Characterizing the Stickiness Property of Fibrous Materials Under Wet Skin Surface: Textile Friction Tester

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ABSTRACT

People sweat when being in hot environment or exercising. The sweat will be absorbed by clothing and the attractive force between skin and fabric will be risen by sweat, causing sensorial discomfort. Pressure and friction in combination with moisture can lead to skin irritations or even skin contact injuries. Hence, a sensitive, accurate and reliable measurement method is proposed for measuring the frictional property of textiles. The proposed 'dragging type' measurement tester connects the fabric to the force gauge, moves it at a constant speed and the lateral force against the dragging distance is measured. The uniqueness of this instrument is that the amount of water supply can be standardized to simulate different sweating conditions, ranging from mild to profuse sweating. This instrument is useful for product selection especially for sportswear, hygiene products or medical textiles application. Correlation with subjective sensorial evaluation is planned to examine its reality to actual wear condition. Compared with conventional instrument, like Kawabata Evaluation System for Fabric, the proposed method is simple, versatile, and closer to wear condition at an acceptable cost. With this instrument, fabric can be characterized efficiently which would benefit the textile industry.

Keywords: Fabric, stickiness, friction, comfort, textiles

1 INTRODUCTION

Human skin is practically in extended contact with textiles during various activities. Textiles to skin friction play an important role in governing the behavior of textiles in wear and use. Stickiness, in term of friction and surface tension of water, at the skin-textile interface is often associated with a clingy or clammy sensation (i.e. the feeling of discomfort). If the contact pressures and shear forces are high or continue over long period of time, it will cause skin irritations, abrasions or other skin injuries, like decubitus. With elevated skin moisture level, the attractive force at fabric-water and water-skin rises, the situation will be even worse.

The optimum frictional properties of textiles depend on the specific application. For sportswear or hygiene products, textiles with low coefficient of friction against skin seem to be an appropriate solution. So far, product development has mainly focused on other comfort-related properties, like water absorbency, water vapour permeability and air permeability, whereas frictional characteristics of textiles against moist or wet skin surface have hardly been taken into account.

In order to investigate the frictional properties of textiles, it is possible to conduct human subjective tests [1, 2] or in vivo study [3-5]. However, the variability between the participants and many uncontrollable errors do exist [3]. Additional work is required to quantify the amount of water on skin so as to accurately evaluate the effect of water on friction and stickiness. Additionally, a large sample size should be tested in order to reduce error and this would be a time-consuming and costly task. This hinders the use of subjective test to quantify the performance of fabric and so instrumental measurements are an efficient alternative, providing objective and more reproducible results.

Different measurement devices using linear [6-8] or rotational [9] relative movements have been developed in the past (Table 1). However, majority of the conventional testing methods have limited implication in clothing comfort. Arbitrary materials such as steel [9, 10] and piano wire [11] were used as the counterpart in contact with textiles. The surface and frictional properties of these materials may differ from human skin remarkably. Some studies investigate the friction in fabric-to-fabric contact [8, 9]. However, this might have limited implication in clothing comfort. Second, inadequate information about the frictional property is obtained by the conventional methods. Only dry state of the fabrics was investigated in most of the studies [11] whereas the frictional properties of fabrics against moist and wet skin were seldom examined. In the tribological studies, the relationship between skin moisture and friction has been investigated recently. Linear [12], power-law [13], exponential [14] and bell-shaped [15] relationships between skin hydration and friction were reported. There is no definite conclusion about the type of relationship observed; hence, a dry friction value cannot be used to predict its frictional behavior during wet state. And the nature of friction between moist, wet skin and textiles are poorly understood, hindering progress to improve products. Van Amber et al. [8] is one of the exception that they investigated the friction properties of textiles in damp condition against simulated skin (LoricaSoft). They used a

Wascator to prepare for a damp fabric. However, no effort was made to standardize the volume of water held in the specimens in their study. Gerhardt et al. [12] did a vivo study on friction measurement between hydrated human skin and wetted hospital fabrics. Same to Van Amber et al.'s [7] work, the amount of moisture applied is not standardized, thus the reproducibility of the result is questionable. Third, the cost for the conventional machinery is rather high. All these shortcomings associated with the growing demand on clothing comfort pose an insatiable desire on an innovative evaluation method. Therefore, the aim of this project is to fill this research gap to develop a novel testing method that is easy to use, precise and should be available at an acceptable cost. The proposed instrument can be tested under mild and profuse sweating condition.

