FRICTORQ: Evaluation of Friction Coefficient in the Presence of Cosmetic Creams

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Abstract

There are numerous applications in which products or materials are in contact with the human body, including the skin, such as clothing, fine papers and even cosmetics. In this sense, and with special emphasis on cosmetic products, there are several parameters for assessing its quality and applicability. The coefficient of friction is one of these parameters for the objective assessment of a concept commonly known by touch. This paper aims to review the main developments that led to the redesign of FRICTORQ device for measuring the coefficient of friction of cosmetic creams, and the first preliminary tests carried out with cosmetic products are also presented, analysed and discussed. It was determined that the friction coefficient of a moisturizing cream is higher than the one obtained for an exfoliating cream.

Keywords: FRICTORQ, cosmetic creams, friction coefficient

1. Introduction

An important feature of the products that make contact with the human body, such as tissues, fine papers, and cosmetics, among others, is the coefficient of friction. This is one of the most important parameters in the objective evaluation of a concept commonly known as *touch*, difficult to define and measure, which is related with the quantification of the level of comfort provided by the contact with the skin of the human body.

Therefore there is a great interest in studying this subject, and some laboratory equipments have been developed, most of the times not so easy to be used, and with higher costs involved. In this sense, FRICTORQ has been developed by the Department of Mechanical Engineering (University of Minho), for the measurement of the friction coefficient in non-rigid materials (see figure 1).

This device was designed for the objective analysis and characterization of fabrics, mainly in terms of surface finish, since it is related with the comfort level generated by its contact with the human skin [1]. Later, design changes have been carried out to improve the reliability of the testing device and to enable other experiments and evaluations, namely within a liquid environment.

This paper highlights the development of the FRICTORQ device since its beginning up to the analysis of the friction coefficient of cosmetic creams. On the following sections further references will be made to the experimental procedure used to test cosmetic creams and to the analysis and discussion of the preliminary results obtained so far.

Fig.1 – The FRICTORQ instrument

2. FRICTORQ Working Principle

This device has a working principle based on a rotary action and, therefore, on the measurement of the reactive torque generated by the drag between two bodies in relative motions. It combines the following components:

1. An accurate torque sensor, with the respective data acquisition system,
2. A direct current motor with a gear reducer and a timing belt to drive the entire support

of the lower sample holder, and
3. A computer application that commands and controls the whole system, allowing the acquisition and visualization of experiment data for further statistical treatment.

An important factor considered in the FRICTORQ development was the contact (upper) body (see figure 2), that slides over the fabric sample; it pushes the torque sensor probe to measure the torque generated by the sliding friction occurring by the contact of the two bodies, the fabric sample and the contact body.

Fig.2 - Metallic (ring type) upper body used in previous FRICTORQ fabric tests

Other upper contact bodies were produced to enable different testing conditions (with different surfaces and contact pressures). Another type of contact body used presents just three contact surfaces placed at 120º (see figure 3), in which a new fabric portion is always tested by the contact established by the three surfaces.

Fig.3 - Upper body with three contact surfaces

A third design phase was also carried out, in which some arrangements were designed to enable experiments in a liquid environment. At this stage it was necessary to replace some of the contact body materials to increase its durability.

3. Modifications in the FRICTORQ

To use the FRICTORQ friction tester with cosmetic creams was necessary to carry out some modifications to the device. The upper test body, shown in figure 3, had to be rebuilt in AISI 304 stainless steel.

The sponged support base surface, where the fabric samples were placed in the previous FRICTORQ method, was replaced by a silicone rubber, since it was the material that better simulates the human skin [2, 3]. Since the FRICTORQ is a rotary tribometer, the test support base (as presented in figure 4) is a disc shape with a thickness of 3 mm.

