FRICTORQ, DESIGN AND DEVELOPMENT OF AN ADD-ON FUNCTION TO MEASURE FABRIC FRICTION IN A LIQUID ENVIRONMENT

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Abstract

Most textile materials are used near humans and frequently touched by the human skin. There are several parameters to evaluate the quality and the applicability of fabrics. The coefficient of friction is one of those parameters, being one of the most important factors to objectively evaluate the concept usually known as *handle*.

FRICTORQ is a laboratory equipment designed to measure the coefficient of friction in fabrics and other planar flexible surfaces. It is made up by a torque sensor (with a data acquisition system), a DC motor (with a gear reducer and a timing belt to drive the support of the fabric sample) and by a software application to control the whole system.

This equipment has been redesigned several times since its initial prototype (FRICTORQ I) to its present stage (FRICTORQ II). The latest developments will enable the measurement of the friction coefficient of fabrics in a liquid environment, such as water, for example.

Therefore, this paper will present and summarize all the steps that were carried out to study, design, develop and built this add-on function that will upgrade the present FRICTORQ model.

Keywords*: FRICTORQ; FRICTORQ in a liquid environment; friction coefficient of fabrics*

Resumo

Muitos materiais têxteis são usados ou estão em contacto com o ser humano, existindo vários parâmetros que permitem avaliar a qualidade e a aplicabilidade de tecidos. O coeficiente de atrito é um desses parâmetros, sendo um dos principais indicadores para a avaliação objectiva de um conceito vulgarmente conhecido por toque.

O FRICTORQ é um equipamento laboratorial que permite medir o coeficiente de atrito de tecidos e outras superfícies planas flexíveis. É constituído por um sensor de binário (com o respectivo sistema de aquisição de dados), por um motor DC (com redutor de engrenagens e correia dentada para accionar o suporte do provete) e por uma aplicação informática que gere e controla todo o sistema.

Este equipamento passou por diversos desenvolvimentos, desde o protótipo inicial, FRICTORQ I, e a sua posterior evolução para um novo protótipo, FRICTORQ II. Desenvolvimentos posteriores vão permitir que, de forma modular e flexível, se consigam realizar ensaios para determinação do atrito de tecidos num meio líquido, por exemplo, aquoso.

Este artigo apresentará e resumirá assim os passos que conduziram ao estudo, concepção, desenvolvimento e construção desta função auxiliar para equipar o modelo FRICTORQ II.

Palavras-chave: *FRICTORQ; FRICTORQ em meio líquido; coeficiente de atrito de tecidos*

1. Introduction

An important feature of fabrics, especially in clothing but also for technical applications, is the coefficient of friction. This is one of the most important parameters regarding the objective assessment and evaluation of a factor usually known as *handle*. This latter parameter is difficult to define and measure, and is generally associated with the quantification of the level of comfort provided by the contact between the clothing and the human skin. It is common practice to slide the tips of the fingers on a fabric to carry out this assessment. The coefficient of friction is also of great importance in some processes in the garment industry, particularly in sewing operations, since it contributes to the stability of the different layers of fabrics that should be kept together and not moving during the sewing process.

Several contributions have been given in the past (Kawabata, 1980; Gupta & El Mogahzy, 1991; Nosek, 1993; Kawabata *et al.*, 1994; Bueno, *et al.*, 1998; Ramkumar, 2004; Behera, 2007; Lima, *et al.*, 2005a, 2005b, 2007, 2009a, 2009b, 2009c are just few examples) and some laboratory equipments have been designed. Although they are not easy to use, some give unreliable results and others have a high cost. Nevertheless all were addressed to the analysis of the hand (*handle*/*touch*) evaluation.

The project herein reported presents a new concept to measure the friction coefficient of fabrics developed by the authors and a laboratory equipment was designed and prototyped. It can be used for the objective evaluation of fabrics, particularly in terms of surface finish and, together with this, a measure of the degree of comfort. Simple to use, precise and a cost-effective solution were the three major requirements for the development of this equipment. This first prototype, named FRICTORQ (after the acronym for **Fric**tion **Torq**ue Tester), is protected by the Portuguese Patent Nº. 102790, entitled "*Método e Aparelho para a Determinação do Coeficiente de Atrito de Materiais Sólidos Planos*" ("Method and Apparatus for Determining the Friction Coefficient of Solid Plan Materials"), from 12 June 2002.

