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The Study of Wearability of Women's Knee High Sock

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In order to study the wearability of women's knee high sock, 7 kinds of common women's knee high socks on the market were selected as research object, which were weaved with different blending ratio and made of different materials. The wearability was tested including air permeability, moisture permeability, abrasion resistance, pilling resistance, tensile elastic recovery performance. Approximate optimal comprehensive judgment method was used to make a comprehensive evaluation of the wearability of women's knee high sock, and sort the wearability of women's knee high sock. It was pointed that the wearability of women's knee high sock which contained high proportion of cotton fiber was relatively good. The conclusion provided theoretical guidance for the production and purchase of women's knee high sock.

1. Introduction

Sock is indispensable in our daily life. With the development of the society and the increase of people's living standard, sock is always in constant development and reveals its infinite charm to people. As important foot clothing, the performance of sock is directly related to the comfort of feet, legs and even the health of human body. Today, the requirement for socks is not only to keep warm, and people pay more attention to the comfort, functionality and safety of sock. In previous studies, the wearability of sock was researched relatively less, and most of the existed researches focused on the pressure comfort of socks and pantyhose (Dan et al (2011)). Knee high sock covers foot and leg, not only can keep foot temperature, but also can modify leg form. With the popularity of Japanese and Korean culture, knee high sock is popular with more and more women. Therefore, it was necessary to study the wearability of women's knee high sock, which has a theoretical significance and practical significance.

2. Experiment

2.1 Experimental materials

In this research, the common 7 kinds of women's knee high socks on the market was selected as research objects, whose raw materials and blended ratio were different. The specification parameter of samples selected was listed in table 1.

2.2 Experimental apparatus and methods

2.2.1 Air permeability testing

With reference to the national standard GB /T5453-1997, textile air permeability testing method, YG641 air permeability tester was used to measure the air permeability of women's knee high sock.

2.2.2 Moisture permeability testing

With reference to the national standard GB /T12704-91, textile moisture permeability testing method, YG601 digital fabric moisture tester was used to measure the moisture permeability of women's knee high sock. The moisture permeability of samples in a certain period of time was measured.

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2.2.3 Abrasion resistance testing

Y522 Disc type fabric flat grinding machine was used to measure the abrasion resistance of women's knee high sock. Because the fabric was thick, we selected 750 cN weight, and the disc rotation frequency was set to 500 times. Each fabric was tested 10 times and the average was calculated.

2.2.4 Pilling resistance testing

With reference to the national standard GB/T 4802.1-2008, textile pilling testing -circular locus method, YG502 circular locus method fabric pilling tester was used to measure the pilling resistance of women's knee high sock. And the final results were modified to nearby 0.5 grade.

2.2.5 Tensile elastic recovery performance testing

With reference to the national standard FZ/T 70006-2004, YG026H electronic fabric strength tester was used to measure and calculate the tensile elastic recovery rate of samples.

Table 1: The specification parameter of samples

Sample number	Material composition	Blended ratio	Horizontal density /(coil number .(5cm)-1)	Longitudinal density /(coil number.(5cm)-1)	thickness /(mm)	Surface density /(g.m^{-2})
1#	cotton / polyester / spandex	55%/43%/ 2%	46	47	1.3	233.51
2#	cotton / polyester / spandex	70%/28%/ 2%	47	49	1.54	283.14
3#	cotton / nylon / spandex	70%/28%/ 2%	48	47	2.38	444.17
4#	cotton / polyester / spandex	83%/15%/ 2%	49	51	1.7	393.4
5#	polyester / spandex	95%/5%	45	47	1.69	333.21
6#	acrylic / polyester / spandex	23%/74%/ 3%	54	53	2.46	357.19
7#	wool / polyester / spandex	30%/67%/ 3%	57	60	3.29	397.27

3. Experimental results and analysis

3.1 Air permeability of women's knee high sock

The testing result of air permeability of women's knee high sock was shown in figure 1.