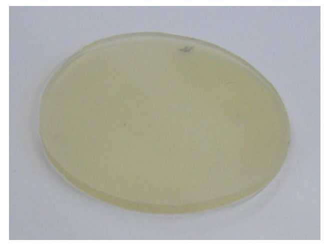

Fig.4 - Support test base surface in silicone rubber

A coupling bar was also designed and built to enable the torque transmission to the torque sensor. To avoid the upper contact body to slide in a radial direction of the silicon rubber, moving it away from the centered position and thus influencing the friction measurement, two notches were added in each of the extremities of the coupling bar to engage the pins of the upper contact body. This coupling bar is depicted in figure 5.

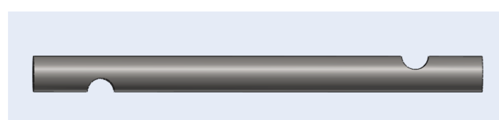

Fig.5 – Coupling bar with specific notches

4. Experimental Procedure and Results

Using the FRICTORQ device prepared for testing cosmetic creams, a series of tests were carried out to determine the friction coefficient of two types of cosmetic creams: a moisturizer daily cream and an exfoliant cream.

3.1 Test Conditions

Preliminary tests were performed initially to analyze the behaviour of the tester device. Some friction measurements were carried out using just the silicone rubber (dry situation), without any kind of cream. Afterwards other tests were performed using a moisturizing cream and an exfoliating cream. In order to standardize the tests, an amount of 0.5 ml of cream was applied and spread manually on the test face of the silicone rubber surface, which has an area of approx. 4.3 cm^2, corresponding to 0.12 ml of cream per cm^2 (see figure 6 for the testing setup and cream deposition).

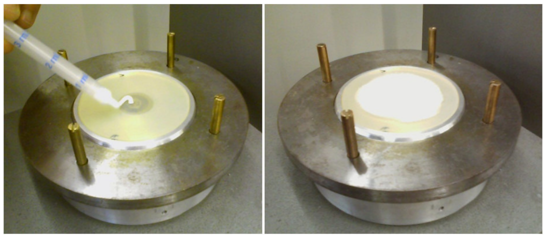

Fig.6 - Deposition of 0.5 ml of moisturizing cream

During the preliminary tests it was found that the amount of cream to be applied was exaggerated, and very high values for the friction coefficient were obtained due to the accumulation of cream at the front of the three contact surfaces of the upper body. It was then decided to apply on the silicone rubber the same amount of cream that would be applied on the same area of the human skin (see figure 7).

Fig.7 - Cream film applied manually to the lower support base of the silicone rubber

It was observed a significant variation of the results for the friction coefficient of the exfoliating cream; a plastic spatula was used to spread the cream over the rubber surface, and to remove the excess of cream, leaving only a thin film of cream on the silicone rubber. For the exfoliating cream, the spatula tends to remove some of the microspheres that are characteristic of this type of cream. Nevertheless, and despite some of this drawbacks, systematic tests were carried out and the results obtained are detailed over the next section.

3.2 Results

The results obtained by the FRICTORQ device are displayed graphically and could be later exported to an Excel worksheet. The graphical outputs represent torque, required to maintain the sliding of the base rubber testing surface, measured by the torque sensor. The input variable is the weight of the upper contact body. The application, through the laws of Amonton and the geometric and physical characteristics of the testing system, converts the torque into a coefficient of friction.

In preliminary tests, multiple measurements were carried out in a dry situation, without any cream present in the contact zone, and then with each one of the creams mentioned in the beginning of this section. In these tests, the cream was spread using a spatula with an amount sufficient to cover the entire silicone rubber surface, corresponding to the amount used on an equivalent area of skin. A typical graphical output obtained in these tests can be found in figure 8.

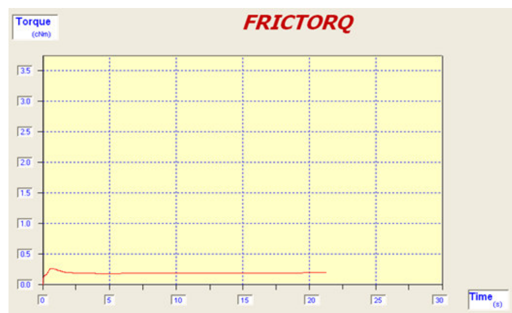

Fig.8 - Graphical output representing the torque measured versus time for the moisturizer cream

In this graph, it is possible to observe the initial peak, which corresponds to the static coefficient of friction. For all the tests, it will only be considered the kinetic friction coefficient.