This paper will summarize, as a project review, all the developments carried out so far at the University of Minho, as well as the new add-on function used to implement the measurement of the friction coefficient of fabrics in a liquid environment.

2. The FRICTORQ Models I and II

The first development has led to the design of a friction test rig whose operating principle is based on a dry clutch disc, where a planar body with an annular configuration (as shown in Figure 1) is dragged onto another flat surface, rotating around an axis perpendicular to the contact plan, under the action of a given normal force (*P*) resulting in an uniform distributed contact pressure.

There are, therefore, two bodies: the upper one with a contact of an annular geometry is placed over a horizontal flat lower sample. The second body is forced to rotate around a vertical axis at a constant angular velocity. The friction coefficient is then proportional to the level of torque being measured by means of a high precision torque sensor and it can be computed using the following equation:

$$\mu = \frac{3 \cdot T}{P} \cdot \frac{D^2 - d^2}{D^3 - d^3} \quad (1)$$

where μ is the coefficient of friction, D and d the inner and outer diameters of the top annular plan body and T the measured torque.

Figure 2 highlights some details regarding the shape of the testing apparatus and the positioning and tightening fabric clamps used in FRICTORQ I.

Figure 1: Geometry of the first adopted theoretical model for the FRICTORQ I

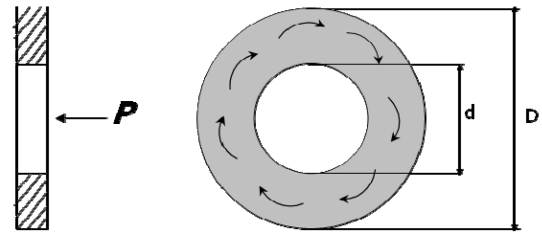
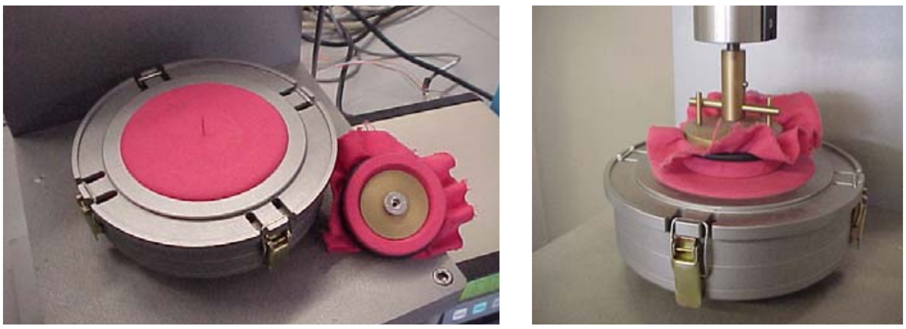


Figure 2: The first developed friction test rig (FRICTORQ I): Detail views (a) of both testing samples; (b) of the positioning and tightening fabric clamps (the fabrics at the start of the test)



(a) (b)

This same apparatus was also used in a steel-to-fabric working principle, instead of the testing arrangement shown in Figure 2. Figure 3 depicts a detail of this new friction area, while Figures 4 and 5 display some results obtained using these two different rubbing methods. According to Figure 4, the first peak is related to the static friction coefficient and besides this parameter all the other obtained/computed parameters are displayed on the right hand side of the software front panel shown: Kinetic friction coefficient, maximum and mean torque measured and total number of collected data points.

Based on these previous arrangements and on all the results obtained, the final solution adopted for the FRICTORQ I model can be observed in Figure 6, comprising a smooth or textured metallic body, with dimensions of ∅50 / 40 mm and producing a distributed pressure of 3.5 kPa.

