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The Influence of the Contact Surface Roughness on the Static Friction Coefficient*

The friction between two solids depends on contact conditions. The knowledge of the surface microtopography is very important for study of tribological processes in contact zone. The coefficient of static friction depends on many factors: the mechanical properties of material, the surface roughness, the mutual dissolution of materials, the contact time, the lubricant film properties, the elasticity of tribosystem, etc. The influence of the contact surface roughness on static friction coefficient was studied in this paper. Today, an engineer has large possibilities for identification of form and size of surface roughness with modern measuring equipment. The complex roughness parameter describes successfully the surface roughness and it is suitable for the static friction coefficient investigation. For experimental investigation of the static friction coefficient, the model with surfaces contact between samples was established. The experimental results are presented in this paper.

Keywords: friction, contact surface, coefficient of static friction

1. INTRODUCTION

The friction coefficient value lies in large interval and depends on many parameters as: the mechanical properties of material, the value of the contact pressure, the lubricant film properties, the contact surface roughness. the mutual dissolution of materials, the contact time, the elasticity of tribosystem, the presence of the extraneous bodies in contact zone, etc.

In experimental investigation, carried out at the Faculty of Mechanical Engineering in Nis, the influence of the surface roughness and hardness of pair contact surface on the static coefficient friction was studied.

The influence of the contact surface roughness on the static friction coefficient was studied in this paper.

2. THE CONTACT SURFACE ROUGHNESS

Real surface of metal parts is rough. Topography shape of surface must be perceived by the three dimensional ways [7]. But, in practice, the surface analysis is very often realized by surface cuts i.e. in two dimensions.

Standard roughness parameters are: arithmetical mean deviation of the profile (R_a), ten point height of irregularities (R_z), maximum height of the profile (R_{max}), maximum height of profile peak (R_p) and profile bearing lenght ratio (t_p).

Friction processes in the contact zone and contact surface bearing depend on material arrangement in their rough layers. The best description of material arrangement in rough layers is by curve of the profile bearing lenght ratio. This curve presents graphic review of dependence between profile bearing length and profile level.

For measuring the roughness profile of samples equipment Surftest 201 Mitutoyo in realized experimental investigation was used. The measuring note of sample surface roughness is shown in Fig. 1.

Surface roughness can be successfully defined with microgeometry complex parameter Δ which is calculated by formula:

