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Research Article

Research on Relationship between Pressure and Area on Lower Leg Cross-Section at Top Part of Men's Socks

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Abstract: Socks are one of the most common wear covering the lower leg in daily life. In this experiment, 40 participants are scanned, all 20 to 22 years old college students, to research the distribution of the pressure of the cross section of the lower leg. First we obtain the figure of the cross section of lower leg at the top part of socks, 6cm above the ankle point, by using 3D body scanner (Tec Math). Next we can draw a standardized figure of the section. After that, 8 equations describing the curve of the section can be achieved by curve fitting. And then, we divide the section into 12 regions by angle (30°) and choose 12 testing points to measure the pressure. Finally, we have calculated the area of each region and have found the relationship between the pressure and the areas.

Keywords: Clothing pressure, ergonomics, mathematic model, socks

INTRODUCTION

With the improving lifestyles and changing notions of people, the clothing comfort has become one of the most important performances required by modern customers day by day (Meng and Zhang, 2006). In Li's research they found that the clothing comfort contains 3 independent factors: thermal comfort, tactual comfort and pressure comfort (Li, 1998). And the pressure comfort researching has become a hot spot in clothing comfort field in recent years.

Socks are one of the most common wear in people's daily life and the research about the comfort pressure value of the top part of socks is very important in designing and developing these products (Li, 2007). Currently, the researches about the pressure comfort of socks are still at early stage, but have covered many fields. Homata (Momota *et al*., 1993) and Toshiyuki (Tsujisaka *et al*., 2004) have found the comfort pressure value of the top part of socks. In 1998, Kenjishoh (Kenji, 1998) began to test the pressure of socks by using elastic optical fibers. Nakahashi learned the influence on the circulatory system caused by the pressure of stockings (Nakahashi *et al*., 2003).

Nowadays, the researches on clothing pressure were still focused on the measuring methods, testing machines and valuing peoples' feelings on the pressures. Current researches showed that there were still some shortcomings and limitations in these fields:

- All the testing machines would change the status of the body when measuring clothing pressures.
- The participants' individual differences were very big, so valuing the comfort of the clothing pressure was very difficult. And the experimental procedure lacked repetition.

In this case, we must find a new method to predict the clothing pressure and value the comfort of pressure. So to build up a mathematic model based on ergonomics to predict clothing pressures became very important (Qiang *et al*., 2010). The cross section on lower leg at the top part of socks and the materials of the socks are both the important factors which could affect the pressure value directly. But now, researches on the figure of the cross section are still quite rare. Proceeding from the ergonomics and differential geometry, a mathematical model could be found to describe the distribution of curvature radius of the cross section, providing a good reference for the foundation of the mathematic model for predicting the pressure.

In this study, we have a research of the research on relationship between pressure and area on lower leg cross-section at top part of men's socks. Forty participants were scanned, all 20 to 22 years old college students, to research the distribution of the pressure of the cross section of the lower leg. First we obtain the figure of the cross section of lower leg at the top part of socks, 6 cm above the ankle point, by using 3D body scanner (Tec Math). Next we can draw a standardized figure of the section. After that, 8 equations describing the curve of the section can be achieved by curve fitting. And then, we divide the section into 12 regions by angle (30°) and choose 12 testing points to measure the pressure. Finally, we have calculated the area of

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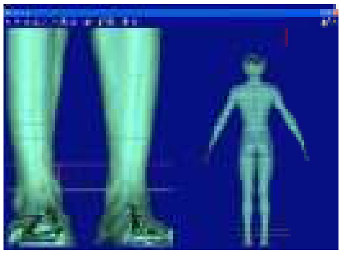

Fig. 1: Position of the cross section

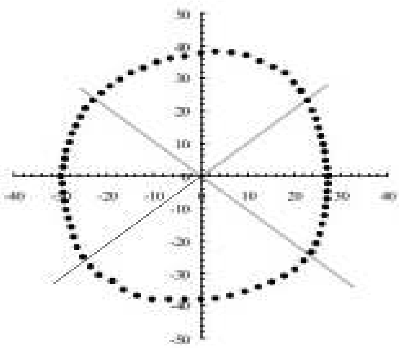

Fig. 2: Standard figure of the cross section at lower leg

each region and have found the relationship between the pressure and the areas.

