(REFEREED RESEARCH)

THE EFFECT OF MOISTURE ON FRICTION COEFFICIENT OF ELASTIC KNITTED FABRICS

ELASTİK ÖRME KUMAŞLARDA NEM İÇERİĞİNİN SÜRTÜNME KATSAYISINA ETKİSİ

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ABSTRACT

The friction between the skin and fabric surface is an important parameter characterising the comfort performance of garments. In this study, the effect of moisture on the friction coefficient of knitted fabrics containing different elastane ratios was investigated. The measurements were carried out by means of the FRICTORQ tester, a new patented measuring instrument developed at the University of Minho and based on a new method of determination of friction coefficient of fabrics. It was found that with increasing moisture level in fabrics, the friction coefficient increases as well, but just to a certain limit. The level of friction coefficient becomes stable over the moisture regain value of 40%. The fabrics which contain elastane yarn in every alternating course and the tight structures exhibit the highest fabric friction values.

Key Words: Friction coefficient, Elastic knitted fabrics, Moisture, Tightness.

ÖZET

Kumaş yüzeyi ile deri arasındaki sürtünme, giysilerin konfor performanslarını belirleyen önemli bir parametredir. Bu çalışmada farklı oranda elastan içeren örme kumaşlarda nem içeriğinin sürtünme katsayısına etkisi araştırılmıştır. Ölçümler Minho Üniversitesinde geliştirilip patent alınmış, kumaşların sürtünme katsayısının belirlenmesinde yeni bir metoda dayalı olarak ölçüm yapan FRICTORQ cihazı ile yapılmıştır. Kumaşta artan nem miktarı ile sürtünme katsayısının belirli bir limite kadar artmakta olduğu tespit edilmiştir. Yaklaşık % 40'ın üzerindeki nem değerlerinde sürtünme katsayısı sabit hale gelmektedir. Yarı elastan içeren ve en sık yapıdaki kumaşlar en yüksek sürtünme değerleri vermiştir.

Anahtar Kelimeler: Sürtünme katsayısı, Elastik örme kumaşlar, Nem, Sıklık .

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1. INTRODUCTION

Interaction of fabrics with the human senses is an essential performance property (1, 2) as most textile materials are used near or in contact with the skin. When a fabric is moved along the skin, this contact is increased and the perception of fabric roughness or smoothness is evoked. The friction between fabric and skin during contact is the key factor for this perception of roughness and smoothness. The friction resistance is mostly (but not always) lower for a fabric with a smooth surface than for a fabric having a rougher surface. Moisture at the skin surface can alter the intensity of fabric roughness perceived. As moisture content increases, the friction and displacement of skin increases, which triggers more touch receptors (3). At higher moisture levels, it causes higher friction, bringing a feeling of discomfort.

Friction coefficient is one of the factors contributing for the so-called parameter fabric hand and its importance justifies the number of contributions given in the past to this problem (4,5,6,7). That is why various researchers focused on the invention of new methods and instruments for the measurement of friction (1,4,8,9).

Fabric friction has been affected by many factors such as the type of fiber, type of blend, blend proportion, yarn structure, fabric structure and compressibility. A. Das, V. K. Kothari and N. Vandana (6) investigated fabric-to-metal surface and fabric-to-fabric frictional characteristics of a series of fabrics containing 100% polyester, 100% viscose, and PES/Cotton & PES/Viscose blends with different blend proportions. For all the fabrics at different levels of normal load, the kinetic friction and the static friction values were measured. They found that fabric-to-metal friction is less sensitive to fabric morphology and rubbing direction, whereas fabric-to-fabric friction is highly sensitive to these factors. According to their results PES/Cotton and PES/Viscose blended fabrics show higher fabric-to-fabric friction than 100% polyester or 100% viscose. PES/Cotton blended fabrics show higher frictional resistance than that of PES/Viscose blended fabrics for the same geometrical parameters of the fabrics. In PES/Cotton and PES/Viscose blended fabrics, the frictional force increases as the cellulose fiber component increases.

S.G. Vassiliadis and C.G. Provatidis (7) measured woven and knitted fabric roughness data using the Kawabata Evaluation System for fabrics. Single jersey, double jersey or interlaced structures were produced using conventional and compact cotton yarns. The specimens were subjected to laboratory surface roughness tests in three different stages: raw form, after the dyeing procedure and after the application of a softening agent. The surface roughness data have been processed using the sliding window averaged FFT method and the wavelengths of the main spectral components were detected. The results showed a very good stability on the geometrical roughness characteristics of the various samples belonging to the same knit group. The coefficient of variation between the wavelengths of the main spectral components within each group is very low, between 0.7 and 2.3 per cent. The low values of the CV indicate that the different yarn production technologies and the different finishing stages do not influence significantly the wavelength of the main spectral component of the geometrical roughness.

