

# Study, Design and Development of a New Add-on Function for the FRICTORQ® – Friction Test Instrument

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## Abstract

*The assessment of handle properties is of utmost importance in materials in our everyday life. There is a wide range of materials there are used in contact with the human skin, which may cause several unpleasant skin reactions. The FRICTORQ® is a laboratory equipment developed by the authors to measure the friction coefficient in fabrics, to enable a quantitative assessment of touch/handle, in order to predict the comfort behaviour of 2D/3D structures when used or touched by humans. In a further development, the FRICTORQ® was redesigned to accommodate a new testing kit function to determine the friction coefficient of fabrics in a liquid environment. This new design will be explained and the results obtained while testing different swimwear fabrics and hospital garments will be also presented and discussed.*

*Keywords: FRICTORQ® tester, Friction coefficient in a liquid environment, swimwear fabrics*

## 1. Introduction

FRICTORQ® is a laboratory equipment designed to measure the coefficient of friction in fabrics and other planar flexible surfaces. Named after the acronym for Friction and Torque, it is protected by the Portuguese Patent N°. 102790, entitled “Method and Apparatus for Determining the Friction Coefficient of Solid Plan Materials”, from 12 June 2002 [1].

This equipment is made up by a high sensitivity torque sensor (with a data acquisition system), a DC motor (with a gear reducer and a timing belt to drive the support of the sample) and by a software application to control the whole system. Its working principle is based on a rotary movement and, therefore, on the measurement of a friction reaction torque. The contact between the sample and the instrument reference surface is restricted to 3 small special elements disposed radially at 120°. With a relative displacement of approximately 90° it is assured that a new portion of the sample is always moved under the contact surface. Friction coefficient is computed from the friction reaction torque measured by the torque sensor.

It has been redesigned several times since its initial prototype (FRICTORQ® I) to its present stage (FRICTORQ® II). This latter setup is only prepared to carry out tests in a dry environment [2-4] and Figure 1 shows the testing apparatus in the Textile Physics Laboratory on the

Department of Textile Engineering, at the University of Minho, as well as a typical graphical output and the reference contact surface used.

Nevertheless there are many fabrics and other structures that are in contact with the human skin and, in many other applications, are mixed with water or human body fluids, such as sweat, urine or blood. This was one of the main reasons to upgrade the FRICTORQ® instrument and to study, design and develop a new add-on testing function to enable the measurement of the friction coefficient of fabrics or other planar and flexible surfaces in a liquid environment. With this new add-on the instrument was named FRICTORQ® III. A detail of the new testing function is shown in Figure 2.

## 2. Purpose and Objectives of This Study

FRICTORQ® is a laboratory equipment developed within a broader research framework to enable a quantitative assessment of touch/handle of fabrics, in order to predict its comfort behaviour, in which many parameters are being involved (friction coefficient, surface roughness, drape coefficient, thickness, bending stiffness, tensile strength and elongation, mass per unit area, wettability, and thermal properties).

Also many studies have been undertaken in this area, supervised by the authors (the latest

have been published elsewhere [5-9]), and the FRICTORQ<sup>®</sup> has been used to test many different materials with different purposes: knitted and woven fabrics, made from different textile fibres and from non-conventional blends (such as polyester/cotton-soya fibre, polyester/cotton-corn fibre or polyester/cotton-cotton [10], polylactic acid fibre and soya protein fibre [11]), as well as toilet papers, paper towels, handkerchiefs and napkins made from different cellulosic soft materials [12]. Safety belts have also been tested using the FRICTORQ<sup>®</sup> apparatus, as demanded by a Dutch safety equipment supplier for the automotive and aviation fields, with the purpose to evaluate its friction coefficient and the comfort provided to its users. In the medical area, nonwovens have also been tested for friction and several subjective evaluation surveys were carried out using semantic differential scales, where the extremes were associated with bipolar labels and with a (central) neutral point [6-8]. This latter evaluation intended to assess the perception of individuals with objects by touch feeling, and it was carried out at the School of Engineering and at two hospitals at the north of Portugal. Nevertheless this assessment will not be presented and referred in this paper. Instead it will review the design stages undertaken to carry out the development of the FRICTORQ<sup>®</sup> III, its construction and implementation on the existing apparatus, as well as the analysis and discussion of obtained results while testing two different swimwear knitted fabrics and hospital garments, such as surgical gowns, covers and blankets.

### 3. Design of the FRICTORQ<sup>®</sup> III Apparatus

As mentioned, FRICTORQ<sup>®</sup> II has been used for testing different 2D structures in a dry situation. Recently, several developments have been carried out by the authors to 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 directed to the design of a *new container* for the liquid environment testing and to the design of a *new upper contact body*, capable to maintain on the samples a contact pressure of 3.5 kPa. (Other design details and further developments are referred elsewhere [13], regarding the container, the upper contact body, as well as the pressure and centring rings needed to operate this function.)

