FRICTORQ, FABRIC FRICTION TESTER BASED ON TORQUE EVALUATION: A MECHATRONIC CONCEPT

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Abstract: One of the most important characteristics of fabrics, either for clothing or technical applications, is the coefficient of friction. This is one of the major factors regarding the objective measurement of the so-called parameter *fabric hand*. Many contributions have been given in the past to this problem and some resulted in laboratory equipment. With this project, a prototype laboratory apparatus is envisaged for the measurement of the coefficient of friction between fabrics that should be easy to use, precise and at an acceptable cost.

1. INTRODUCTION

The concept of clothing, seen as our second skin, has been developing from mass production to a great variety of products with the need of a quick response to shorter fashion periods. Therefore, the Textile Industry is going through a period of great changes, resulting from the revolution on computer science and networks, mechatronics and communications.

Many textile materials are used near humans and frequently touched by the human skin and by the human hand in particular, namely clothing, home furnishings, automotive fabrics. For this reason, the interaction with the human senses is an essential performance property (Kawabata *et al.*, 1994). Traditionally, the quality and characteristics of apparel fabrics is evaluated by touching and feeling by hand, leading to a subjective assessment.

The concept of *Fabric Hand* is very closely related with an important fabric characteristic, both for technical applications as well as for clothing: The *Friction Coefficient* (Gupta and Mogahzy, 1991). This is particularly important in several industrial operations on the clothing process, namely the cutting and sewing, contributing for the stability of the different fabric layers, that are held together with the contribution of surface properties where the friction coefficient certainly plays an important part.

The precise characterisation of the Friction Coefficient could also play a very important role in technical textiles such as the adhesion between the textile reinforcement and resins or polymers in the manufacturing of components using composite materials.

Some contributions have been given in the past to solve this problem, but none was able to impose, either in industry or research centres. With the present concept it is envisaged the development of a laboratory prototype, simple to use, transportable, economical and able to produce consistent results for the characterisation of fabrics by measuring their **friction coefficient**.

2. THE STATE OF THE ART

Friction Coefficient is not an inherent characteristic of a material or a surface but results from the contact between two surfaces, (Nosek, S. 1993).

A simple method to measure the static friction coefficient consists in placing a fabric over a horizontal flat surface and over the fabric a standard flat body. Rising one end of the surface an inclined plane is achieved. When the standard body starts moving, which could be detected by an appropriate sensor, the static friction coefficient is given by the tangent of the angle of the platform with the horizontal plane.

One method to determine the kinetic friction coefficient consists in placing a rectangular sample of fabric on a flat surface, under a pre-set stress, held by two opposite sides. A standard contact probe is put in contact with the fabric under a normal force. The sample is then moved in one direction at a constant speed of approximately 1 mm/s. After a displacement of about 3 cm the movement is reversed. The kinetic friction coefficient is given by the ratio between the tangential force, measured by an appropriate transducer and the normal force.

This is the principle used in the Japanese KES, Kawabata Evaluation System (Kawabata, S., 1980), based on the work of Prof. Sueo Kawabata at the University of Kyoto and latter developed by the Japanese KatoTech company. The KES has not yet imposed itself, specially in industry, mainly due to its high cost. However, despite its difficult handling and not very consistent results, it has seen some acceptance in universities and research institutions.

Another contribution to this problem came from the University of Mulhouse, Fance (Marie-Ange Bueno et al., 1998). Their principle consists also in dragging a standard probe over a fabric sample and measuring the friction force. Alternatively a contactless sensor could be used to give information on the fabric roughness.

All the systems previously described have two aspects in common: there is a standard probe rubbing against the fabric and, when applicable, the final result is based on the measurement of a friction force.

3. THEORETICAL JUSTIFICATION

The new method consists in characterising the friction coefficient of two sheet bodies, namely textile fabrics, based on torque evaluation by means of a new sensitive electronic torque sensor developed by Hes and Skop in 1993, (Domingues, 1994).

To simplify the conditions of the measurement, it was decided to directly drag *fabric against fabric*, avoiding the otherwise need for a standard contact surface.

The new system is based on the dry clutch principle, where a ring or annular shaped flat body, as in figure 1, drags against a flat surface.

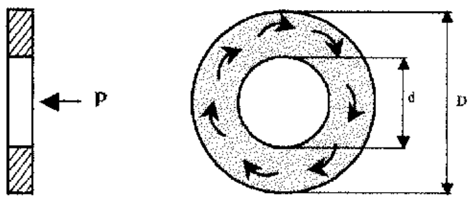

Fig. 1. Geometry of the model

There are two samples: the upper one being annular and placed over a flat lower sample. One of them rotates around a vertical axis with a constant angular velocity. Friction coefficient is then proportional to the level of torque being measured by means of a versatile measuring sensor. Pressure between both samples is constant but adjustable, given by the weight of the block to which the upper sample is attached. In this model, torque, **T**, is given by the following equation,

$$T = 2.\pi.\mu. \int_{d/2}^{D/2} pr^2.dr \qquad (1)$$

where **μ** is the coefficient of friction, **D** and **d** are the outer and inner diameters, **r** is the radius and **p** is the contact pressure.