$$\Delta = \frac{R_{\max}}{rb^{1/v}}$$

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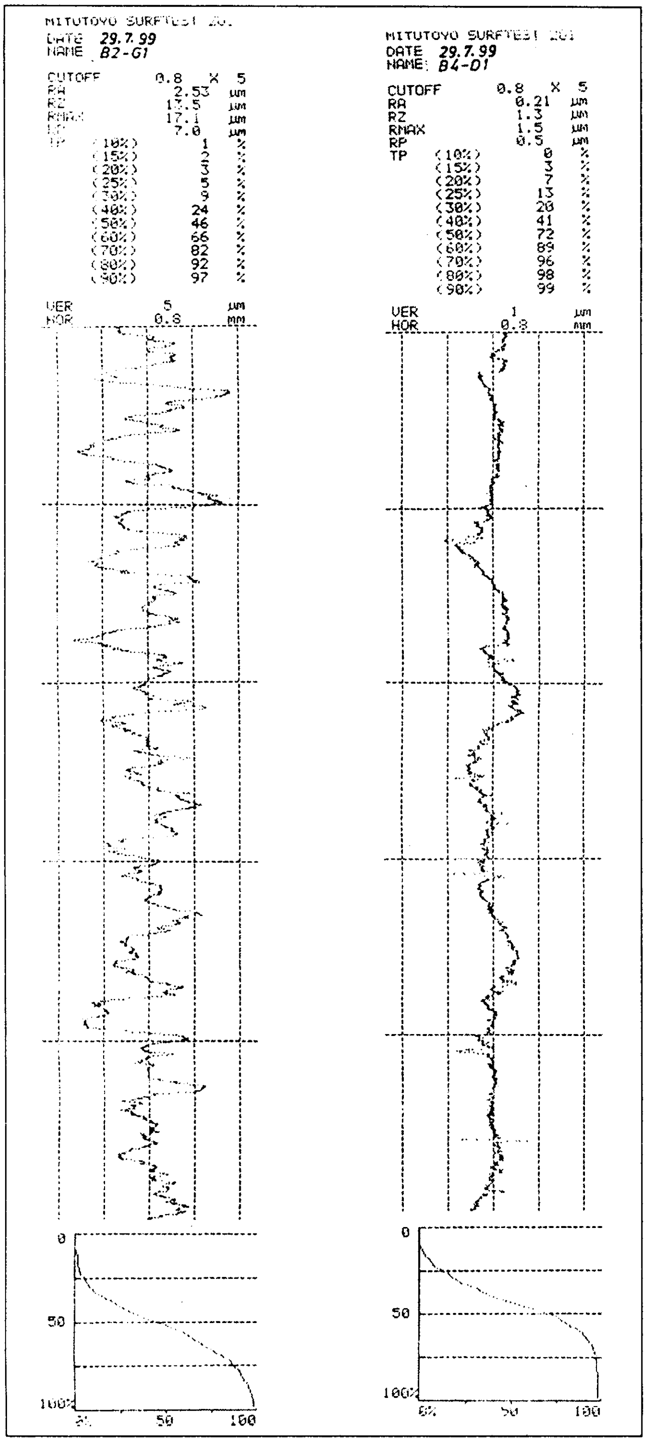
where **r** is the mean radius of asperities,

$$b = t_m \left(\frac{R_{\max}}{R_p} \right)^{v}, \; v = 2t_m \frac{R_p}{R_a} - 1 .$$



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MITUTOYO SURFTEST 201
DATE  29.7.99
NAME  B2-G1

CUTOFF        0.8   X  5
RA             2.53   µm
RZ            13.5    µm
RMAX          17.1    µm
RP             7.0    µm
TP     (10%)      1    %
       (15%)      2    %
       (20%)      3    %
       (25%)      5    %
       (30%)      9    %
       (40%)     24    %
       (50%)     46    %
       (60%)     66    %
       (70%)     82    %
       (80%)     92    %
       (90%)     97    %

VER           5       µm
HOR           0.8     mm
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MITUTOYO SURFTEST 201
DATE  29.7.99
NAME: B4-01

CUTOFF        0.8   X  5
RA             0.21   µm
RZ             1.3    µm
RMAX           1.5    µm
RP             0.5    µm
TP     (10%)      0    %
       (15%)      3    %
       (20%)      7    %
       (25%)     13    %
       (30%)     20    %
       (40%)     41    %
       (50%)     72    %
       (60%)     89    %
       (70%)     96    %
       (80%)     98    %
       (90%)     99    %

VER           1       µm
HOR           0.8     mm
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Figure 1. The measuring record of sample surface roughness, B2 (milling) and B4 (polishing)

3. EXPERIMENTAL INVESTIGATION

The frictional features of tribomechanical systems are estimated in laboratory investigations. Models for establishing frictional features of sliding pair consider kinematic parameters and the way in which the contact is being formed [4]. On basis of these, laboratory apparatus for estimation of friction and wear parameters are made. Therefore, it is very important that experimental samples represent, as better as possible, exploitation parts.

Measuring of friction kinetic force is done without problems considering the facts that process of investigation is realized in long period of time and that this process can be repeated. This way, the mean value of friction coefficient can be established, with sufficient reliability. However, in static friction case, establishing the friction coefficient value is done in a very short period of time at initial start moment of sliding. The static friction force is tangential resistance force which appears during the so called boundary relative displacement. The relative displacement precedes the visible, macro displacement. Because of this fact, static friction force can be measured only in the moment of sliding beginning for the reason that in next moment, after sliding start, this value falls on friction kinetic force value. This process is established by conditions of forming microconnections and it has stohastical (accidental) character.

