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EXPERIMENTAL TESTS PERFORMED USING THREE BALLS TRIBOMETER

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Abstract: *In this paper are presented experimental tests concerning the dry friction coefficient, using the three balls tribometer, for four types of steel, in sliding dry friction conditions. The measurement are made for four different loads and three different slinding speeds.* ***Key words:*** *tribology, friction coefficient, tribometer, dry friction, steel.*

1. INTRODUCTION

Tribology is the science that deals with the processes of friction, wear and lubrication.

This paper deals with the dry friction which is a complex phenomenon, power, molecular and mechanic that arises between surfaces in contact, under relative motion, between which there is no film of lubricant.

Aim of this study is to determine the friction coefficient with three balls tribometer of four types of steel (stainless steel 316, stainless steel 440, chrome steel and tool steel) in sliding process under the OLC45 tribometer disc. The tribometer works under dry friction conditions.

2. TESTING EQUIPMENT

For the experimental tests, was used the three balls tribometer, existent equipment Group of disciplines Machine Elements and Tribology, Department of Mechanical Engineering Systems. The three ball tribometer sketch and the component elements are presented in figure 1.1.

2.1 Construction and operation of the three balls tribometer

The friction force/ friction coefficient is determined by the resistive strain gauges, which requires the removal or movement tendency of an element of the friction coupling. Displacement measuring deformation of the leaf spring which is mounted a resistance strain gauges for a given power (RΩ), and produce a variation of the electrical resistance ΔR is caused by a tangential force which is the force of friction.

The tribometer consists of the following main elements:

- Metal frame (14) supporting the test device and the electric motor drive (1);
- Friction coupling ball /disc elements: three brackets (3) mounted in the 3 fasteners and disc (2) mounted on the main disc (11) which performs rotation.

Rotating disc (11) is rigidly fixed to the main shaft (12), which in turn is mounted on two bearings with angular bearings (13).

Through the electric motor (1), the rotation is transmitted to the main shaft (12), with a V-belt transmissions.

The spindle speed (12), and hence the disc (2) speed is n=350 rot/min.

Disk (4) is based on disk (2) by the three brackets (3) and the tendency of turning off the leaf spring (9) through pin (7), pressed to the fixed disc (4).

Applying weights of 12.8 N, 16N, 18.2 and 19.65 N (5), to the fixed disc (4) is achieved the normal workload for the friction coupling.

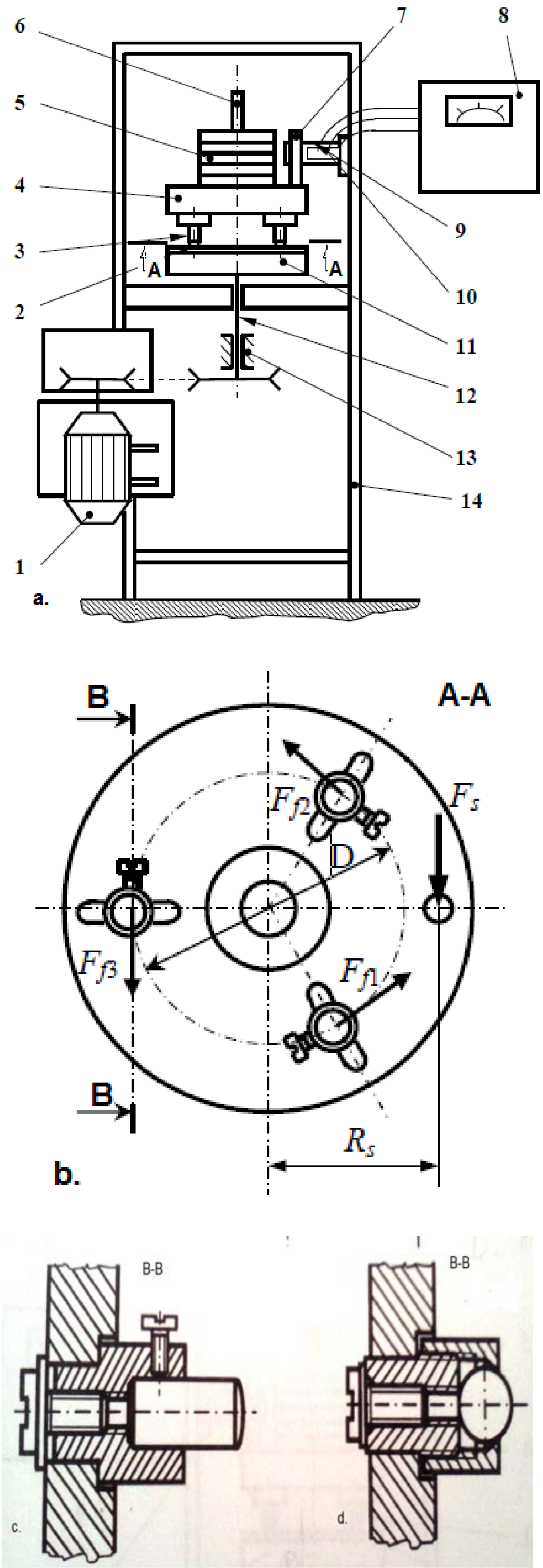

Fig. 1.1. Three balls (pins) tribometer.