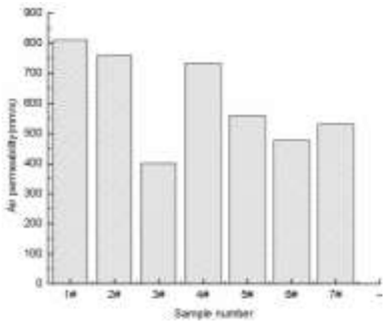

Figure 1: The testing result of air permeability of women's knee high sock

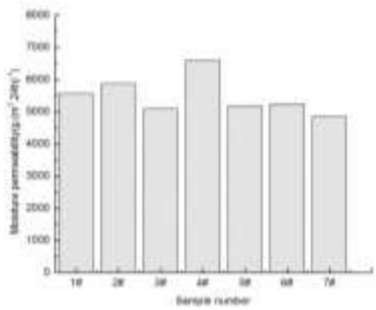

Figure 2: The testing result of moisture permeability of women's knee high sock

Body skin breathes every moment, so women's knee high sock must have air permeability to guarantee the exchange of gas inside and outside of foot and leg, to promote the metabolism of skin of foot and leg. It could be seen from figure 1 that the order of air permeability of women's knee high socks was 1#>2#>4#>5#>7#>6#>3#. In 1#, 2# and 4# cotton / polyester / spandex women's knee high socks, the air permeability of 4# women's knee high sock was the worst. This phenomenon was mainly because the thickness, surface density and density of 4# women's knee high sock were bigger than that of 1# and 2# women's knee high socks. The air permeability of fabric generally have a negative correlation relationship with the thickness, surface density and density of fabric (Jing and Li (2010)). The air permeability of 5# women's knee high sock was better because the density of fabric was smaller and the gap of yarn was greater mainly.

Compared with 2# women's knee high sock, the air permeability of 3# women's knee high sock was worse, the reason was that the thickness and surface density of 3# women's knee high sock was more greater than that of 2# women's knee high sock. The air permeability of 7# women's knee high sock was better than that of 6# women's knee high sock, because the proportion of polyester fiber of 7# women's knee high sock was smaller than that of 6# women's knee high sock, the air permeability of polyester fiber was worse. And the proportion of wool fiber of 7# women's knee high sock was higher than the proportion of acrylic fiber of 6# women's knee high sock, wool fiber was plump and fluffy and the air permeability of wool fiber was better.

3.2 Moisture permeability of women's knee high sock

The testing result of moisture permeability of women's knee high sock was shown in figure 2.

In stationary state or motion state people discharge constantly water vapor and secretion to the outside, so clothing must have good moisture permeability to maintain dry feeling of human body skin, and make people feel comfortable. It could be seen from figure 2 that the order of moisture permeability of women's knee high sock was 4#>2#>1#>6#>5#>3#>7#. 1#, 2# and 4# women's knee high socks were all cotton / polyester / spandex fabric, their moisture permeability was good. And the moisture permeability of 4# women's knee high sock was the best, mainly because the proportion of cotton fiber of 4# women's knee high sock was the highest. The reason of good moisture permeability of cotton fiber is that main ingredients of cotton fiber is cellulose which contains a large number of hydrophilic group, and there are many holes on the fiber surface, too (Yu and Qian (2011)). The moisture permeability of 3# and 7# women's knee high socks was bad, the main reason was that the thickness and density of the two was bigger. With the increase of the thickness and density of fabric, the impedance of the water vapor diffusion from fabric increases. The moisture permeability of 5# and 6# women's knee high socks was relatively poor, which was caused by poor moisture permeability of fiber itself.

3.3 Abrasion resistance of women's knee high sock

The testing result of abrasion resistance of women's knee high sock was shown in figure 3.

