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DEVELOPMENT OF TRIBOMETER AND MEASUREMENT RESULTS OF STATIC COEFFICIENT OF FRICTION SLIDING AND COEFFICIENT OF ROLLING FRICTION BY PRINCIPLE STEEP PLANE

Tadić[1] B., Jeremić[1] B., Vukelić[2] Đ., Mitrović[1] S., Erić[1] M.
[1]Faculty of Mechanical Engineering Kragujevac
[2]Faculty of Technical Science Novi Sad

Abstract: *The paper presents a solution of new developed tribometer intended measuring that static coefficient of friction sliding and static coefficient of rolling friction materials of various types. Principles of measurement are theoretically analyzed, presented the basic of structural solutions and some results of measurements. Tribometer is based on the principle of the steep plane and provides a rotation angle of the steep plane with an accuracy of one minute, which provides high precision of measurements. From the point of the possible values of the load contact pairs developed tribometer belongs to a class of micro and nano tribometers.*

1. INTRODUCTION

Tribology as a science and technology largely allows the solution of many global problems related to consumption of materials, energy, reduces costs and increases reliability of complex technical systems [8]. Tribology in the field of tribo-diagnostics and development of modern measuring systems at the present time is experiencing a full expansion. The reasons are primarily in the fact that the analysis and quantification of complex tribological processes are necessarily reliable on measuring devices and machines. Due to the complexity of processes occurring in the zones of contacts tribology is largely based on experimental research methods. Modern methods of experimental research, in addition to required reliability of measurement system, are placing a number of other complex requirements and restrictions. All this imposes a constant need for developing new and improving existing measurement devices and machines, not only in the specific field measuring system and accompanying software, but also in the field of measurement and the very principles of physics processes. Tribological studies of experimental type at the present time are not only the needs of research institutions but also production of many companies who recognize that due to their survival in the market that this is necessary.

Research in the field of modern equipment tribo-diagnostics deals with many global and specialized institutes. In short, research has been pointed to the improvement and standardization of existing solutions and development of new solutions of tribometers. A large number of existing global solutions of tribometers is standardized (ASTM and ISO standards) under the terms of making contact. Today, these structures of tribometers are improved the most in terms of software solutions and improve the technical characteristics (increased levels of stress, increase speed skating, rolling, an increase of temperature, vacuum chambers, etc.).. In many cases the already standardized solutions of tribometers arise tribometer in a highly improved performance that is designed research to a much wider range of load, speed skating, rolling, operating temperature, lubrication conditions, the presence of abrasives etc. There is also a number of solutions of tribometers covering several types of contacts. These solutions are more universal in character and are often designed in a modular system design. There are also a number of special solutions (structures) tribometers intended tribological tests of gear pairs, hard coatings, plastics and other materials. The world has developed a number of dedicated testing tribometers, tribological properties of materials in a vacuum, and tribometers intended for testing in conditions of extremely high temperatures and pressures of contact pairs. The development of nano tribometers as a special field of tribology, initiated the development of a large number of highly sophisticated solutions of nano tribometers. Development of new solutions of tribometers, largely, initiated the development of new materials and coatings, special loading conditions, hostile environments and other specific conditions.

A large number of papers in leading journals is treating the static coefficient of friction. In this regard it should be noted that research moved in more directions, such as: a) research on the design of the topography of contact surfaces that provides the maximum value of static coefficient of friction [2], b) Research related to development and tribological tests of composite biomaterials [3] c) Research related to identification and quantification of the impact of various factors on the size of the static coefficient of friction in systems for rail equipment for metal processing [6], d) Investigations related to the impact of vibration, humidity and other factors on the bearing capacity of the connection that has generated friction [7] e) The development of devices for measuring the static coefficient of friction, the initial moment of motion detection and measurement of adhesion forces [1]. f) development of theoretical models for calculating the value of static coefficient of friction of certain materials [4]. From this partial review of the literature can be concluded that the area of research related to the static coefficient of friction is very topical. Given the topic of the paper should emphasize that the research on the measurement of coefficient of friction on the principle of the plane is also very relevant [5] particularly in terms of comparing the results with those obtained by measuring the static friction coefficient by other methods.

Within the Center for the revitalization of the industrial system and the center for tero-technology Mechanical Engineering in Kragujevac was designed a new tribometer, designed for determining the static coefficient of friction sliding and rolling friction. Tribometer operates on the principle of the plane and is characterized by high precision measurements. Since, the world realized tribometers solutions of this kind, that developed tribometer has advantages and can be one of the current program of domestic metal industry.