Figure 3: The steel-to-fabric working principle used in FRICTORQ I

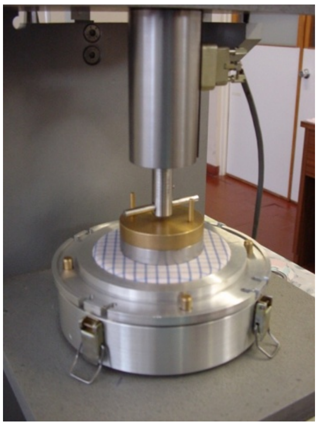
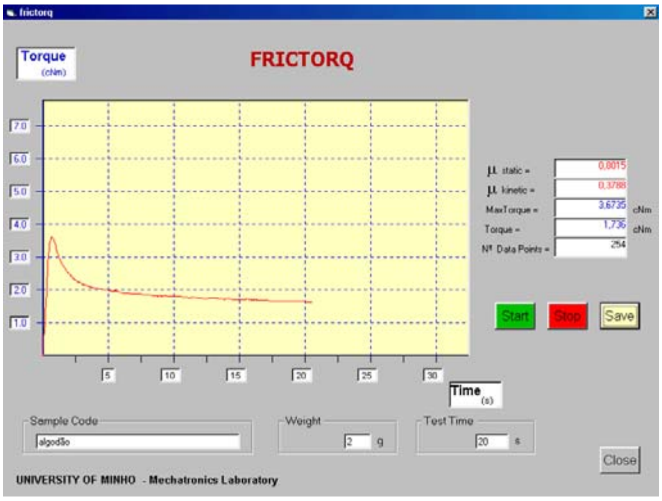


Figure 4: A typical graphical output obtained with FRICTORQ I in a fabric-to-fabric arrangement



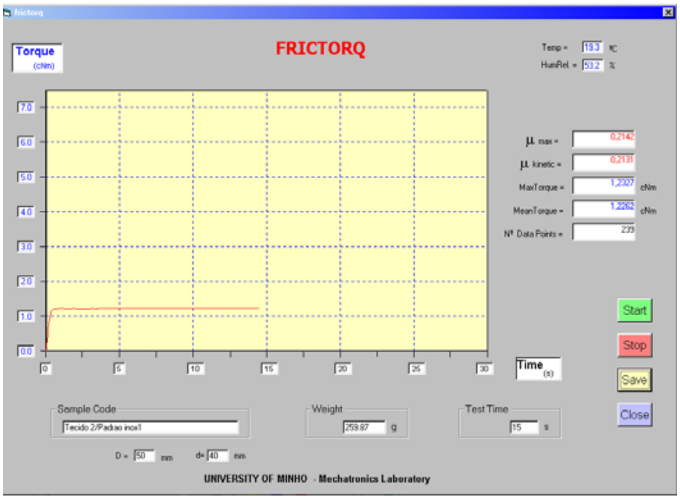
All these prototyped and tested solutions have already been published elsewhere (see Lima, *et al.*, 2005a, 2005b, 2007, 2009a, 2009b, 2009c for further details). Nevertheless the model shown in Figure 6 went through various development stages and some of the detected weaknesses suggested that a different approach could be explored: the rotary action remained the same as before, but the contact is now restricted to three small special elements (or feet), radially disposed at 120°. Providing a relative displacement of approximately 90°, it is assured that a new portion of fabric is always moved under these contact elements.

A schematic representation of the latest adopted model named FRICTORQ II is highlighted in Figure 7, which also details the upper body that includes three small pads with an approximately square shape, covered by a number of calibrated steel needles of 1 mm diameter. According to this new adopted model, the coefficient of friction (μ) can be computed as:

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

where *T* the measured torque and *P* the normal force, as before, and *r* the radius of the upper body setup as identified in Figure 7(a). (These contact elements are presently being redesigned to accommodate a special polymer to simulate the human skin.)