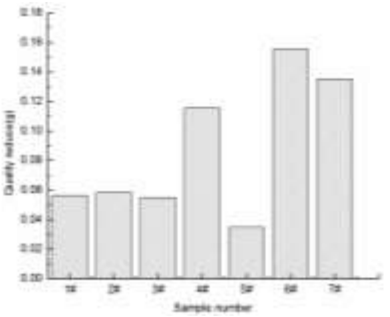

Figure 3: The testing result of abrasion resistance of women's knee high sock

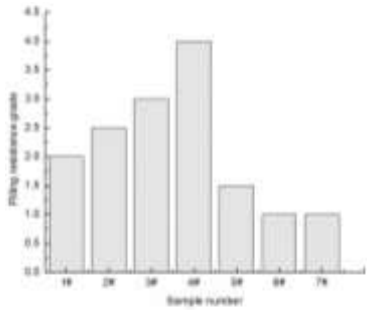

Figure 4: The testing result of pilling resistance of women's knee high sock

In the process of wearing, women's knee high sock not only produces friction by human foot but also by shoes when the movement, so the study of abrasion resistance of fabric of women's knee high sock can help us to choose appropriate women's knee high sock correctly. It could be seen from figure 3 that the order of quality reduce of women's knee high sock was 6#>7#>4#>2#>1#>3#>5# after a certain degree of abrasion. The more quality reduced, the worse abrasion resistance of fabric was. The abrasion resistance of 5# and 3# women's knee high socks was very good. The main reason was that 3# women's knee high sock contained nylon fiber which had excellent abrasion resistance and 5# women's knee high sock contained high percentage of polyester fiber. In 1#, 2# and 4# cotton / polyester / spandex women's knee high socks, 1# women's knee high sock contained the most polyester composition, its abrasion resistance was better. 4# women's knee high sock contained the most cotton content, and its abrasion resistance was the worst. This was because the abrasion resistance of polyester was better than that of cotton, with the increase of cotton content the abrasion resistance of women's knee high sock became worse. 6# and 7# women's knee high socks contained acrylic and wool fiber composition and organizational structure was relatively loose, tie points exerted on fiber was few, in the wear process yarn was vulnerable to external force and collapsed, which reduced the abrasion resistance of fabric greatly and made degree of abrasion of fabric serious.

3.4 Pilling resistance of women's knee high sock

The testing result of pilling resistance of women's knee high sock was shown in figure 4.

Fabric pilling destroys the appearance of fabric and reduces the wearability of fabric greatly (Qu and Bu (2008)). It could be seen from figure 4 that the order of degree of fabric pilling was 7#=6#>5#>1#>2#>3#>4#. The pilling of 7#, 6# and 5# women's knee high socks was serious, the main reason was that 7# women's knee high sock contained higher proportion of wool and polyester, 6# women's knee high sock contained higher proportion of acrylic and polyester, 5# women's knee high sock contained higher proportion of polyester. Acrylic fiber was soft, plump, fluffy, wool fiber was also soft, plump, and there were a lot of wool plush on the surface of wool fiber, so acrylic fiber and wool fiber were easy to pilling exerted by external friction. Most of polyester fiber used in women's knee high sock was short fiber, and short fiber was easy to pilling, which was the main reason that women's knee high sock containing higher proportion of polyester fiber had poor pilling resistance. In 1#, 2# and 4# cotton / polyester / spandex women's knee high socks, the pilling resistance of 1# women's knee high sock was relatively poor because of higher proportion of polyester fiber and the pilling resistance of 4# women's knee high sock was relatively good because of higher proportion of cotton fiber. It was known from the above analysis that the fabric containing polyester and nylon short fiber was easy to pilling, and the pilling resistance of fabric containing cotton fiber was good, even if fabric had pilling, the pilling fell off soon and had a little effects on appearance.

3.5 Tensile elastic recovery performance of women's knee high sock

The testing result of elastic recovery rate of women's knee high sock was shown in figure 5.