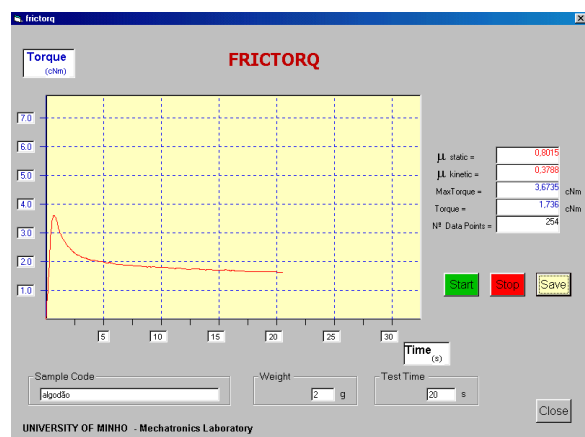


Fig. 1 – FRICTORQ<sup>®</sup> II (top); Typical graphical output (centre) and Reference contact surface (needle body) NB 3,5 kPa (bottom)

The final adopted design, represented in a CAD 3D model, is presented in Figure 2, as well as the new built add-on kit function. Figure 3 presents the kit function implemented in the apparatus to provide the measurement of the friction coefficient in a liquid environment.

### 4. Methodology

Friction tests were carried out using the FRICTORQ<sup>®</sup> III apparatus, with a set of 2 different fabrics:

- Commercial swim suit (SSC) and
- Sportive swim suit (SSS).

The two fabrics were tested in water and using the reference contact needle body NB 3.5 (3,5 kPa) and an artificial skin (AS, a polymer with a surface roughness that reproduces the

touch of the human skin) applying the same contact pressure of 3,5 kPa. A total of 13 samples have been tested for each fabric and the coefficient of friction was computed in a dry (D) and wet (W) environment, as well as in the inner-faces (IF) and outer-faces (OF) of the samples.

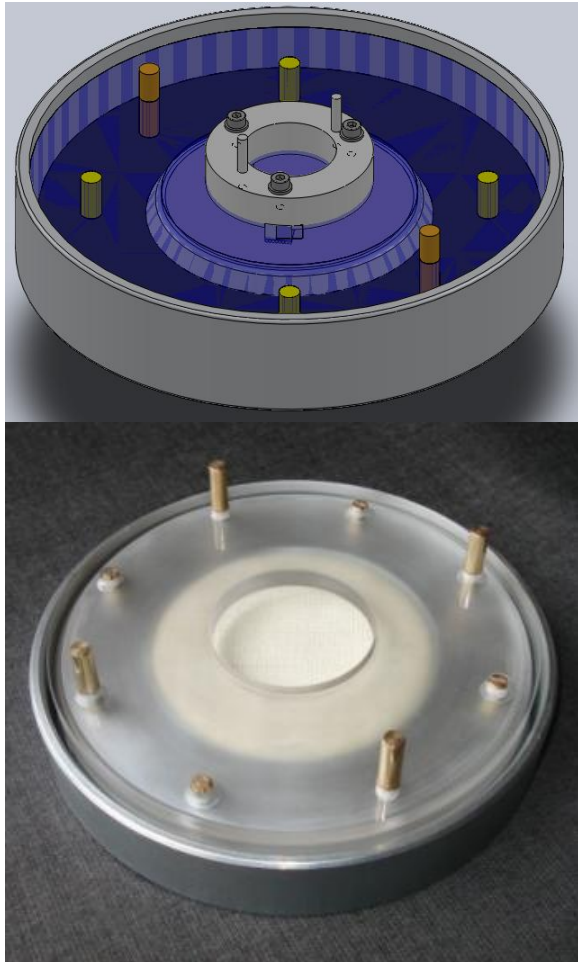


Fig. 2 – FRICTORQ® III: Final virtual 3D model (top); New add-on kit function with fabric sample (bottom)

All tests were carried out under a standard atmosphere (of 20 °C and 65% RH), and all the fabrics were conditioned for a time period over 48 hours.

The obtained results were analysed using the SPSS18® statistical package.

## 5. Results

Figure 4 shows the box plot representation of the obtained friction coefficients results for SSS fabric – inner (IF) and outer-faces (OF) – using the needle body (NB) and artificial skin (AS).

Figure 5 shows the box plot representation of the obtained friction coefficients results for SSC fabric in the same condition as previous.