Experimental model for establishing the static friction coefficient, projected specially for this investigation, is shown on figure 2. Based on these, the measuring table was made and investigation was done with samples in form of plates.

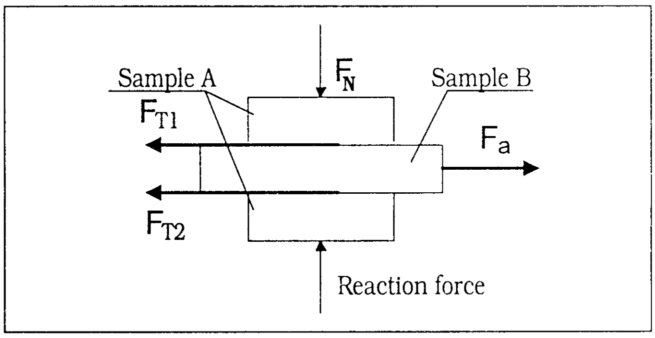

Figure 2. Shematic review of experimental model

The aim of the experiment was examining the influence of the surface roughness on the static friction coefficient. It was executed with samples in plate form on the measuring table which is specially made for this occasion (Fig. 3).

This measuring stand should enable conditions for measuring vertical load values (F_N) and longitudinal force (Fa) which present friction force at the beginning of the samples sliding. Beside forces, sample movement should be measured also, because it was necessary to record force just in the moment of the samples mutual displacement. The mentioned method, the measured mechanical values by electrical means is used. This method is reliable and respected in modern metrology.

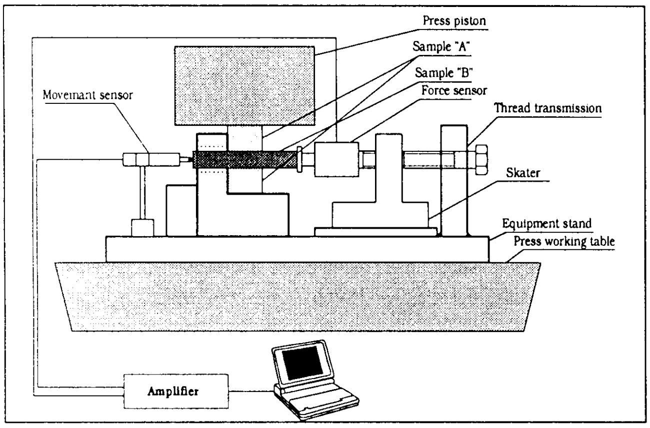

Figure 3. Schematic review of measuring stand for measurement of the static friction force

Diagram force-movement recorded in the experimental process with samples in plates form is shown on Figure 4.

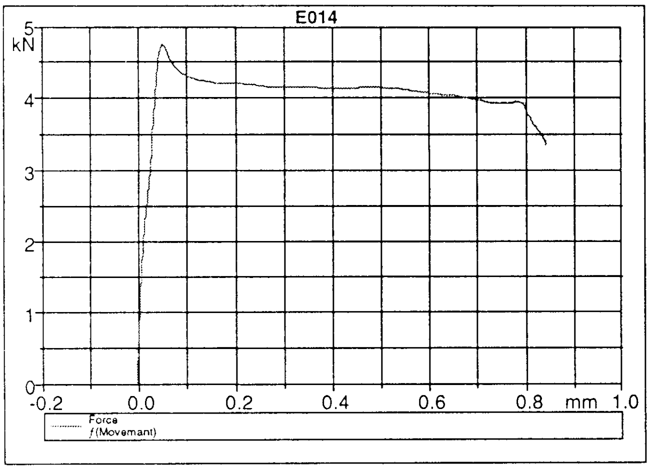

Figure 4. Diagram force - movement of plates sliding process

The measuring equipment which was used in the experiment is made by HBM Germany and it is of high precision class. The computer unit with program BEAM 3.1 is specially useful for measuring mechanical values by electrical way.