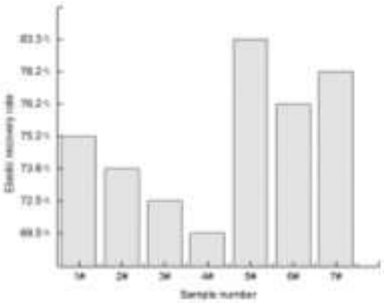

Figure 5: The testing result of elastic recovery rate of women's knee high sock

Good elasticity can improve the wearability of women's knee high sock. Women's knee high sock were weft knitted fabric, and most area of knee high sock was used to cover leg, so we selected hose as test materials, and studied the elasticity of fabric in weft direction. It could be seen from figure 5 that the order of elastic recovery rate of women's knee high sock was 5#>7#>6#>1#>2#>3#>4#. The elastic recovery rate of 5#, 6# and 7# women's knee high socks was higher. The main reason was that 5#, 6# and 7# women's knee high socks contained higher proportion of polyester and spandex and polyester and spandex both had good elastic recovery rate. 1#, 2# and 4# women's knee high socks were all cotton / polyester / spandex fabric, and the proportion of spandex was the same. 1# women's knee high sock contained the lowest proportion of cotton fiber and the highest proportion of polyester fiber. 4# women's knee high sock contained the highest proportion of cotton fiber and the lowest proportion of polyester fiber. Because the elastic recovery rate of cotton fiber was worse than that of polyester fiber, the elastic recovery rate of 4# women's knee high sock was lower than that of 1# women's knee high sock. 3# and 2# women's knee high socks contained the same proportion of cotton fiber, spandex fiber, nylon fiber and polyester fiber, because the elastic recovery performance of polyester fiber was better than that of nylon fiber, the elastic recovery performance of 2# women's knee high sock was better than that of 3# women's knee high sock.

3.6 The approximate optimal judgment of the wearability of women's knee high sock

For the women's knee high sock used in this experiment, according to the given index (the index of wearability measured in this experiment), we can use approximate optimal comprehensive judgment method to decide the wearability of women's knee high sock. The basic idea is to establish mathematical model and solve first, then sort to find the optimal value (Zheng et al (2011), Huang et al (2009), Kong and Yan (2007)).

3.6.1 The determination of approximate optimal grey element model

The element whose information is incomplete or whose connotation is hard to end is referred to as grey element in grey system theory (Wu and Yu (2008)). If you have $F_j(j=1,2,\cdots,m)$ women's knee high socks, $C_i(i=1,2,\cdots,n)$ indexes and corresponding whitening grey measures value $\bar{\otimes}_{ji}$, then the composite grey element having m kinds of women's knee high socks and n d indexes is referred to as $\bar{\otimes}R_{m\times n}$, namely,

$$\bar{\otimes}R_{m\times n} = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} F_1 & F_2 & \cdots & F_m \end{array} \\ \begin{bmatrix} \bar{\otimes}_{11} & \bar{\otimes}_{21} & \cdots & \bar{\otimes}_{m1} \\ \bar{\otimes}_{12} & \bar{\otimes}_{22} & \cdots & \bar{\otimes}_{m2} \\ \vdots & \vdots & \vdots & \vdots \\ \bar{\otimes}_{1n} & \bar{\otimes}_{2n} & \cdots & \bar{\otimes}_{mn} \end{bmatrix} \end{array} \tag{1}$$