Figure 5: A typical graphical output obtained with FRICTORQ I in a steel-to-fabric arrangement



The friction torque tester has been used so far with the contact arrangement presented in Figure 7(b) and according to all tested materials and obtained results it is possible to draw the following conclusions:

- FRICTORQ shows good capabilities of accessing fabric friction;
- FRICTORQ is a portable, precise and reliable instrument, and
- FRICTORQ represents a good contribution to the objective characterization of the surface properties of 2D structures, such as textile fabrics, nonwovens and soft papers (tissue).

3. The FRICTORQ III

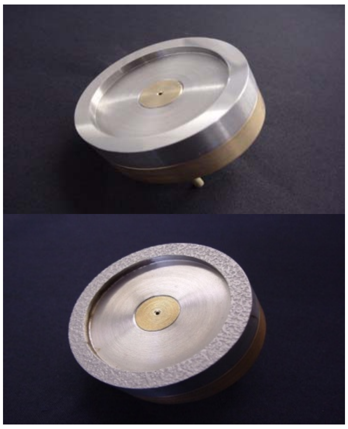
Although it has been used for testing different 2D structures in a dry situation, the latest developments carried out by the authors will enable the measurement of the friction coefficient in a liquid environment, such as water, for example.

After identifying the purpose of the outcome and the functions and sub-functions to be achieved in this design problem, the team efforts were divided into two fundamental aspects:

- On the design of a new container for the liquid environment testing, and
- On the design of a new upper contact body, maintaining the contact pressure of 3.5 kPa.

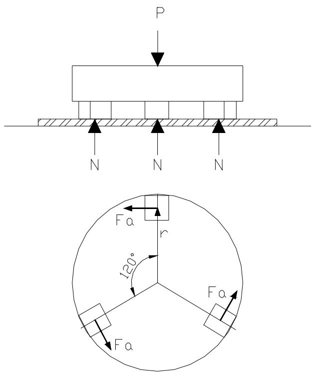
Figure 6: Final adopted friction testing arrangement for the FRICTORQ I model: (a) General view of the testing apparatus; (b) Detail of the smooth (upper image) or textured (lower image) metallic bodies

(a)

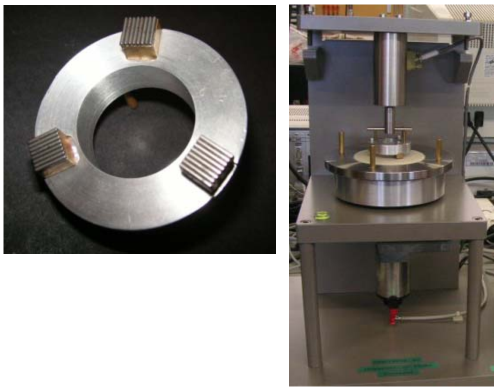


(b)

Figure 7: FRICTORQ II: (a) The latest adopted model for the friction tester setup; (b) Detail view of the upper contact body, with three small square shaped pads, and final testing arrangement



(a)



(b)

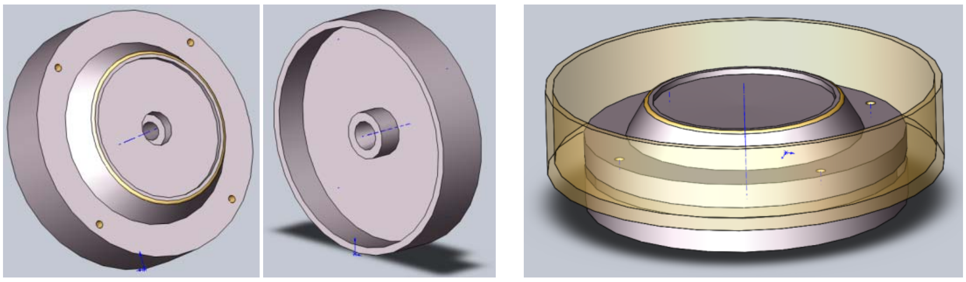
3.1 The Container

Several aspects were considered in this design:

- The container should be capable of being in contact with a liquid without undergoing in any kind of degradation during its use and also to ensure a perfect isolation of the rest of the equipment, especially the transmission system placed below the support plate as presented in Figure 7(b), and
- Towards the development of a modular solution to enable a flexible equipment set-up; this new arrangement should also use a minimum number of changeable components so the container could be easily operated, not only to provide a quick replacement of the testing liquid but also to prevent any contact between the operator with the fluid.