2. MEASURING COEFFICIENT OF FRICTION ON THE PRINCIPLE OF THE PLANE

The principle of measuring the coefficient of friction over the plane (figure. 1) is essentially based on the power of the earth's gravity. Sliding friction coefficient, is well known ,represents ratio of friction force and the force perpendicular to the surface of contact. In the limiting case of sliding friction is true equality:

$$\mu = \frac{T}{N} = \frac{G \cdot \sin\alpha}{G \cdot \cos\alpha} = tg\alpha,$$

where the:

$\mu -$ size of static friction coefficient; T -friction; G -gravitation force; α -angle of the plane.

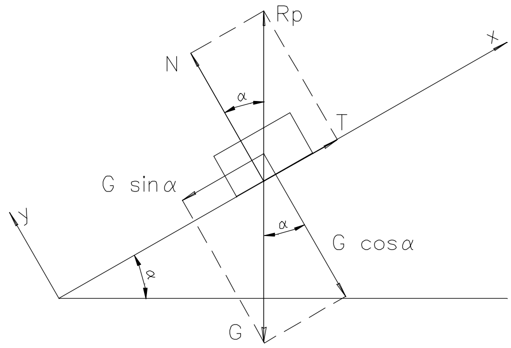
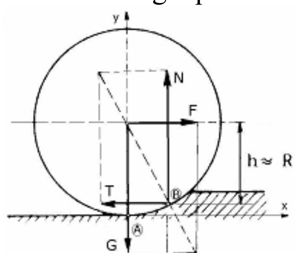
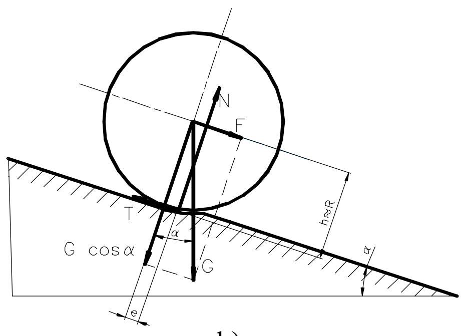


Figure 1. The balance of the body on a steep plane

In the case of friction rolling borderline case (figure 2a and 2b) rolling friction coefficient follows from the following equation:



a)



b)

Figure 2. *The balance of the body when rolling*

$$\sum M_A = 0 \Rightarrow N \cdot e - F \cdot R = 0$$

In the limiting case of drive torque $M_K = N \cdot e$ must be equal to the moment of resistance which is

$$M_P = F \cdot R$$

From this dependence follows:

$T = F = N \cdot \frac{e}{R} = f \cdot N$ apropos:

$f = \frac{e}{R} = tg\alpha$, which follows from the equations of equilibrium body rolling down an inclined plane (figure.2b.),
apropos:

$$\sum F_i(y) = 0 \Rightarrow N = G \cdot \cos\alpha$$

$$\sum M_A = 0 \Rightarrow G \cdot \sin\alpha \cdot R = N \cdot e = G \cdot \cos\alpha \cdot e \Rightarrow \frac{e}{R} = tg\alpha$$

where the:
$f -$ static coefficient of friction rolling;
$e -$ coordinates,which determines the position of the resultant reaction N; $R -$ radius of the body to roll; $\alpha -$ angle of the plane

3. DESCRIPTION OF THE REALIZED SOLUTION OF TRIBOMETER

Completed (Presented) tribometer is designed to measure the static and rolling coefficient of friction of all kinds materials. Figure 3. is schematically showing construction design of this tribometer.

In the base (position1) are set out specially designed screws (item 11) which are used for leveling the base of tribometer. Leveling is performed through a specially prepared vials for leveling in two planes. Support plate (position 2) slides on the prepared groove on the base. On the support plate (position 2) is attached nut (position 12), and zero-point position pointer (position 19.). On the base (position 1) the bearing plate are attached, (position 6) in which are placed radio-axial bearings (position 7). Screw spindle (position 9) of step 1 mm coupled with a nut (position 12), and nonius (position 8) through which the movement is read with an accuracy of one minute. On the support plate (position 2) dug a groove through which enables vertical movement of shift pins (position 5) on which are on both sides affixed two ball bearings (position 10). Ball bearings are indented in discs (positions 3 and 4). On disk (position 3) is engraved angle scale in degrees and fixate two pins (position 14). On the inside of the disc (position 3.) two boundary balls are attached (position 13). Contact pair (positions 15 and 16) with a weight (position 17) which is attached to separate connection for the sample (position 16) are placed on the pins (position 14). Turning nonius (position 8) support plate (item 2) moves in a straight line, while disks (positions 3 and 4) rolling on the top of the base (position 1) and thus swing plane fits the contact pairs (positions 15 and 16) for the desired angle. Additional load can be added via changeable weights (position 17)

Figure 4 give photographic overview of the device and sets of samples while in figure 5 presents details of the leveling device and nonius scale.