EXPERIMENT

Standard figure of the cross section:

Data acquisition and processing: To make a study of the distribution of curvature radius of the cross section on the lower leg at the top part of socks, the figure of the section must be obtained. 3D body scanner was used to do this job, Fig. 1 showed the position of the section (6 cm high from the ankle point). In this experiment, 40 participants, 20-22 years old male college students were tested under the condition of 25°C and RH 52±2%. Then 40 section figures (right leg) were obtained through Scanworx software.

Standard cross section figure acquisition: Firstly, set a plane right angle coordinate according to the origin and the axis confirmed by the scanner. Secondly, 72 points (every 5° angle) were selected in each figure. By averaging x values and y values of the 72 sets of coordinate, a standard shape of the cross section could be obtained. Figure 2 showed the standard shape of the cross section.

Obtaining the curvilinear equation of the cross section: To obtain the curvilinear equation of the cross section, we used SPSS to fit the curve, X is independent variable and Y is dependent variable. In this process, we chose square model to fit the curve. We divided the curve of the section into 8 parts by angle of every 45° according to the shape.

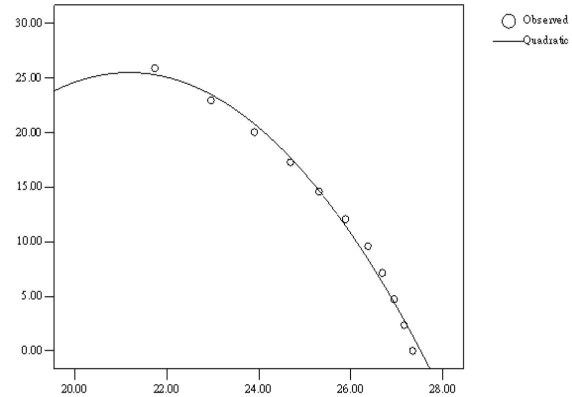

Fig. 3: Fitting the curve between the angle 0°- 45°

When $\theta \in [0, 45]$ the equation of the regression curve was:

$$Y = -0.636X^2 + 26.937X - 259.793$$

Figure 3 showed the shape of the curve, with θ between the angles of 0-45°.

In the same way, we obtained other 7 regression curves and the corresponding equations:

$\theta \in [45°, 90°]$,
$Y = -0.044X^2 + 0.387X + 37.779$

$\theta \in [90°, 135°]$,
$Y = -0.026X^2 + 0.061X + 37.701$

$\theta \in [135°, 180°]$,
$Y = -0.352X^2 - 15.165X - 138.876$

$\theta \in [180°, 225°]$,
$Y = 0.739X^2 + 35.074X + 389.509$

$\theta \in [225°, 270°]$,
$Y = 0.035X^2 + 0.342X - 38.402$

$\theta \in [270°, 315°]$,
$Y = 0.028X^2 - 0.056X - 38.24$

$\theta \in [315°, 360°]$,
$Y = 1.14X^2 - 52.169X + 570.972$

Calculating the area of each region: We divided the section into 12 regions and pick out 12 testing points as Fig. 4 showing. S1, S2…… S12 were the regions and A, B, C……L were the testing points. Each testing point was at the middle of the corresponding region's edge, so the pressure which we measured could reflect the force on the state of the forces on the regions correctly.

And we can calculate the area of each region. Let's take the calculation of S1 for example.