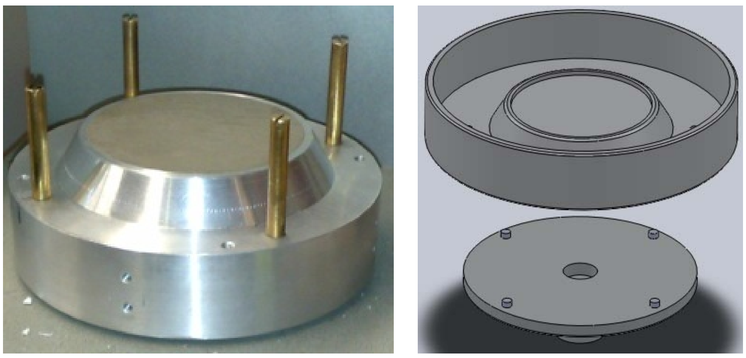
Several containers and attachments were developed and considered as reported in Figure 8. Nevertheless each one of these solutions presented several drawbacks regarding its attachment to the transmission system and the excessive volume of the testing liquid in the container.

Figure 8: FRICTORQ II: Several solutions considered for the container during the design phase



The final adopted solution can be observed in Figure 9. The base plate used in FRICTORQ II, as shown in Figure 9(a), has been replaced by other two components – see Figure 9(b): The upper part (the container) is to be made in stainless steel AISI-316 and the lower part (the interface with transmission system) is to be made in a typical aluminium alloy. Using the proposed solution the transmission system used so far does not need to be changed and it is perfectly isolated from the testing liquid. This solution also enables a quick replacement of the liquid, as the pins on the upper face of the interface component allow the fitting and the positioning of the container in place during the testing procedure.

Figure 9: FRICTORQ III: (a) Initial base plate to support, position and clamp the testing specimens (used in FRICTORQ II); (b) General view of the developed liquid container



(a) (b)

3.2 The Pressure Ring

The main function of this ring is to keep the testing specimens in place and stretched. One of the designed solutions can be observed on the right hand side of Figure 8; this solution has been abandoned due to the fact that it was difficult for the operator to remove this component after the experiment, as well as the centring ring, without touching the testing fluid. Based on this solution, two screwed rods have been introduced to guarantee that the FRICTORQ operator has no contact with the testing liquid and to ease the disassembly and the removal of the specimens. As well as the container, this component is also to be made in stainless steel AISI-316. The redesigned ring can be observed in Figure 10.

3.3 The Centring Ring

The centring ring is used to line up the upper body (with the three small pads) with the “T” shape inverted end of the torque sensor – see again Figures 2(b), 3 or 7(b). Due to all modifications carried out, this component has also been redesigned and two more holes and cap screws have been added. This centring ring, which can be found in Figure 11, is to be made using Perspex® acrylic.

Figure 10: FRICTORQ III: The redesigned pressure ring

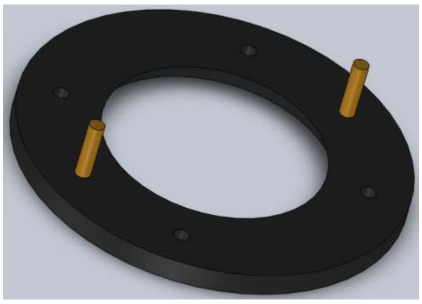
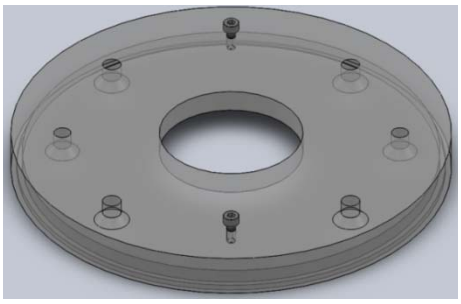


Figure 11: FRICTORQ III: The redesigned centring ring



3.4 The Upper Contact Body

The upper contact body is the component forced to rotate around a vertical axis at a constant angular velocity. Due to the fact that this upper element is in contact with the testing specimen in a liquid environment, a special precaution should be addressed to its redesign.