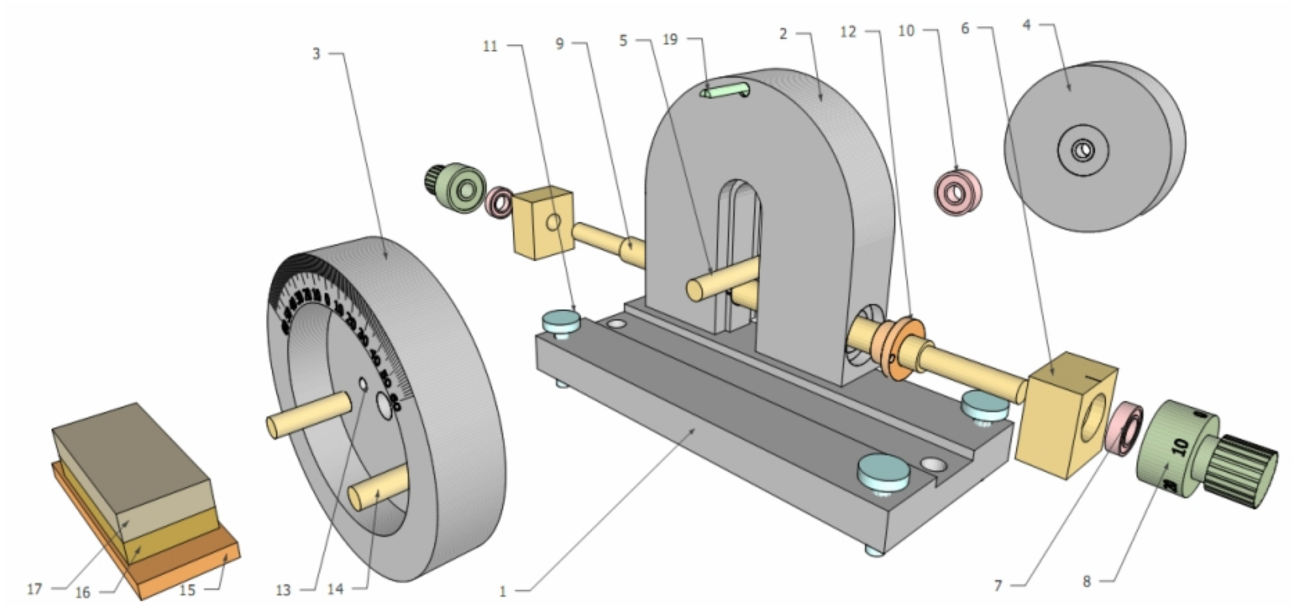


Figure 3. Schematic of tribometer

a) sliding friction b) rolling friction

Figure 4. The initial positions of contact pairs and a set of contact pairs of samples

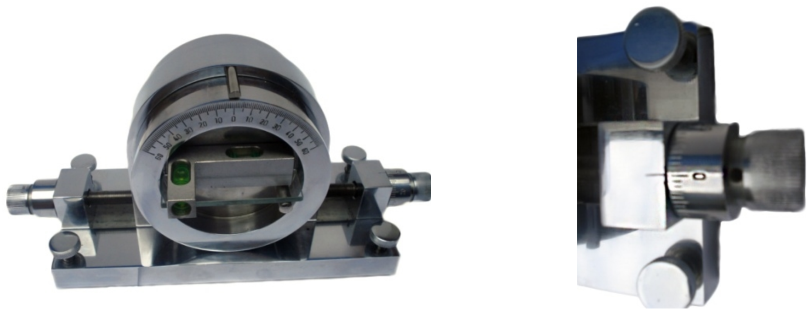


Figure 5. Details related to leveling devices and nonious scale

4. MEASUREMENT RESULTS

For the described device, measurements were made of the coefficient of friction sliding and rolling friction coefficient of various metallic and nonmetallic materials with various loads. Investigated metal materials (steel, cast iron, aluminum, brass and bronze) determined the mechanical properties were brought grinding to approximately the same value of the arithmetic mean deviation in the amount of profile. For the observed non-metallic materials (glass, wood, plastic, leather and rubber) which are closer to specific mechanical properties and friction coefficient measurements were made in a part of these materials to have a comparative character. In figure 6. diagram gives the results of measurements of static coefficient of friction sliding. Each measurement was performed with 20 repetitions on the basis of which they calculated the mean value and dispersion coefficient of friction. The diagram as a background pattern that indicated in figure 3 defines the position15 while the other contact pair is marked as a template (position 16 to figure 3).