Study	Type	Principle
Kawabata (1975) [11]	Sliding type	The sample was laid flat and the probe is pressed onto the fabric. The coefficient of friction given by the ratio of force registered in the transducer, attached to the friction probe, to the normal force, is plotted as a function of the transverse distance.
Carr et al. (1988) [8]	Dragging type fabric-to-fabric test	The test samples were attached to the aluminium platform and the Plexiglas sled using water soluble glue. The sled was connected to a thread passed through a low friction pulley to Instron tensile tester.
Kenins (1994) [5]	Dragging type in vivo study	The subject's forearm or hand was placed in the support and a strip of fabric was draped across the skin. One end of fabric was suspended with a dead weight while another end was attached to a strain gauge.
Ajayi (1992) [17]	Dragging type Fabric-to-fabric test	It is based on the principle of rectilinear motion of a sled over a horizontal platform. A sled connected to a constant rate of elongation tester slides over platform.
Van Amber et al. (2015) [7]	Dragging type fabric-to-Simulated skin test	
Ramkumar et al. (2003) [19]	Dragging type	The artificial finger sledge was attached to a weight (Mg) on the free end. By satisfying the condition, Mg > F, the movement of the sledge can be reversed and frictional behavior over a number of cycles of reciprocating traverse can be examined.
Hermann et al. (2004) [18]	Dragging type	The test samples were attached to the aluminium platform using double-sided tape. The PMMA sled was connected to a thread passed through a low friction pulley to the tensile tester.
Lima et al. (2005) [9]	Rotary type	The principle is based on the dry clutch, where an annular shaped flat upper body rubs against a lower flat surface, which rotates around a vertical axis at a constant angular velocity. Friction coefficient between the two surfaces is proportional to the level of the dragging torque.
Gupta et al. (2008) [16]	Inclined plane method	The bottom of the block and the platform is covered with the test material. One end of the platform, which is initially horizontal, is slowly raised until the block resting on it starts to slide. The angle θ, causing slippage reflects the frictional behavior.
Gerhardt et al. (2008) [12]	In vivo sliding type study	Frictional measurements were carried out using a triaxial quartz force plate. The volunteers rubbed their inner forearm in a reciprocating and uniform motion against the textiles on the force plate and the force required is measured.
Wang et al. (2009) [20]	In-vivo study, dragging type	Forearm or simulated forearm was mounted onto the armrest. Both end of the fabric was mounted with clamp. The fabric was then pulled across the forearm and the roller. The friction equipment pulls forearm up and down and the relative dragging friction between fabric and skin was measured.
Wang et al. (2012) [21]		

Table 1: Different friction test methods.

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2 SET-UP

In order to determine the stickiness property of fibrous materials under wet skin surface, a Textile Friction Tester (TFT) is developed. The TFT is diagrammed in Figure 1. This TFT is capable of measuring textile-skin friction from mild to profuse sweating condition. The set up can be broadly divided into three parts: (i) measurement part, (ii) sample holder and (iii) water supply part.

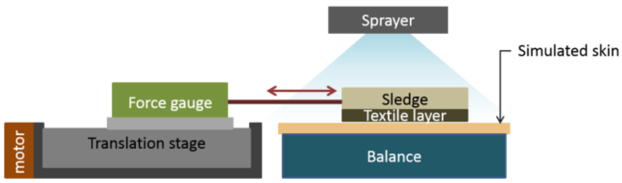

Figure 1: Construction of the TFT.