L. Hes (10) measured thermal conductivity, thermal resistance, water vapour permeability and air permeability of cotton, cotton/PA, PP and cotton/PES woven fabrics both in dry and wet state. He investigated the effect of structure and composition on these comfort properties. The results showed that with increasing fabrics humidity, the thermal resistance, water vapor permeability and air permeability decreased; whereas the thermal conductivity and total cooling heat flow (due to water evaporation from the wet fabric surface) increased.

Unlike previous researches, in this study the effects of elastane and moisture on the friction coefficient of single jersey fabrics were investigated.

The use of garments made from knitted fabrics in casual wear, sports activity and also in working life has been increased in recent years due to the demand for fabric elasticity. But the recovery forces in single jersey fabrics after stretching are generally low, and therefore elastane is increasingly used to impart a greater level of stretch and higher dimensional recovery than can be achieved with cotton alone. The use of elastane has resulted in fabrics with better body fit like a second skin and offers good shape retention without any deformation throughout the garment lifetime (11, 15).

Papers describing the effects of the elastane in knitted fabrics are generally related to dimensional properties of the fabrics (12, 13, and 14). A. B. Marmarali (15) investigated the physical and dimensional properties of elastic single jersey fabrics, and A. Marmarali, N. Özdil and S. D. Kretzschmar (16) studied the effect of the elastane content in fabrics on their thermal properties and relative water vapor permeability.

2. THE MODEL OF FRICTORQ

FRICTORQ II instrument was used to determine the surface friction coefficient of the samples. This model went through various development stages (17,18,19). Figure 1 is a schematic representation of the latest model named FRICTORQ II. The laboratory prototype of the instrument is shown in Figure 2.

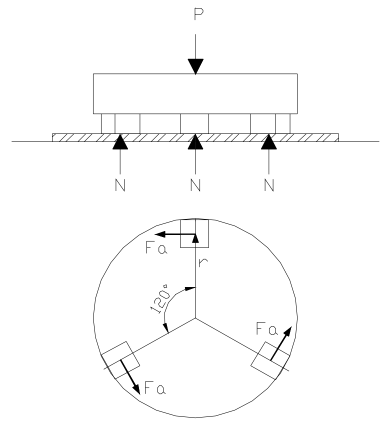


Figure 1. The FRICTORQ II model

Figure 2. FRICTORQ II laboratory prototype

The rotary action remains, but the contact is now restricted to 3 small special elements or feet, disposed at 120°. Providing a relative displacement of approximately 90°, it is assured that a new portion of fabric is always moved under the contact sensors. For this model, torque is given by:

$$T = 3\, F_a\, r \quad (1)$$

Being, by definition, $F_a = \mu N$ and from Figure 1, $N = P/3$, where P is the vertical load, the coefficient of friction is then expressed by:

$$\mu = \frac{T}{P \times r} \quad (2)$$

Previous exploratory work led to the establishment of some design parameters, namely contact pressure and linear velocity in the geometric centre of each contact foot, the latter set to approximately 1,57 mm/s.

For dynamic friction the data collected between 5 and 20 seconds of the test is used. As well as other well known methods, such as KES, this one is not covered by any standards. The contact surface is made of standard and commercially available steel needles of 1 mm diameter joint side by side in a square shape as it is seen in Figure 1. Therefore this surface is well characterized and easily reproducible.

3. MATERIAL AND METHODS

3.1 Materials

In this study the fabrics knitted with Ne 30/1 ring spun cotton and 44 dTex elastane yarns that commonly used in the market were tested. Knitting process was carried out on a Relanit 3.2 (28 gauge, 32” diameter) Mayer&Cie circular knitting machine. During the knitting process 50 feeders were used. Three separate single jersey samples were produced: one with cotton alone and the other two as half plating cotton/elastane fabrics (elastane in alternating courses) and full plating cotton/elastane fabrics (elastane in every course). Full plating samples were obtained at three different loop length values representing a range of tight, medium and loose fabrics. An IRO MER2 system was used to feed the elastane and yarn tension was chosen at 6 cN, as proposed in previous papers (14, 20 and 21). The samples were dyed in accordance with current manufacturing practices.

3.2 Methods

The samples were cut with a circular template in 100 cm^2 area. Then they were put into oven at 105 ºC for one hour and weighted. This value was accepted as the dry weight of the sample and was used in the formula which calculates weight of the samples in various moisture regain values (20%-40%-60%-80%-100%), given below:

$$\text{Moisture regain (\%)} = \frac{W_1 - W}{W} \times 100 \quad (22)$$

Where:

W= Weight of oven dry specimen, g.

W_1 = Weight of specimen as received, g.