While testing the exfoliating cream, the microspheres are dragged by the upper contact surfaces, and the friction coefficient is higher and the torque versus time graphical output denotes some variations.

The friction coefficient of the silicone rubber, in a dry situation is within the range of the friction coefficient obtained by Cottenden studies [4], regarding the friction coefficient of the forearm skin. However, as it was expected, it was observed that the friction coefficient obtained with the silicone rubber is always higher than the one obtained with the exfoliating and moisturizing creams. The exfoliating cream presents, nevertheless, the lower coefficient of friction.

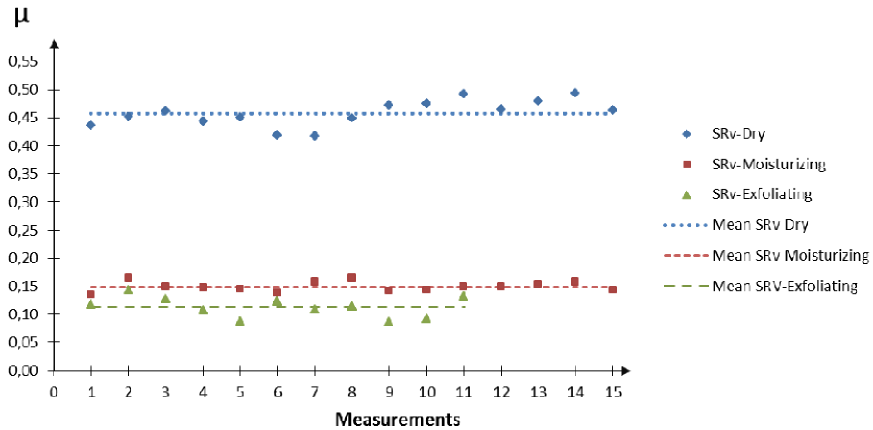

Fig.9 - Preliminary results of the kinetic friction coefficient obtained for cosmetic creams

Figure 9 display the results obtained in this phase of tests. The exfoliating cream, due to its properties, has been difficult to evaluate, and at this stage only some results have been acquired.

One of the limitations of these tests is the deposition of a desired quantity of cream. Although a specific spatula was used to spread the cream and to avoid an excessive amount in the rubber surface, the total amount available for the test is dependent on the pressure exerted by the spatula: when the pressure is high, the film cream breaks up, and the torque sensor not only measures the friction of the cream as well as the friction of the silicone rubber (this effect is verified for both tested creams); when the pressure is reduced, a prominently cream film is deposited on the rubber surface and some (if not many) microspheres are removed from the film. When this happens, and due to the reduced viscosity of the exfoliating cream, it generates a (very) lower friction that the torque sensor cannot measure.

5. Conclusions

Using a testing device that was commonly used to measure the friction coefficient of fabrics, some new components design was carried out to accommodate a new function to measure the friction coefficient of cosmetic creams.

Using the moisturizer cream, the mean kinetic friction coefficient measured remained almost unchanged throughout all experiments. The same is applied to the friction coefficient measured for the silicone rubber in a dry situation.

In global terms, it was observed that the kinetic friction coefficient of the silicone rubber is always higher than the friction coefficient obtained with the moisturizer cream, being the latter, despite all limitations, higher than the one obtained with the exfoliating cream. The average values of the kinetic friction coefficient obtained with the silicone rubber is 0.46, while for the moisturizer cream is 0.15, and for the exfoliating cream is 0.11.

Future work will be based on the design and development of a proper and more adequate system to deposit and spread the cream on the active silicone rubber surface, and new more systematic experiments will be carried out.

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