Therefore it was necessary to find a solution that should not bring any major changes to the basic FRICTORQ structure already conceived and all its components should also be made using stainless steel AISI-316.

On the other hand, and due to the fact that the contact pressure should be kept the same as before (3.5 kPa), the contact feet and the support annular shape were redimensioned, as well as the height of the two rods to connect this contact body with the “T” shape inverted end of the torque sensor. This component has already been manufactured and it can be observed in Figure 12.

To carry out a precise evaluation of the coefficient of friction it was decided to verify the influence of the liquid environment in the output of the torque sensor. A simulation of the flow conditions was studied and Figure 13 highlights the flow lines of the fluid (water was considered in all simulations) around one foot of the contact body. An experimental test was also carried out for measuring the reactive torque caused by the water flow around all three contact feet. As expected, both studies led to the conclusion that the reactive influence of the liquid environment is practically negligible and it does not affect the results obtained when measuring the coefficient of friction of fabrics in a liquid environment. Nevertheless it must be emphasized that if the testing fluid is different or the operating conditions have been changed (for example, increasing the linear velocity of the contact feet), new simulations and/or experimental tests must be carried out to evaluate the influence of the new fluid in the torque sensor readings.

The final adopted solution for the FRICTORQ III model can be found in Figure 14.

Figure 12: FRICTORQ III: The redesigned contact body, with three small square shaped pads

Figure 13: FRICTORQ III: Water flow lines around one contact foot

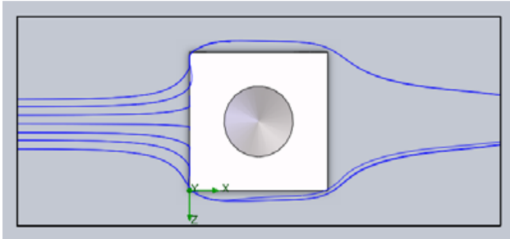
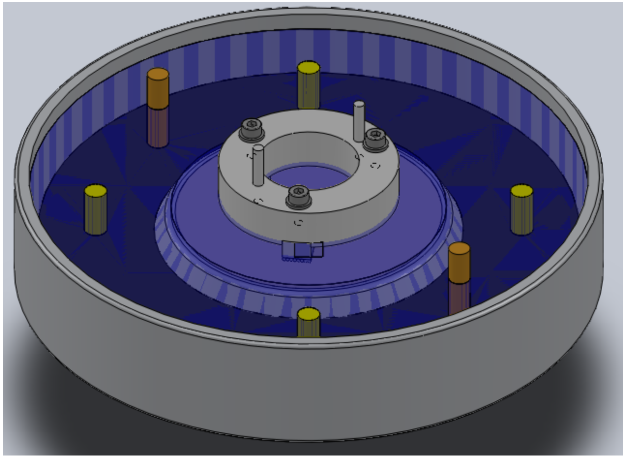


Figure 14: FRICTORQ III: Final adopted model



4. Conclusions and Future Work

The work herein reported presented a further research effort carried out by the authors in the development of new products and equipment goods for the textile industry. In this particular case, an “upgrade” of a laboratory friction testing equipment (named FRICTORQ) has been proposed to enable the determination of the friction coefficient of different 2D structures in a liquid environment. To accomplish this objective several components had to be redesigned and a special care was undertaken for the design of a new container for the testing liquid, and of a new upper contact body. This new add-on function is being manufactured and the first results should be obtained in a near future.

As mentioned previously, this contact body is been redesigned and prototyped to accommodate a special polymer to simulate the touch of human skin and another new add-on function (including its controller) is also been studied to enable systematic tests varying the temperature. This new testing equipment is to be named FRICTORQ IV. Future work will be also focused on the development of tests using this new “upgrade”.

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