The samples were kept in distilled water for one hour, then dripped water was taken out with a tissue and samples were left in standard atmospheric conditions. As soon as the desired moisture regains were obtained, kinetic friction coefficients were measured using FRICTORQ II instrument. As for the performance of the FRICTORQ instrument, this has demonstrated to be a good tool to determine and differentiate friction in fabrics, both in dry and wet state. This equipment also shows no influence from external factors, such as operator skills.

The photos were taken using a Leica projection microscope to see the samples surface structure. All tests were carried out under a conditioned atmosphere of 20 ± 2 ºC and 65 ± 4 % RH.

The test results were evaluated using SPSS 13.0® for Windows statistical software. To determine the statistical importance of the variations, ANOVA tests were applied. To deduce whether the parameters were significant or not, significance value (p value) were examined. If p value of a parameter is greater than 0.05 (p > 0.05), the parameter will not be important and should be ignored.

4. RESULTS AND DISCUSSION

4.1 Effect of fabric structure on surface friction

4.1.1 Effect of elastane

Figure 3 shows the effect of elastane ratio on the surface kinetic friction coefficient. The results of statistical evaluation indicate that half plating fabric containing elastane yarn in every alternating course has significantly higher fabric friction value. But the differences between the kinetic friction coefficient of the samples with full plating and the samples without elastane are not statistically significant.

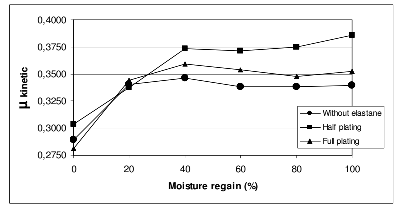
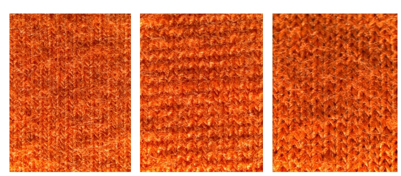


Figure 3. Kinetic friction coefficient diagram for different elastane and moisture levels

Textile fabrics are rarely balanced in terms of surface appearance and it is known that the friction between skin and fabric is greater with fabrics having a rougher surface than with fabrics having a smoother one. As it can be seen from Figure 4, the structure of half plating fabrics causes an unbalanced surface appearance and threads which are in courses without elastane become bulky in every alternating course. As a consequence, the surface of half plating fabrics has a rougher structure and wavy surface than surfaces of fabrics knitted using elastane in every course or without elastane. That’s why the half plating fabric exhibits the maximum friction coefficient value as mentioned in previous research (22).



(a) (b) (c)

Figure 4. The surface images of fabrics with different elastane ratios

a- full plating cotton/elastane fabrics,

b- half plating cotton/elastane fabrics,

c- without elastane

4.1.2. Effect of fabric tightness

Figure 5 shows the effect of fabric tightness on the surface kinetic friction coefficient. It can be seen that, as the fabric tightness increases the surface kinetic friction coefficient increases as well. In other words loose structures possess lower friction values. Statistical evaluations showed that only the differences between tight and loose structures are significant for all moisture levels.

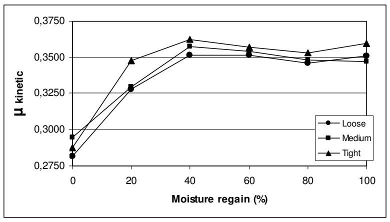


Figure 5. Kinetic friction coefficient diagram for different tightness factors and moisture levels

This situation can be explained by increased contact area as mentioned by E.P. Bowden and D. Tabor (23). The size of contact area directly affects the coefficient of friction. A tighter structure creates a greater contact surface area and this will increase the number of contact points; therefore contributing to a friction increase.

4.2 Effect of moisture on surface friction

As it is shown in Figures 3 and 5, for all fabric types the friction coefficient values increase with the increment of moisture regain. Statistical evaluations indicate that 40% is the critic value for surface friction. The differences between the friction coefficient values of 40%, 60%, 80% and 100% are not significant. This is the expected result as mentioned before (10). This specific behavior can be explained by different form of water distribution in the fabric structure. At lower moisture regain, water enters the micro-capillary channels and does not create a surface film. Continuous film appears at higher moisture levels, which causes higher hydrodynamic friction.

5. CONCLUSIONS

In this study, the effects of fabric structure and moisture on the friction coefficient of fabrics with different elastane ratios were investigated. With increasing moisture level, the friction coefficient values increase but at moisture regain of 40%, the friction coefficient becomes stable. So it is possible to say that, fabric gives discomfort skin feelings for over 40% moisture regain values, because of higher friction.

As far as the effect of the fabric structure is concerned, the half plating fabric containing elastane yarn in every alternating course exhibits the highest fabric friction value. This result can be explained as a consequence of the increasing fabric roughness. Furthermore, the fact that the loose structures possess lower friction values is determined and explained by the amount of contact area. As a result the half plating fabrics and tight structures will give rougher feeling because of their high friction values.

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