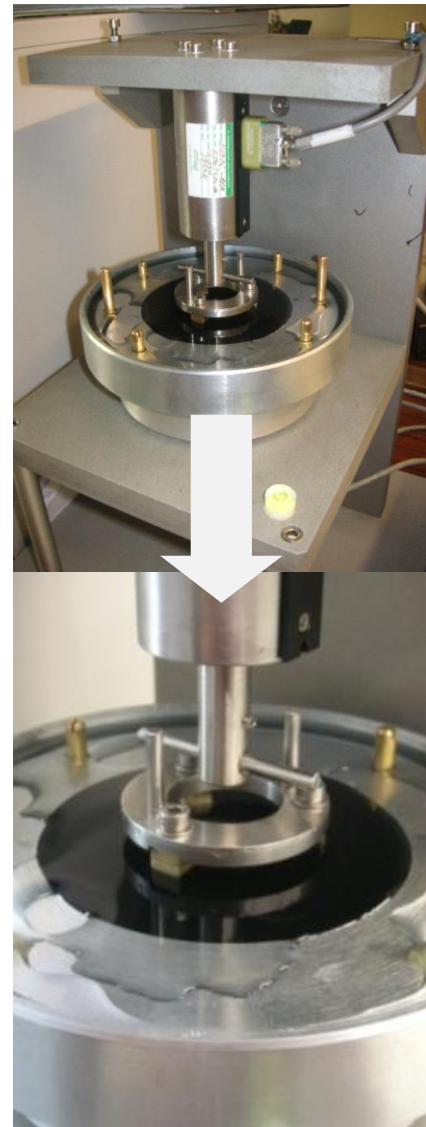


Fig. 3 – FRICTORQ® III: New add-on kit function to measure fabric friction coefficient in a liquid environment

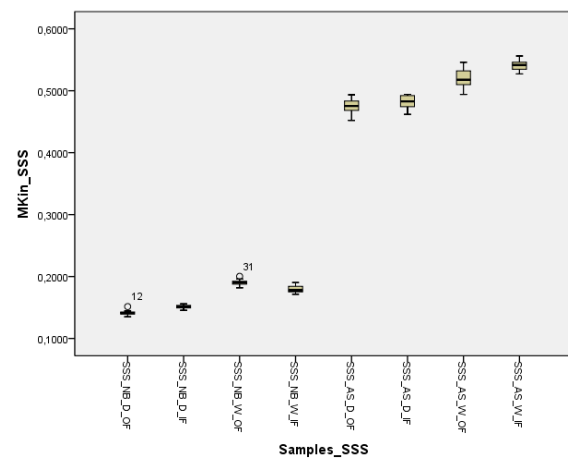


Fig. 4 – Sportive swim suit (SSS) friction coefficient

It is possible to observe that the coefficient of friction is always higher for the wet samples, due to the fact that the fluid tends to hold the movement of

the contact body; it is also possible to observe that the friction coefficient is always higher for the inner-faces. These same observations can also be found using the artificial skin as contact element. Although the increase of the friction coefficient is not so evident for the dry situation, comparing IF with OF, the tendency is the same as for the contact needle body. Nevertheless, all the friction coefficients computed are higher for the artificial skin. The artificial skin seems to be holding even more the movement of the contact element reproducing, therefore, a higher friction coefficient.

For an easy visualization, the box-plot representation of Figure 6 summarizes the results obtained for the SSC and SSS fabrics using the contact needle body and AS. It compares the mean values obtained for the SSS fabric using the contact needle body and the artificial skin. As previously, the friction coefficient is always higher for the wet situation, being also higher than the friction computed with the needle body.