4. INFLUENCE OF THE CONTACT SURFACE ROUGHNESS ON THE STATIC FRICTION COEFFICIENT

In industrial practice is usual that the necessary surface quality of mechanical parts is obtained through the choice of machining regime. Surfaces with different class of roughness (with different values of R_a) have different friction features. Therefore, it can be seen that surfaces with the same class of roughness, have different friction features if they were made by different kind of machining. Because of that, it is necessary to analyze experimental results representing roughness and the way of machining effects. Complex parameter of roughness takes into consideration the both factors.

Surfaces of experimental samples in plate form were machined by milling, lapping and polishing. The roughness parameter values of samples are shown in Table 1.

Table 1. The roughness parameter mean values of experimental samples

Machining	R_a [μm]	R_z [μm]	R_{max} [μm]	Δ	Roughness class
MILLING	3.84	22.50	26.75	0.0172	N8
LAPPING	0.28	2.59	3.32	0.0051	N4/N5
POLISHING	0.19	0.98	1.53	0.0018	N3/N4

Considering the way of machining, the static friction coefficient values are shown in Table 2. The graphic presentation of these values is shown in Figure 4. The static friction coefficient mean value in case of milling surfaces contact is 37% greater than the value in case of lapping surfaces contact and 50% greater than the polishing surfaces.

Table 2. The friction coefficient values considering the way of machining

Machining	Total tests number	Max. value	Min. value	Mean value
milling/milling	17	0.1258	0.0744	0.0928
milling/lapping	36	0.0984	0.0638	0.0782
milling/polishing	38	0.1020	0.0576	0.0728
lapping/lapping	22	0.0769	0.0517	0.0676
lapping/polishing	43	0.0881	0.0542	0.0661
polishing/polishing	25	0.0717	0.0522	0.0618

Thus, the way of machining is a parameter with important influence on the static friction coefficient. The way of machining causes not only surface roughness but arrangement of material in micro region, and this arrangement is very important for tribological processes.

The results of experimental investigation assure that the static friction coefficient value increases if contact surfaces have bigger roughness parametars [1,2,4]. If the hardness of solids in contact are not the same, the more important is the roughness of the harder metal because asperities of the harder surface plow the surface of the softer metal [1,2].

The presentation of the dependence between complex parameter of roughness and static friction coefficient, which is obtained in experiment,is shown in Figure 5.