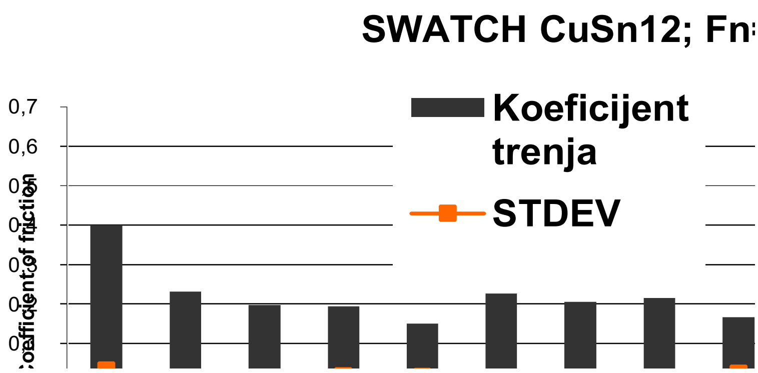


Figure 6. Histogram report on the results of measurement of static coefficient of friction sliding of materials.

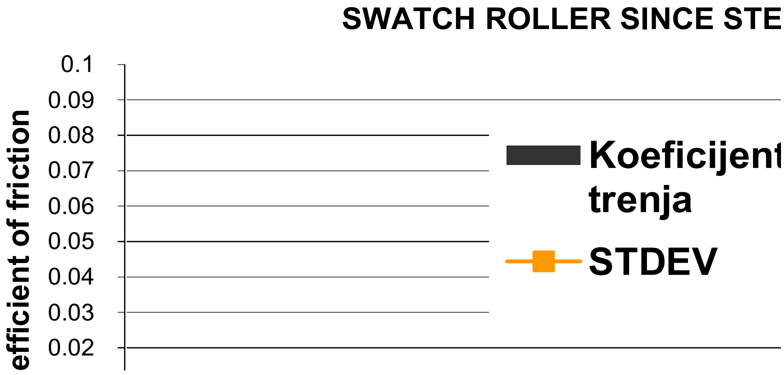


Figure 7. Histogram of results of measurements of static coefficient of friction rolling various materials.

In figure .7. presents some results of measurements related to measuring the static coefficient of friction rolling.

5. CONCLUSIONS

Based on the above we can conclude the following:

- Results of the analysis of literature sources indicate that the theoretical and experimental research in the field of static friction are current problems. The research is focused in many directions. Some current areas of research are: a) research on the design of the topography of contact that provides the maximum value of static coefficient of friction [2], b) Research related to development and tribological tests of composite biomaterials [3], c) Research related to identification and quantification of impact various factors on the size of the static coefficient of friction in systems for rail equipment for metal processing [6], d) Investigations related toinfluence of vibration , humidity and other factors on the bearing capacity of the connection that is generated by friction [7]e) The development of devices for measuring the static friction coefficient , the initial moment of motion detection and measurement of adhesion forces [1]. f) development of theoretical models for calculating the value of static coefficient of friction of certain materials [4].
- Given the topic of the paper should emphasize that the research on the measurement of coefficient of friction on the principle of the plane is also very relevant [5] particularly in terms of measuring devices and compare the results with those obtained by measuring the static friction coefficient by other methods.
- Developed a device for measuring static coefficient of friction sliding and rolling friction is zero-the plane is designed to allow very precise determination of the static coefficient of friction. Error reading angle value is less than one minute so that, in this regard, the error measured values of sliding friction coefficient is negligible. When it comes to measuring the coefficient of friction rolling maximum error of measurement does not exceed 5%, which is quite acceptable given the very low value of coefficient of friction rolling and measurement errors on the different kinds of devices.
- The results of measuring the static coefficient of friction sliding and static friction coefficient of rolling various materials obtained by using the realized devices are supported by the literature.

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