Serbian Tribology Society

SERBIATRIB '19

16th International Conference on Tribology

Faculty of Engineering
University of Kragujevac

Kragujevac, Serbia, 15 – 17 May 2019

DEVICE FOR DETERMINING THE COEFFICIENT OF SKIN FRICTION

Branislav Dimitrijević[1], Milan Banić[2], Dušan Stamenković[2]
[1]College of applied professional studies Vranje, Serbia,
[2]Faculty of mechanical engineering Niš, Serbia,
*Corresponding author: b.dimitrijevicvr@gmail.com

Abstract: *Skin tribology is very important scientific area because of its presence in everyday life in form of friction in contact of skin surface and various materials. The most often it appears between palm skin and fingers and object which are in someone hands (pencil, mobile phone, tools, etc), and friction between skin and clothing and footwear. It is very important to know the value of friction coefficient between human skin and different materials. This paper describes a device used to determine the coefficient of friction between the palm skin and fingers and various materials that are in daily contact with the skin. The friction coefficient is determined by the use of a special device (Tribometer) designed and constructed for this purpose. This paper describes the device, the measurement procedure performed on the skin of the fingers and the palm in vivo, and gives a summary of the results.*

Keywords*: Skin, tribology, coefficient of friction, measurement, tribometer*

1. INTRODUCTION

In order to get a clear picture of the value of the friction coefficient and how different materials affect the friction that occurs in contact with the skin, it has been necessary to develop a special device. The development process of the device is based on the dynamics caused by various factors: materials, sample size (hand), intensity of force... There are many authors who investigate contact between human skin and other materials.

Two different methodologies for assessing the friction between plantar skin and sock textiles are compared in paper [1]. The first approach uses a custom-built friction plate rig. The second approach uses a pneumatically-driven foot probe loading device. Both approaches allow friction coefficients to be calculated from load data collected during the sliding phase of movement. In the dry conditions tested, the cotton-rich sock was found to provide lower friction that the anti-blister sock material.

N. Veijgen, in his thesis [2] discuss about parameters in the interaction between human skin and other materials. First he gives some information about skin friction and current knowledge on skin friction, then presents the RevoltST, the tribometer that was specially developed for skin friction research and which meets the objectives described in the thesis and finally presents the results of the skin friction measurements obtained with the RevoltST.

Authors in paper [3] discuss the specific nature of tribological systems that include the human skin and argues that the living nature of skin limits the use of conventional methods.

Author in his papers [4] presents a research about various fundamental aspects of finger pad friction are reviewed, including the effects of applied force, skin moisture, material, surface texture etc., and the influence that they have on friction mechanisms such as adhesion, deformation, interlocking and hysteresis. The first is rugby balls and the effect the ball surface pimple pattern has on friction. The second study related to friction modifiers used in sports such as rock climbing and athletics Frisbee interactions were investigated.

Authors in paper [5] present an overview of different studies in area of every day tribology. Those are shoe-floor friction, vehicle movement of the road, friction between skis and snow, friction between ball and hands skin.

Paper [6] has developed an instrument that allows optical analysis and tribological measurements for contacts between solid bodies. An interferometric optical analysis can be used to measure and observe contact size, contact geometry, near contact topography, tribofilm formation, tribofilm motion, tribofilm thickness, wear debris formation, and wear debris morphology

Authors in paper [7] investigate friction of untreated human skin (finger) against a reference textile with 12 subjects, using a force plate. In touch experiments, in which the subjects assessed the surface roughness of the textile at normal loads of 1.5 ± 0.7 N, the average friction coefficients ranged from 0.27 to 0.71 and varied among individuals due to different states of skin hydration.

In paper [8] authors used IR sensors to measure the temperature of the ice track in front of and behind the contact region. In addition, thermocouples integrated into the polyethylene slider measured the temperature close to the interface.

Another device developed by authors is describe in paper [9]. Device have a property to provide an accurate measurement of skin friction between a reference material and the skin of the volar forearm.

This paper describes the device, the measurement procedure performed on the skin of the fingers and the palm in vivo, and gives a summary of the results.

2. SKIN FRICTION

The human skin is very interesting and important for tribology research. In daily life, the human skin is constantly in interaction with other materials, like wood, stone, silk, cotton, glass, skin, plastics, metals, etc. Interaction of human finger and mobile phone touch screen is everyday very illustrative example of skin friction. [6] There are many examples of skin friction like in sport, when the basketball or tennis player holds the ball, or when the athlete performs acrobatics.

Figure 1. Examples for skin friction

Skin friction involves the interaction of the skin and the contact material, and consequently it depends on the properties of the skin, the contact material and its properties, the parameters of the contact between the materials and the environment surrounding the materials [3].

Such a system includes not only the influence of the two materials, in this case the human skin and another material, but also the environment of the materials and the contact parameters, such as the force with which the two materials are pushed together (normal load), the type of movement and the velocity of the relative motion. The skin is a living material; therefore, it is not only the skin of the anatomical location of interest that is important for the frictional properties, but also the characteristics of the individual subject.