Integrating and replacing **p** by its value,

$$p = \frac{P}{A} = \frac{4.P}{\pi.(D^2 - d^2)} \qquad (2)$$

the equation for the coefficient of friction is obtained,

$$\mu = \frac{3.T}{P}\frac{D^2 - d^2}{D^3 - d^3} \qquad (3)$$

4. WORKING PRINCIPLE

The principle of the new method is now given by equation 3. To rotate one of the samples against the other that is kept static, a certain amount of torque has to be supplied. This torque is provided by means of an electric DC motor with speed reducer and a conveniently designed timing belt transmission.

A high sensitivity purpose built strain gauge based torquemeter is used, the signal digititalised through an electronic interface and fed into a PC where the software gives an output as shown in figure 3.

The output of the torquemeter is an analogue signal between 0 and 2,5 VDC. The signal is filtered to reduce noise, amplified to improve resolution and, after being converted into a digital signal is sent trough the parallel port. For a better understanding, a block diagram of this process is presented in figure 2.

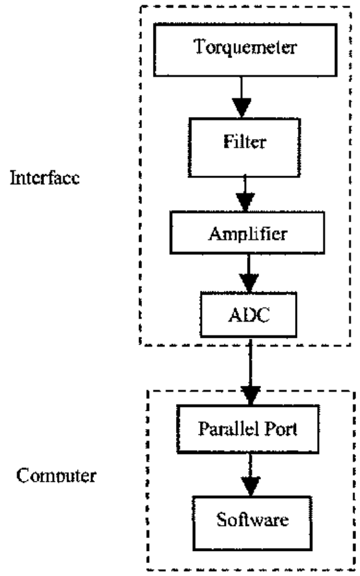

Fig. 2. Block diagram of the Frictorq experimental rig

In the development rig, the process begins by activating the motor responsible for rotating the support of the upper sample. The data from the torquemeter is then acquired and fed into the PC to be on-line represented in graphic mode. After 60 seconds, the process is automatically stopped. The values of the maximum and medium torque, as well as the maximum and medium friction coefficient are displayed as seen in figure 3. The data from the first 10 seconds of the process is ignored to allow for the output signal to stabilise.

5. TESTS AND RESULTS

Figure 3 is a graphic display of an experiment showing the most relevant aspects. The experiment takes place during 60 seconds. Initially, for a very short while torque builds up. The sample stays momentarily static and the output is a very deep straight line. When static friction torque is overcome, movement starts and torque falls instantly. The pick value could be extracted to give the static friction coefficient μ_{sta}. After a few seconds, torque stabilises, maintaining a moderate fluctuation up to the end of the experiment. The system software is prepared to compute the average torque in the interval from 10 to 50 seconds and, using equation 3, works out and displays the kinetic or dynamic friction coefficient, μ_{kin}.

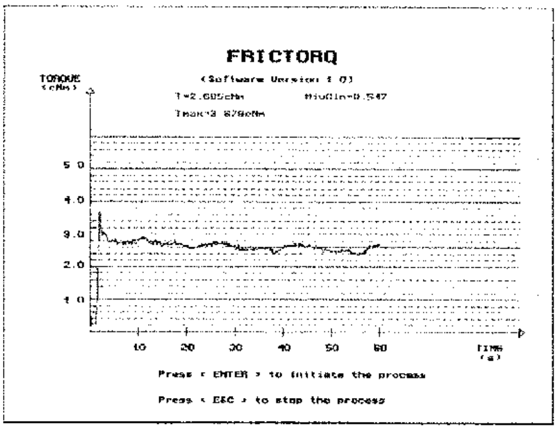

Fig. 3. Computer graphic output of an experiment

In order to test the FRICTORQ feasibility, an initial experimental work was carried out using 7 plain weave fabric samples produced from 8 different natural and man made textile materials. Table 1 summarises the main characteristics of the tested samples, where the following abbreviations were used:

WO - Wool
CO - Cotton
PAN - Polyacrylonitrile
PES - Polyester
VS - Viscose

PVA - Poly (vinyl-alcohol)
POP - Polypropylene
PAD - Polyamid

Table 1 Fabrics characteristics

Material	Linear density		Density	
	Warp (tex)	Weft (tex)	Ends/cm	Picks/cm
WO	38*	36*	22	18
CO	20	22	36	24
PAN	28	27	22	18
PES	42*	42*	22	18
VS	24	25	27	22
PVA	30	28	22	18
POP	30	30	22	17
PAD	13**	13**	32	26

* Folded yarn
** Filament yarn

The results of this experiment are summarised in Table 2. Column 1 identifies the material followed by the results for each of the 7 samples. In the last column the mean value is presented.