The whitening grey measures value in equation (1) was processed in measureless steel and to be mapped to [0, 1] area, converted into approximate optimal whitening grey measures value $\overline{\otimes}'_{ji}$, m kinds of women's knee high socks and n d approximate optimal composite grey element was referred to as $\overline{\otimes}'R_{m\times n}$, thus there are,

$$\overline{\otimes}'R_{m\times n}=\begin{array}{c c} & \begin{array}{cccc} F_1 & F_2 & \cdots & F_m \end{array} \\ \begin{array}{c} C_1 \\ C_2 \\ \vdots \\ C_n \end{array} & \begin{bmatrix} \overline{\otimes}'_{11} & \overline{\otimes}'_{21} & \cdots & \overline{\otimes}'_{m1} \\ \overline{\otimes}'_{12} & \overline{\otimes}'_{22} & \cdots & \overline{\otimes}'_{m2} \\ \vdots & \vdots & \vdots & \vdots \\ \overline{\otimes}'_{1n} & \overline{\otimes}'_{2n} & \cdots & \overline{\otimes}'_{mn} \end{bmatrix} \end{array} \tag{2}$$

$\overline{\otimes}'_{ji}\,(j=1,2,\cdots,m;i=1,2,\cdots,n)$ in equation (2) expressed the approximate optimal whitening grey measures value of the i_{th} index of the j_{th} kind of women's knee high sock. And its determination method can be processed according to the following method, namely,

① The bigger index that is better

$$\overline{\otimes}'_{ji}=\overline{\otimes}_{ji}/\max\{\overline{\otimes}_{ji},u_{\max}\} \tag{3}$$

② The smaller index that is better

$$\overline{\otimes}'_{ji}=\min\{\overline{\otimes}_{ji},u_{\min}\}/\overline{\otimes}_{ji} \tag{4}$$

③ The moderate index that is better

$$\overline{\otimes}'_{ji}=\min\{\overline{\otimes}_{ji},u_0\}/\max\{\overline{\otimes}_{ji},u_0\} \tag{5}$$

In equations, $\max\overline{\otimes}_{ji}=\max\{\overline{\otimes}_{j1},\overline{\otimes}_{j2},\cdots,\overline{\otimes}_{ji}\}$, $\min\overline{\otimes}_{ji}=\min\{\overline{\otimes}_{j1},\overline{\otimes}_{j2},\cdots,\overline{\otimes}_{ji}\}$, $u_{\max}$ was the specified larger value, $u_{\min}$ was the specified smaller value, u_0 was the specified moderate value.

3.6.2 The solve and sorting of approximate optimal degree

The approximate optimal whitening grey measures value in equation (2) is a decentralized approximate optimal comparison, which can't be used to compare women's knee high sock on the whole. Therefore, it was necessary to convert the approximate optimal whitening grey measures value into approximate optimal degree, it referred to a kind of measurement that was used to measure the approaching degree between all kinds of women's knee high socks and comparison standards. s_j was selected to express the approximate optimal degree of the j_{th} kind of women's knee high sock. Thereby, the approximate optimal whitening grey measures value was processed and converted into approximate optimal degree composite grey element $\overline{\otimes}R_s$, there was,

$$\overline{\otimes}R_s=S_j\begin{array}{c} \begin{array}{cccc} F_1 & F_2 & \cdots & F_m \end{array} \\ [S_1 \quad S_2 \quad \cdots \quad S_m] \end{array}=S_j\begin{array}{c} \begin{array}{cccc} F_1 & F_2 & \cdots & F_m \end{array} \\ \left[1/n\sum_{i=1}^{n}\overline{\otimes}'_{i1} \quad 1/n\sum_{i=1}^{n}\overline{\otimes}'_{i2} \quad \cdots \quad 1/n\sum_{i=1}^{n}\overline{\otimes}'_{im}\right] \end{array} \tag{6}$$

Sorting on the basis of the approximate optimal degree of all kinds of women's knee high socks calculated according to equation (6), we could determine the rank of the women's knee high socks. The approximate optimal degree of women's knee high sock was more close to 1, indicating that the wearability of the women's knee high sock was better.