Other variables that influence the friction measured on the human skin include the environment and the contact parameters. These factors are usually described in terms of ambient temperature, relative air humidity, and normal load, relative velocity and type of movement respectively [3].

3. DEVICE DESCRIPTION

The device (Fig. 2) was developed for measuring a coefficient of friction between any two materials in laboratory conditions. The device consists of one force sensor that measure horizontal force F_H (force of friction), and the other force sensor that measure normal force F_N. The friction coefficient is determined by using the equation:

$$\mu = \frac{F_H}{F_N} . \qquad (1)$$

Using this device, one can determine coefficient of friction between hand palm and any material.

All parts of the device were made of aluminum alloy 1050. The device consists of several parts: basic housing of the device on which the bearings are placed in order to neutralize friction between device parts, force transducer (horizontal) is also hitched on basic housing with screw and measure the horizontal force (force of friction), the lower part of smaller housing carry another force transducer (vertical) and upper part of smaller housing, and all together slides over the bearings and hit the first sensor. The plate on which the test material was placed is connected with upper part of smaller housing with screws. All the elements of device were obtained by cutting the aluminum plate and welding the parts by the TIG procedure in workshop. After welding all elements were grinded.

Table 1. Characteristics of device

Device dimension	240 x 160 x 95 mm
Normal force value	Max 100 N
Horizontal force value	Max 500 N
Contact area dimension	140 x 190 mm

This device is made to determine coefficient of friction between palm of hand or fingers and other different materials, but can be used for determine coefficient of friction between any two materials.

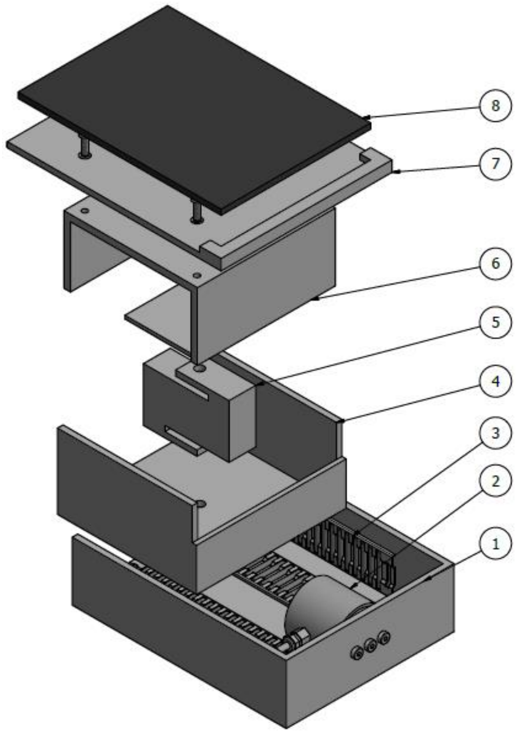

Figure 2. Exploded view of device

1) Basic housing, (2) Force transducer (horizontal), (3) Bearings, (4) Lower part of smaller housing, (5) Force transducer (vertical), (6) Upper part of smaller housing, (7) The plate, (8) Test material

The following force transducers were used – HBM S2M for the vertical (normal) force and HBM U1 for the horizontal (friction) force. The sensors are connected to the NI cDAQ universal data acquisition device connected to the computer with LabVIEW software via the USB interface.

4. MEASURING PROCEDURE

Skin interaction with various materials and some aspects of skin tribology have been studied by some researchers and they have found that the static friction coefficient for different areas of the body varies in a wide range from 0.05 to 3.86. Lately, experimental tests have been carried out and various procedures have been applied. Thus, measuring points for the contact of the human palm and certain objects that may have different contact conditions are designed.

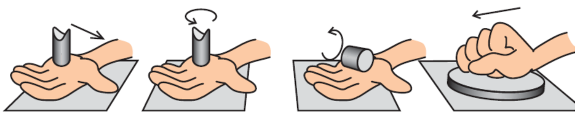

Figure 3. Different types of hand and hard object contact

The following contact conditions can be identified: material moves linearly (a); the material rotates and the contact is conical (b); the material rotates, and the contact is by volume (v); skin, palm linear movement (g). Kinematics (d) was chosen because it is considered that this kinematics of motion corresponds most closely to real conditions.

Different tests were carried out using this device, but this paper show results only in one case. Procedure for determining coefficient of friction is very simple. In this case is necessary to determine coefficient of friction between palm of hand and rubber. Rubber sample are cut on predefined dimension and mounted on the device. Test was carried out between dry palm and rubber (hardness of rubber is about 90 shores). Determination of the friction coefficient was performed by three volunteers using the following procedure:

- Connect the sensors and the computer
- Place a sample of material on the surface of the device (rubber in this case)
- Place the palm on the surface of the material
- Gently move forward until the palm start sliding (Fig. 4)