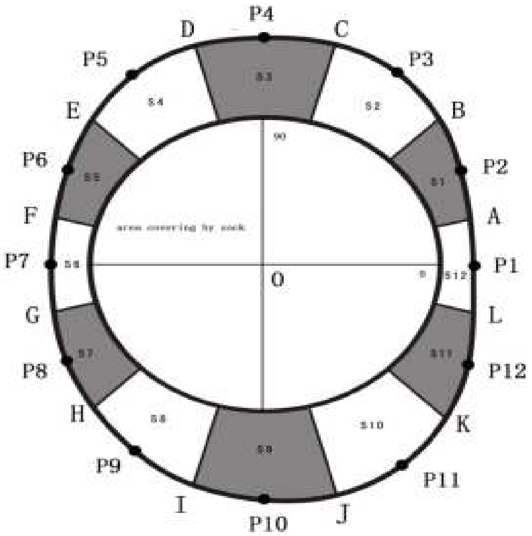

Fig. 4: The regions and the testing points

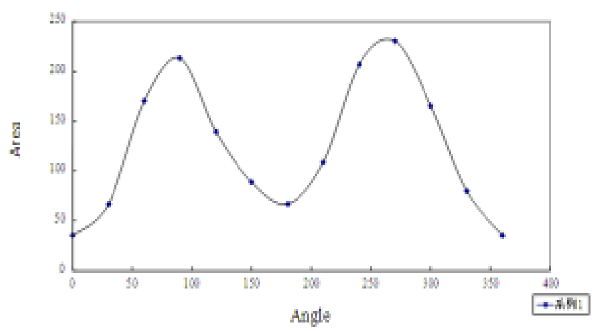

Fig. 5: Area distribution changing with the angle

The area of the Sector1 (0°-15°):

$$\int_a^b f(x)dx = \int_{26.54}^{27.62}(-0.636x^2 + 26.937x - 259.793)dx = 3.45983$$

Sector1 = ½ (26.54*7.113) + 3.45983 = 97.85

Likewise, the area of the Sector 2 (0°-45°) = 326.54

Considering the circle of the socks we used is 16 cm and then we can obtain the area of S1.

S1 = Sector 2 - Sector 1 - area of sock's/12 = 326.54 - 97.85 - 162.21 = 66.48

Similarly, we can also obtain other areas: S2 = 170.39, S3 = 213.17, S4 = 139.26, S5 = 88.68, S6 = 66.73, S7 = 108.81, S8 = 206.95, S9 = 230.23, S10 = 165.25, S11 = 79.69, S12 = 35.46.

Figure 5 showed the distribution of the areas changing with the angle.

Pressure testing: We chose 6 socks (A1, A2, A3, B1, B2, B3) with same circle of 16 cm in the pressure tests,

Fig. 6: AMI 3037-5S cells pressure tester

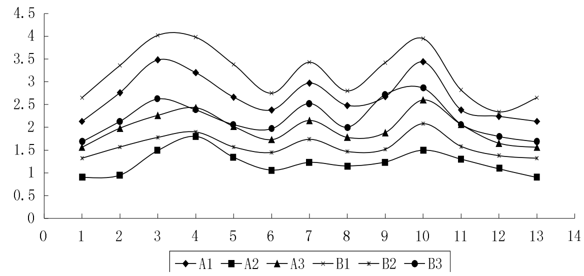

Fig. 7: Pressure distribution of each socks

but the materials and the structures were different. We also selected one participant with a standard shape of the lower leg section to wear these socks and we could measure the pressure of each testing point by the AMI 3037-5S cells pressure tester.

First, we marked 12 spots on the surface at the lower leg of the participant. Next, the participant wore the socks. After that, put the cells of the pressure tester between the top part of socks and the surface of lower leg at the testing points. And then, we adjusted the socks to make the tension of the top part equal. Finally, we recorded the data. Figure 6 shows the AMI 3037-5S cells pressure tester.

Table 1 showed the pressure of each point and we also obtain the average pressure of each point from different socks. Figure 7 described the distributions of the pressure and Fig. 8 showed the average pressure distribution. From the figure we could also find that although the pressure of each sock was different, the regularities of the distributions were almost the same. The highest pressure of each socks occurred at the angle of 270° and the lowest at 0°.

RESULTS AND DISCUSSION

Correlation analysis between the pressures and the areas of the regions: According to the results of experiments, we found that the changing of pressure and the areas of the regions with the angle were similar. So we tried to get the relationship between the pressure and the area by SPSS Pearson's correlation analysis.

Table 1: The pressure at the testing points of each socks

	Pressure/Kpa						
Angle	A1	A2	A3	B1	B2	B3	Average
0	2.13	0.90	1.56	2.65	1.32	1.68	1.71
30	2.76	0.95	1.98	3.36	1.57	2.13	2.13
60	3.48	1.49	2.26	4.02	1.78	2.62	2.61
90	3.20	1.80	2.43	3.98	1.90	2.38	2.62
120	2.66	1.34	2.02	3.38	1.57	2.06	2.17
150	2.38	1.06	1.73	2.75	1.45	1.97	1.89
180	2.97	1.23	2.15	3.43	1.74	2.52	2.34
210	2.48	1.15	1.78	2.80	1.47	2.00	1.95
240	2.67	1.24	1.88	3.42	1.52	2.72	2.24
270	3.44	1.50	2.60	3.95	2.08	2.86	2.74
300	2.38	1.30	2.06	2.82	1.58	2.07	2.04
330	2.24	1.09	1.65	2.34	1.38	1.80	1.75
360	2.13	0.90	1.56	2.65	1.32	1.68	1.71