3.6.3 Approximate optimal decision and discussion

In the case of the 7 kinds of women's knee high socks in this research, the 5 indexes corresponding with the wearability of women's knee high sock was used to establish the composite grey element that contained 7 kinds of women's knee high socks and 5 indexes, namely,

$$\overline{\otimes}R_{7\times 5}=\begin{array}{r c} & \begin{array}{ccccccc} F_1 & F_2 & F_3 & F_4 & F_5 & F_6 & F_7 \end{array} \\ \begin{array}{r} \text{Air permeability} \\ \text{Moisture permeability} \\ \text{Quality change} \\ \text{Pilling resistance grade} \\ \text{Elastic recovery rate} \end{array} & \begin{bmatrix} 809 & 758 & 401 & 733 & 560 & 477 & 532 \\ 5566.83 & 5871.87 & 5083.27 & 6599.45 & 5181.85 & 5243.62 & 4859.27 \\ 0.0564 & 0.0584 & 0.055 & 0.1155 & 0.0347 & 0.1554 & 0.1352 \\ 2 & 2.5 & 3 & 4 & 1.5 & 1 & 1 \\ 75.2\% & 73.6\% & 72.5\% & 69.5\% & 83.3\% & 76.2\% & 78.2\% \end{bmatrix} \end{array} \tag{7}$$

The approximate optimal composite grey element $\overline{\otimes}'R_{7\times5}$ was obtained by using approximate optimal conversion to process equation (7) in accordance with equations (3)~(5).

$$\overline{\otimes}'R_{7\times5} = \begin{array}{r} \\ \text{Air permeability} \\ \text{Moisture permeability} \\ \text{Quality change} \\ \text{Pilling resistance grade} \\ \text{Elastic recovery rate} \end{array} \begin{array}{c} \begin{array}{ccccccc} F_1 & F_2 & F_3 & F_4 & F_5 & F_6 & F_7 \end{array} \\ \begin{bmatrix} 1 & 0.937 & 0.4957 & 0.906 & 0.6922 & 0.5896 & 0.6576 \\ 0.8435 & 0.8898 & 0.7703 & 1 & 0.7852 & 0.7946 & 0.7363 \\ 0.6152 & 0.5942 & 0.6309 & 0.3004 & 1 & 0.2233 & 0.2567 \\ 0.4 & 0.625 & 0.75 & 1 & 0.375 & 0.25 & 0.25 \\ 0.9028 & 0.8836 & 0.8703 & 0.8343 & 1 & 0.9148 & 0.9388 \end{bmatrix} \end{array} \quad (8)$$

The approximate optimal degree was calculated in accordance with equation (6),

$$\overline{\otimes}R_s = S_j \begin{array}{c} \begin{array}{ccccccc} F_1 & F_2 & F_3 & F_4 & F_5 & F_6 & F_7 \end{array} \\ \begin{bmatrix} 0.7523 & 0.7859 & 0.7034 & 0.8081 & 0.7705 & 0.5545 & 0.5679 \end{bmatrix} \end{array} \quad (9)$$

Namely, $S_4 > S_2 > S_5 > S_1 > S_3 > S_7 > S_6$

There is, $F_4 > F_2 > F_5 > F_1 > F_3 > F_7 > F_6$

It could be seen from the evaluation results that the comprehensive evaluation of the wearability of 4# women's knee high sock was the best in 7 kinds of women's knee high socks in this experiment. And the sorting of the wearability of 7 kinds of women's knee high socks from priority to inferiority was 4#>2#>5#>1#>3#>7#>6#.

4. Conclusions

Approximate optimal comprehensive judgment method was used to solve the evaluation problem of the wearability of women's knee high sock, and the order from priority to inferiority of wearability of women's knee high socks was ranked, which gave a theory basis to the comprehensive evaluation of the wearability of women's knee high sock, making a better evaluation effect. And the research results also pointed out that the wearability of cotton / polyester / spandex women's knee high sock which contained higher proportion of cotton fiber was better. The research results could provide a certain theoretical guidance for the manufacture of enterprises and the choice of consumers of women's knee high socks.

Acknowledgements

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