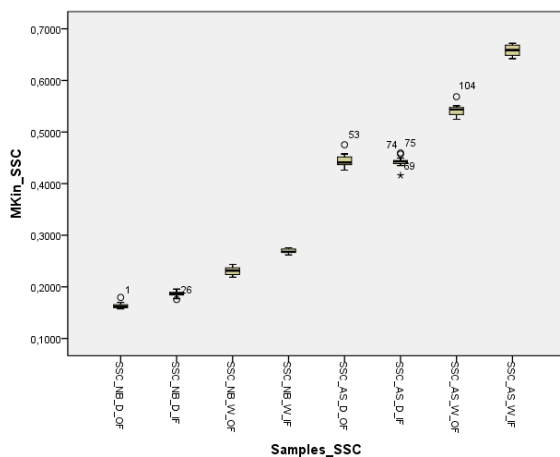


Fig. 5 – Commercial swim suit (SSC) friction coefficient

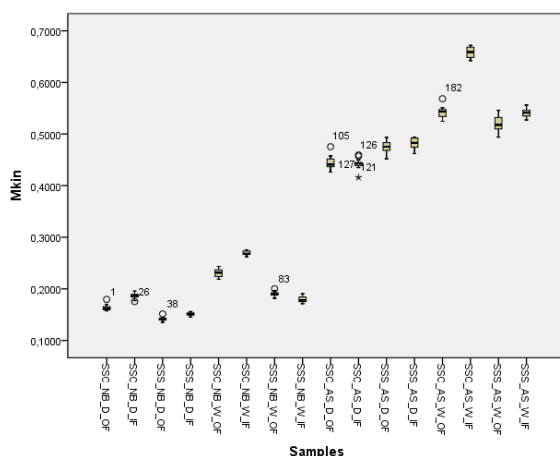


Fig. 6 – SSS and SSC fabrics friction coefficient, with the reference contact needle body (NB) and artificial skin (AS) for the inner (IF) and outer-faces (OF) samples

A Scheffe analysis was done in order to compare the results obtained from the two tested materials in

different conditions. The means for groups in homogeneous subsets are shown in table 1.

The statistical analysis shows that the behaviour of these two samples tested in six different ways (IF, OF, NB, AS, W and D) are grouped in eleven different subgroups: the SSS fabric presents no significant statistical difference between the outer and inner faces when the test is carried out with NB. Similar behaviour is present when the tests are carried out with SSC (OF) and SSS (IF).

Dry and wet situations present no significant statistical difference between SSC (OF) and SSS (IF).

## 6. Conclusions

A new add-on kit function has been proposed and implemented on a previously developed apparatus for measuring the coefficient of friction in fabrics in a wet environment.

It represents another contribution, as a working instrument, to the study of textile fabrics and other planar flexible materials to accomplish the overall objective of this project.

Two different fabrics have been tested in six different situations, half of them in dry conditions and the other half in wet conditions.

Based on the results obtained some conclusions can be drawn:

- SSS fabric in a dry situation has the same behaviour in IF and OF using NB (1) and AS (8), higher in the last one. The same situation occurs when a wet situation with NB (4).
- The value obtained for the SSC fabric, tested with AS in a dry condition, is the same for IF and OF (7).
- The following groups present significant statistical difference: SSC\_NB\_W\_OF (5), SSC\_NN\_W\_IF (6), SSS\_AS\_W\_OF (9), and finally SSS\_AS\_W\_IF (11).

In all tested cases, the friction coefficient is always higher when the tests were carried out in wet, liquid environment. On the other hand it was also observed, when using the artificial skin, that the test results are always higher than those obtained when using the needle body.



Table 1 – Homogeneous subsets for the tested swimsuit fabrics

| Samples     | N  | Subset for alpha = 0.05 |       |       |       |       |       |       |       |       |       |       |
|-------------|----|-------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|             |    | 1                       | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    |
| SSS_NB_D_OF | 13 | 0,141                   |       |       |       |       |       |       |       |       |       |       |
| SSS_NB_D_IF | 13 | 0,152                   | 0,152 |       |       |       |       |       |       |       |       |       |
| SSC_NB_D_OF | 13 |                         | 0,164 | 0,164 |       |       |       |       |       |       |       |       |
| SSS_NB_W_IF | 13 |                         |       | 0,179 | 0,179 |       |       |       |       |       |       |       |
| SSC_NB_D_IF | 13 |                         |       |       | 0,186 |       |       |       |       |       |       |       |
| SSS_NB_W_OF | 13 |                         |       |       | 0,190 |       |       |       |       |       |       |       |
| SSC_NB_W_OF | 13 |                         |       |       |       | 0,231 |       |       |       |       |       |       |
| SSC_NB_W_IF | 13 |                         |       |       |       |       | 0,269 |       |       |       |       |       |
| SSC_AS_D_IF | 13 |                         |       |       |       |       |       | 0,442 |       |       |       |       |
| SSC_AS_D_OF | 13 |                         |       |       |       |       |       | 0,444 |       |       |       |       |
| SSS_AS_D_OF | 13 |                         |       |       |       |       |       |       | 0,475 |       |       |       |
| SSS_AS_D_IF | 13 |                         |       |       |       |       |       |       | 0,481 |       |       |       |
| SSS_AS_W_OF | 12 |                         |       |       |       |       |       |       |       | 0,519 |       |       |
| SSC_AS_W_OF | 13 |                         |       |       |       |       |       |       |       |       | 0,541 |       |
| SSS_AS_W_IF | 13 |                         |       |       |       |       |       |       |       |       | 0,542 |       |
| SSC_AS_W_IF | 13 |                         |       |       |       |       |       |       |       |       |       | 0,658 |
| Sig.        |    | ,930                    | ,718  | ,312  | ,874  | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |

Uses Harmonic Mean Sample Size = 12,933.

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