Table 2: Correlation coefficients for the pressure and the area

	A1	A2	A3	B1	B2	B3	Average
Coefficient	0.682*	0.857**	0.770**	0.706**	0.741**	0.771**	0.787**

*: Significant correlation ($p<0.05$); **: Significant correlation ($p<0.01$)

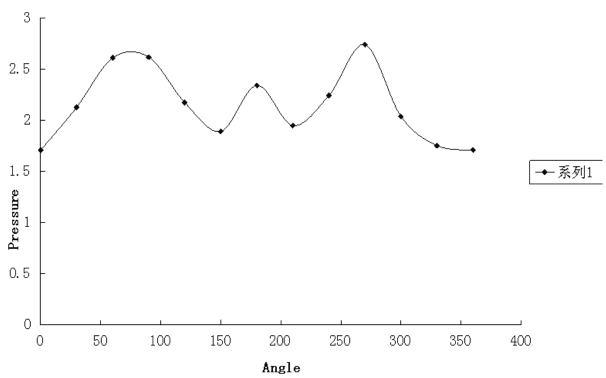

Fig. 8: The average pressure distribution

Table 2 showed the correlation coefficients for the pressure and the area of each socks.

From Fig. 5, 8 and the data of Table 2, we could draw a conclusion that there is a significant correlation between the pressures and the areas of the regions.

Regression analysis for the pressures and the areas of the regions: Supposing that the pressure was caused by the elastic potential energy of the materials and the energy was distributed by the area ratio, we used aE/X to calculate the pressures; Considering that the elastic coefficients of skin and muscle changed with the angle, we added a function Sin (c*X + d) to correct the pressure. So we could build a mathematic model to describe how the pressure changes with the areas of regions. Equation 1 showed the relationship between the 2 variables, pressure and area:

$$Y = aE/X + b*\mathrm{Sin}\,(c*X + d) + e \quad (1)$$

Y = Pressure
E = Energy of socks
X = Area of region
a, b, c, d, e = Constant

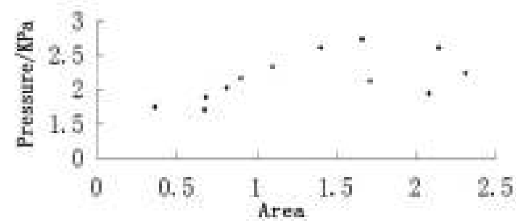

Fig. 9: Scatter diagram of area and pressure

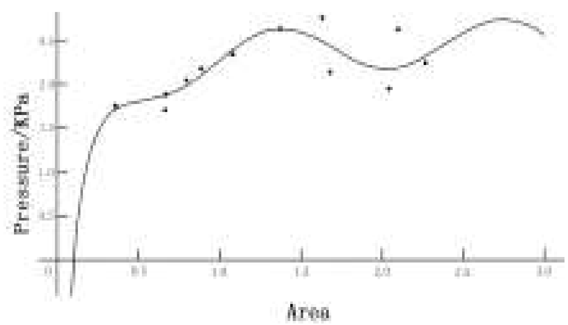

Fig. 10: Curve fitting of the regression equation

Because the elastic potential energy of each socks would be a content while the person was selected, Eq. (1) could be simplified to Y = a/X + b*Sin (c*X + d) + e. And then, we can find all the constants by nonlinear regression analysis. Finally, the regression equation was listed below:

$$Y = -0.309/X + 0.265\mathrm{Sin}\,(4.625*X + 26.686) + 2.591 \quad R^2 = 0.672$$

Making the areas as abscissa and the corresponding pressure as vertical coordinate, we could draw a scatter diagram (Fig. 9) to show how the pressure changed with area of each region. And Fig. 10 showed the relationship between pressures and areas by curve fitting. From Fig. 10, we found that most of the spots were on the curve and the rest were nearby. That meant we could predict the pressure by checking the area of each region and the materials of the socks.

CONCLUSION

In this research, we tried to find a method to predict the pressure when a man wears socks. The experiments have shown that there was a significant correlation between the pressure and the area and it might be possible to predict the pressure distribution by this way. And we also believe that the elastic potential energy must be linked with the pressure.

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