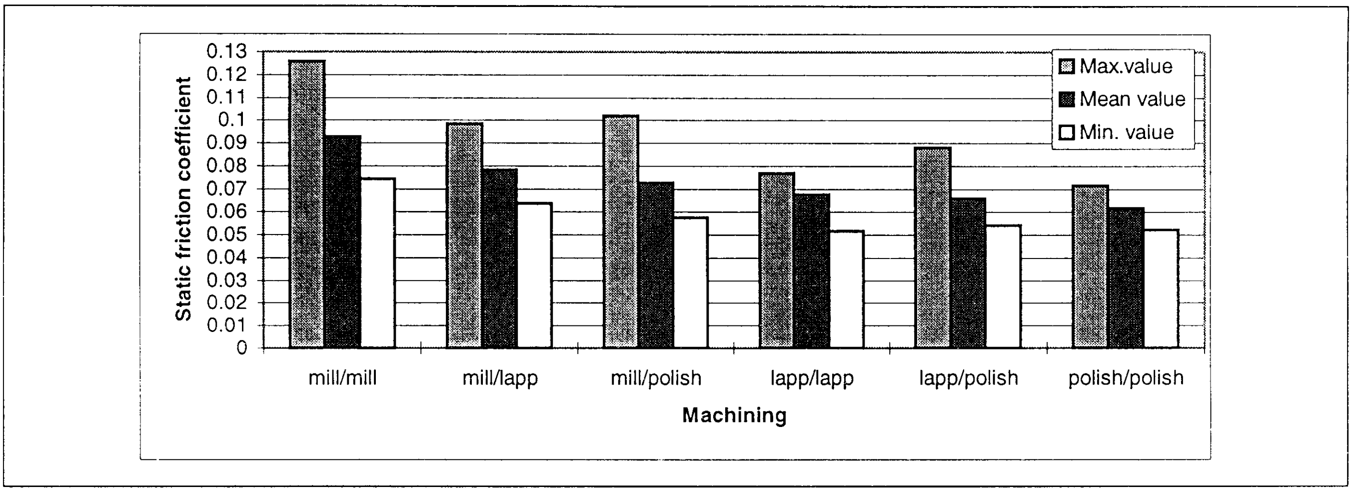

Figure 4. The friction coefficient values considering the way of machining

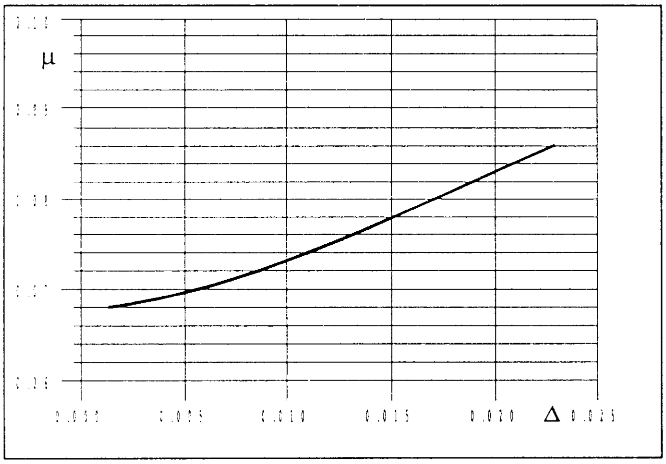

Figure 5. Dependence between complex parameter of roughness Δ and the static friction coefficient

5. CONCLUSION

Contact surface roughness has direct influence on the static friction coefficient. Generally, it can be assured that the static friction coefficient increases with surface roughness parameters. But, there is the difference in static friction coefficient values in the same roughness class. This difference is the result of the way the surface is machined. It is not same, in tribological meaning, if surfaces with same value of roughness parameter R_a are manufactured for example by milling or by turning. This difference can be successfully expressed by microgeometry complex parameter.

REFERENCES

[1.] *Bowden, F., Tabor, D.*, **Friction - An Introduction to Tribology**, Florida, USA 1982.

[2.] *Krageljskii, I., Alisin, V.*, **Trenie iznašivanie i smazka**, Spravočnik - kniga 1 Moskva, 1978.

[3.] *Krageljskii, I., Dobàčin, M., Kombalov, V.*, **Osnovi rasčetov na trenie i iznos**, Moskva, 1977.

[4.] *Belogo, V., Ludemà, K., Màškina, N.*, ***Tribologi® - Issledovani® i prilozeni®***, Moskva, 1993.

[5.] *Ivkovic, B., Rac, A.*, **Tribologija**, Kragujevac, 1995.

[6.] *Zivkovic, Z., Djurdjanovic, M., Stamenkovic, D., Jovanovic, S.*, **The influence of the friction coefficient for the force fit assemblies**, 2nd INTERNATIONAL CONFERENCE ON TRIBOLOGY "BALKANTRIB 96" Thessaloniki - Greece, 1996.

[7.] *Scott, P., Characterization of 3D surface roughness*, **Advanced Mathematical Tools in Metrology II**, The University of Birmingham-England, 1996.

[8.] *Stamenkovic, D.*, **Istrazivanje nosivosti presovanog spoja kao tribosistema u okviru pogonskih sklopova zeleznickih vozila**, Doktorska disertacija, Masinski fakultet Nis, 1999.