Table 2 Data on Friction Coefficient from the experiments with 7 samples of 8 different textile materials

Sample	1	2	3	4	5	6	7	Mean
WO	0,542	0,536	0,560	0,554	0,558	0,524	0,531	0,544
CO	0,355	0,440	0,372	0,424	0,411	0,436	0,418	0,408
PAN	0,431	0,421	0,402	0,402	0,397	0,419	0,406	0,411
PES	0,397	0,410	0,403	0,467	0,409	0,477	0,400	0,423
VS	0,359	0,378	0,368	0,381	0,402	0,357	0,355	0,371
PVA	0,336	0,324	0,326	0,332	0,332	0,326	0,313	0,327
POP	0,445	0,461	0,457	0,455	0,436	0,459	0,459	0,453
PAD	0,180	0,191	0,191	0,181	0,192	0,187	0,175	0,185

Figures 4a and 4b are graphic representations of the data from table 2. For reasons of clarity the results were grouped in two different graphs: The first grouping WO, CO, PVA and POP; the second grouping PAN, PES, VS and PAD.

These initial results are quite encouraging and promising. As it was expected, the wool fabric, due to the particular nature of its fibres surface, shows the highest FC, while PAD, a very smooth and slippery interlinen woven fabric to our senses, due to the use of a very smooth filament yarn, shows the lowest.

Also it can be noticed that the results show an homogeneity of variance, as represented in the box-plot of figure 6.

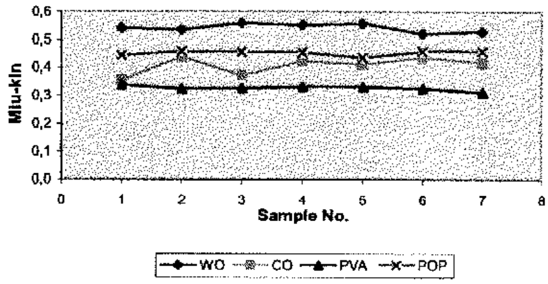

Fig. 4a. Graphic representation of Friction Coefficient for WO, CO, PVA and POP fabrics

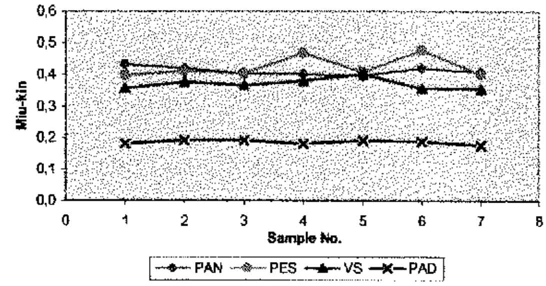

Fig. 4b. Graphic representation of Friction Coefficient for PAN, PES, VS and PAD fabrics

In figure 5 the Friction Coefficient mean values from the last column of table 2 are represented in a bar chart.

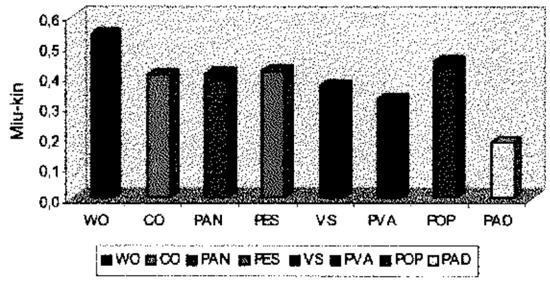

Fig. 5. Graphic representation of Friction Coefficient mean values

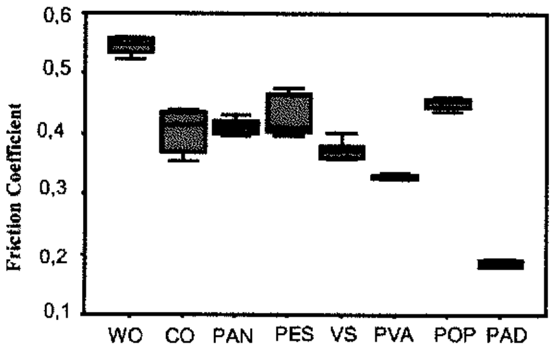

Fig. 6. Box-plot of data from experiment

6. CONCLUSIONS AND SUGGESTIONS FOR FUTURE DEVELOPMENT OF THE FRICTORQ TESTER

Future work will focus on the final design for a prototype equipment with a redesigned mechanical and electronic system. Also, the software will need improvement in order to be more user friendly. Some contacts have been established with manufactures of laboratory equipment for the textile industry in order to improve this product and give it a market acceptance.

This work is a contribution for the objective characterisation of fabrics, that will pave the way for the establishment of solid quality criteria, perhaps the only method to face the rising competition from low costs economies supported by cheap labour.

Patent protection of this new measuring method is now under preparation.

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