Figure 4. Start position of testing

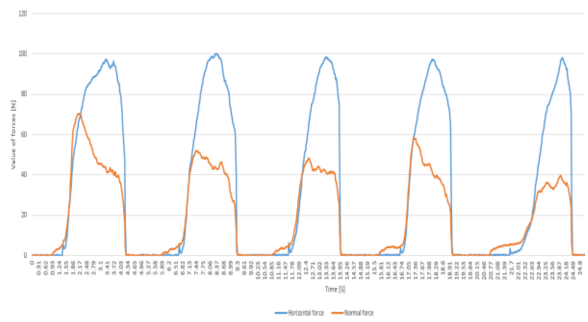

Figure 5. Diagram of normal and horizontal forces

When palm is placed on material surface (Fig. 4), the sensor inside the device registers a normal force (normal force is variable because one can't hold constant value) During the entire duration of the test, the sensor measures horizontal force, and in moment when hand slides, value of force corresponds to the kinetic friction force. Sensors are connected with acquisition device connected to the computer which captures in real time the values of normal and horizontal force. Fig. 5 shows the values of normal and horizontal force versus time in 5 subsequent measurements. The normal force oscillates due to inability of human operator to hold the steady value of normal force.

5. EXPERIMENTAL RESULTS

Average coefficient of friction between palm and rubber in this experiment ranged from 1.37 to 1.83. In table 2, in addition to all the measured friction coefficient values, one can see the average value. It can be concluded that the coefficient of friction for the same material varies depending on the palm of the volunteer.

Table 2. Values of friction coefficient

Coefficient of friction for value of normal force 50 N		
V1	V2	V3
1.79	1.31	2.03
2.03	1.18	1.65
1.93	1.36	1.89
1.77	1.62	1.54
1.59		2.00
Average value		
1.83	1.37	1.82

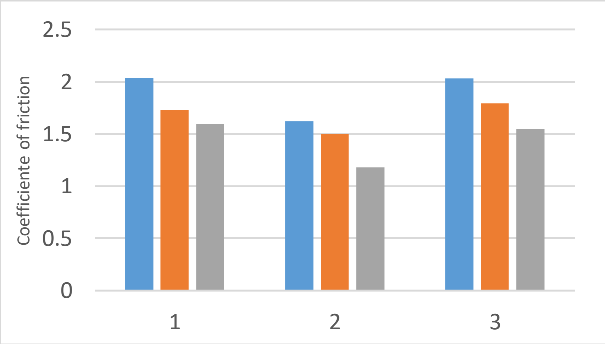

Figure 6. Diagrams of max, min and average friction coefficient for all three volunteers

The following diagram show the maximum (blue), average (orange) and minimum (gray) values of the friction coefficient when the value of normal force of 50N for all three volunteers.

6. CONCLUSION

The development of measuring devices is very important for skin tribology research because one can determine friction coefficient of the skin in contact with any materials. In this paper, the experimental research and determination of friction coefficient between palm skin and rubber is shown. One can conclude that coefficient of friction are obtained for different persons i.e. for different palms. It can be explained different palm surface (different topography, roughness, hardness, skin moisture, temperature, etc). The described procedure will be used in future research of skin friction with different materials and contact conditions, including lubricated (wet contact) conditions, different sliding speeds, temperature, etc.

REFERENCE

[1] M. Carréa, D. Tasrona, R. Lewisa, F. Hashmib: Investigating foot-sock friction: A comparison of two different methodologies, Procedia Engineering, Vol. 147, pp. 759-764, 2016.

[2] N. Veijgen: *Skin friction a novel approach to measuring in vivo human skin*, PhD Thesis, University of Twente, Enschede, NL, 2015.

[3] E. Van der Heide, X. Zeng, M. Masen: *Skin tribology: Science friction*, pp. 130-142, 2013.

[4] R. Lewisa, M.J. Carréa, S.E. Tomlinsona: Skin friction at the interface between hands and sports equipment, Procedia Engineering, Vol. 72, pp. 611 - 617, 2014.

[5] D. Stamenković, M. Nikolić, LJ. Vasin, M. Banić, A. Militenović: Research on tribology penomena in every day life, in: *14th International Conference on Tribology – SERBIATRIB '15*, Beograd, Serbia, pp. 535 - 542, 2015.

[6] B. Krick, J. Vail, B. Persson, G. Sawyer: *Optical* In Situ Micro Tribometer for Analysis of Real Contact Area for Contact Mechanics, Adhesion and Sliding Experiments, Tribology Letters, Vol. 45, No. 1, pp. 185 - 194, 2012.

[7] S. Derler, U. Schrade, L.-C. Gerhardt: Tribology of human skin and mechanical skin equivalents in contact with textiles, Wear, Vol. 263, pp. 1112 - 1116, 2007.

[8] L. Baurle, D. Szabo, M. Fauve, H. Rhyner, N.D. Spencer: Sliding friction of polyethylene on ice: tribometer measurements, Tribology letters, Vol. 24, No. 1, pp. 77 – 84, 2006.

[9] J. Asserin, H. Zahouani, Ph. Humbert, V. Couturaud, D. Mougin: Measurement of the friction coefficient of the human skin in vivo Quantification of the cutaneous smoothness, Colloids and Surfaces B: Bio interfaces, Vol. 19, pp 1 - 12, 2000.