending on the number of friction cycles*

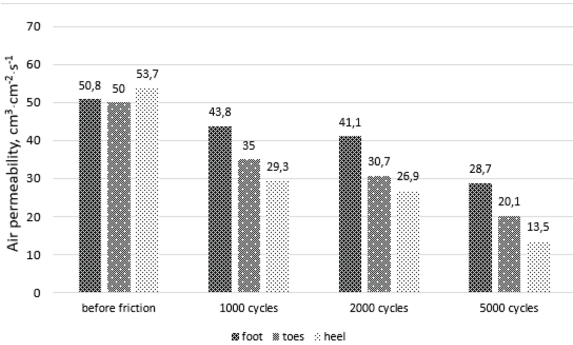


Figure 3. *Change of air permeability on the face of parts of socks 2 depending on the number of friction cycles*

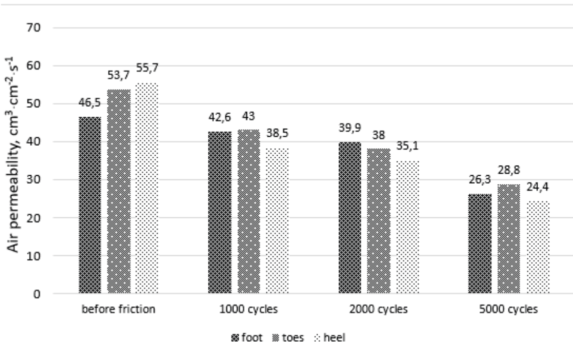


Figure 4. *Change of air permeability on the back of parts of socks 2 depending on the number of friction cycles*

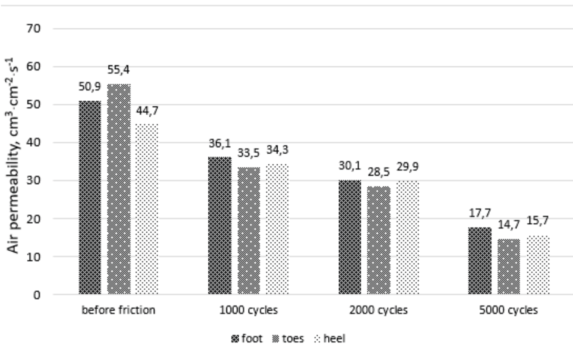


Figure 5. *Change of air permeability on the face of parts of socks 3 depending on the number of friction cycles*

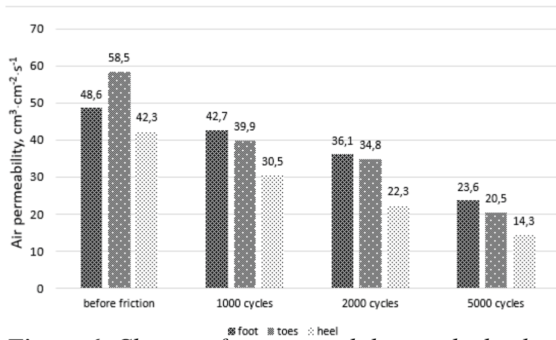
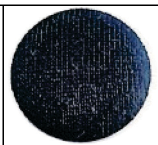
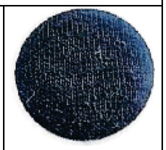
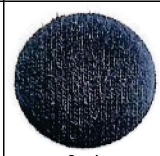
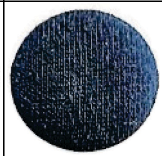
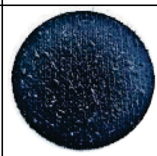
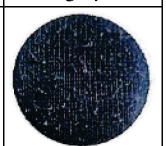
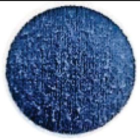
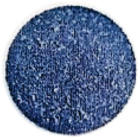


Figure 6. *Change of air permeability on the back of parts of socks 3 depending on the number of friction cycles*

Table 3. Results of evaluation of the change in the surface of knitwears after friction

Number of cycles	Foot	Toes	Heel
Sock 1			
1000	 4-5	 4-5	 4-5
2000	 3-4	 3-4	 3-4
5000	 2-3	 2-3	 2-3
Sock 2			
1000	 3-4	 3-4	 3-4
2000	 2-3	 3-4	 3-4
5000	 1-2	 1-2	 1-2
Sock 3			
1000	 3-4	 2-3	 2-3

2000	 2-3	 1-2	 1-2
5000	 1-2	 1-2	 1-2

Analyzing the results from the table, it can be seen that with the increase in the number of friction cycles, there is a decrease in air permeability in all samples of sock parts. It is assumed that due to the pressing of the knitwear on the felt and the circular movements of the friction machine, thanks to the felting, i.e. by rubbing the fibers in the structure of the knitwear, it becomes denser (that is, the volumetric mass increases), regardless of the fact that the fibers fall out, the appearance of protruding fibers and the formation of knots from them. For these reasons, there is a decrease in air permeability. The biggest drop in air permeability is with sock 3, and the probable reason is in the raw material composition. With them, polyamide - regenerated material was used, and because of this, damage to the fibers and their greater felting in the structure of the knitwear occurs more often. Of course, the differences in air permeability between the parts of the socks (as well as before the treatment) are also a consequence of different structural characteristics.

After 1000, 2000 and 5000 friction cycles, the best scores are for sock 1 (from 4-5 to 2-3 for all knitwear samples), slightly lower scores for sock 2 and the worst for sock 3. The probable reason is the same as in the case of air permeability due to the use of poorer raw material (polymad - regenerated) and the increased tendency to form lumps. The difference in scores that occurs between socks 1 and 2 is attributed to the structure of the knits and the longitudinal weight of the yarn. The classification is determined by visual comparison of the sock samples with standard grade 1-2, 2-3, etc. (grade 1-2 is poor quality and 4-5 is good quality) which are part of the James Heal 900 device set according to the Martindale method [15,16,17].

There were no changes in the color fastness to friction (dry friction) (all samples were rated 4-5), which means that the coloring process was done correctly with high-quality colors. The classification is also determined by visual comparison with gray scale 1, 1/2, 2, etc. (rating 1 is poor quality and 5 is excellent quality) [18].

CONCLUSION

Air permeability is one of the key factors that should be given great importance because it affects the quality and comfort of knitwear, and therefore must be carefully monitored and examined. The air permeability of the face of the knitwear reflects the ability of the knitwear to bring in air from the surrounding space and ventilate it for a comfortable feeling on the skin of the feet. Also, the air permeability of the back of the knitwear reflects the ability of the knitwear to absorb and transport moisture to the environment.

Although changes on the surface of socks are a common case when they are subject to friction - abrasion, the influence of a worse batch of yarn in production can further worsen the situation and lead to faster formation of piles and other changes on the surface. Tests like this are of great importance for textile manufacturers, in order to identify the factors that affect product quality and thus improve production.

The analysis of the surfaces of the knitwears showed that the quality of the material in the socks has a direct effect on their resistance to friction.

Therefore, with future products, it is necessary to pay attention to the quality of the material used for production, in order to ensure longevity and user satisfaction. This research can serve in the study of key factors in increasing the performance of socks that provides additional information for potential future improvements.

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