Highlights of the TFT as shown in Figure 1 are listed below:

- Capable of simulating different skin conditions (moist, wet)
- Applicable to test various types of fabrics
- Comprehensive description on frictional and stickiness behavior of fabrics against skin
- Simple and robust machinery design with high system accuracy
- Short testing and fabric preparation time
- Affordable cost
- Useful for product selection especially for sportswear, hygiene products or medical textiles application

3 DATA COLLECTION

In the TFT, a series of frictional parameters will be calculated. And based on the selected parameters, a fingerprint describing comprehensive frictional behavior will be developed. The plot of force against sliding/dragging displacement is commonly stick-slip in nature. A hypothetical friction curve is shown in Figure 2. The softer and more viscose-elastic the material, the more prominent is the stick-slip pattern [19].

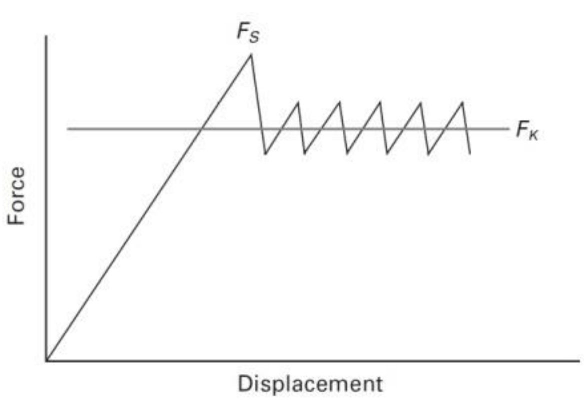

Figure 2: Hypothetical friction trace for a textile material

In order to verify the validity and versatileness of TFT, the results obtained from TFT would be correlated to some tests as stated in Table 1. The testing results of the proposed TFT testing method and the conventional testing methods will be statistically analyzed in order to find out their relationship. Apart from that, the CV % by each method will be investigated in order to compare its repeatability. Independent t-test is used to check the significant of difference.

4 CONCLUSION

Frictional property is important for sportswear, intimate apparel, functional clothing, hygiene products, hospital textiles and medical textiles. In addition to friction, stickiness of fabric under moist and wet conditions dominated the adverse effects to user, and this is a big research gap for the textile study. Prolonged contact with textiles of high friction can lead to abrasion and the situation is exacerbated when the skin is wet. When exercising with a cotton shirt, sweat will accumulate within the fabric, cling to the skin and evoke a clammy, sticky and clingy sensation. For aged person who has urinary incontinence and wear hygiene products regularly, their skin is prone to have poor mechanical strength and is greatly susceptible to friction-evoked skin injury. To minimize the discomfort feeling and avoid skin injuries, like decubitus, proper evaluation of fabric’s frictional property can ensure the quality of the product. In the textiles industry, there is a well-known system, Kawabata Evaluation System for Fabrics (KES-F), to characterize the frictional property of fabrics. Despite the cost, this is accurate and reproducible. But the main problem is that KES-F cannot characterize the frictional behavior in moist or wet skin-textiles contact. In other study field, like skin tribology, they found that the correlation between dry friction of skin and wet skin surface is uncertain, implying that the wet skin-textiles friction cannot be simply predicted from dry friction value. It poses a need to have an accurate method to characterize the frictional behavior of textiles under different skin conditions according to the product end-use. Through this study, a sensitive, reliable and accurate measurement system (Textile Friction Tester, TFT) will be developed at a relatively low cost, with a wide range of distinguished features of which various types of fabric could be tested. Frictional behavior in moist, wet ‘skin’ conditions can be tested. Studying the effect of different set-up parameters would be helpful to optimize the instrument enhancing its accuracy. After testing on a batch of fabrics, a database of fabric information related to frictional property can be established. This might help to understand the actual wear comfort of a fabric quickly and economically. Product manufacturer can predict the performance of their product within a short span at a low cost, meeting the needs of the fast-changing market. Also, comparison with the conventional testing methods might help to understand the comparative strength and weakness of the proposed method.

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