On the three pins tribometer, the device used for fixing the three pins, was adapted for using balls instead of pins, as shown in figure 1.1.d.

3. THE FRICTION FORCE DETERMINATION

The figure 1.1b, is the sketch for determining the forces required friction.

Friction arises between OLC45 disc and ball bearings, so the fixed disc (4) tends to rotate, but is stopped by the spring leaf (9) which are fixed two resistive strain gauges (10). These trasmitters are connected to an electronic strain gauge (8), which helps to determine the leaf spring deformation.

The figure 1.1b shows the fixing disc with three balls and friction forces acting on each ball ($F_{f1,2,3}$) and the force F_s acting on the pin. Total moment of friction forces is given by:

$$T_{tf} = \left(F_{f1} + F_{f2} + F_{f3}\right)\cdot\frac{D}{2} = F_f \cdot \frac{D}{2}\ , \qquad (1)$$

where Tt_f is the the total friction moment [N·mm];

$F_{f1,2,3}$ – friction forces of the three ball bearings, in contact with disc (2) [N];

D – the circle diameter where the ball bearings are mounted [mm].

From ecuation (1), it results:

$$F_f = \frac{2 \cdot T_{tf}}{D} = \frac{T_{tf}}{R}\ , \qquad (2)$$

The value for the F_s force is established from the characteristic leaf spring according to the number of divisions read to the electronic strain gauge (Figure 1.2), where k is a constant of proportionality obtained by strain gauge calibration.

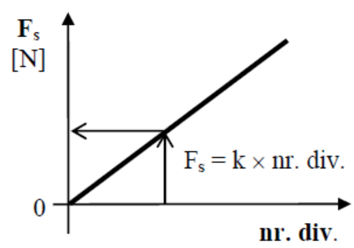

Fig. 1.2. Characteristic of the leaf spring.

The value of the diameter D of the circle on which the samples are mounted can be reduced (enlarged) by moving radial samples (3), so the friction moment is given by:

$$F_f = \frac{F_s \cdot R_s}{R}, \qquad (3)$$

where: *Fs* is the spring leaf reaction, acting on the testing balls [N];

R_s – constant distance between the pin center 7 and the disc center 4; R_s = 50 mm.

Friction coefficient will result taking into account the friction force (3) and the applied load for the friction coupling:

$$\mu = \frac{F_f}{F_n} \qquad (4)$$

4. EXPERIMENTAL RESULTS

Experimental tests were performed on four friction coupling materials: stainless steel 316/OLC45, stainless steel 440/OLC45, chrome steel/OLC45 and tool steel/OLC45.

The application of each load was varied the sliding speed, achieving determinations for three different sliding speeds: 1.555 m/s, 1.900 m/s and 2.246 m/s. For each pair of materials were made 12 measurements, varying the sliding speed and load. Using the above formulas were obtained friction forces and friction coefficients in table 1 for the four types of steels, depending on sliding speed and load.

For the friction coupling stainless steel 316/OLC45, the friction coefficient values varied in the range 0,461-0,591 with a medium value of 0,507083.

Table 1

Friction force and friction coefficient results

Nr. crt.	Div. nr.	F_n [N]	v [m/s]	F_f [N]	μ_i
Friction coupling 1: Stainless steel 316/OLC45					
1	4	12,8	1,555	5,902	0,461
2	5	16	1,555	7,377	0,461
3	6	18,2	1,555	8,533	0,486
4	7	19,65	1,555	10,328	0,520
5	5	12,8	1,900	6,036	0,471
6	6,5	16	1,900	7,847	0,490
7	7,5	18,2	1,900	9,054	0,497
8	8,25	19,65	1,900	9,96	0,501
9	6	12,8	2,246	6,64	0,518
10	8	16	2,246	8,683	0,542
11	9,75	18,2	2,246	9,96	0,547
12	11,5	19,65	2,246	11,747	0,591

Table 1(continue)

Nr. crt.	Div. nr.	F_n [N]	v [m/s]	F_f [N]	μ_i
Friction coupling 2: Tool steel/OLC45					
13	3,75	12,8	1,555	5,533	0,432
14	5	16	1,555	7,377	0,461
15	5,75	18,2	1,555	8,484	0,466
16	6.5	19,65	1,555	9,591	0,483
17	6	12,8	1,900	7,243	0,565
18	7,5	16	1,900	9,054	0,565
19	9	18,2	1,900	10,865	0,597
20	9,75	19,65	1,900	11,770	0,592
21	7	12,8	2,246	7,1507	0,558
22	8,75	16	2,246	8,938	0,558
23	10	18,2	2,246	10,215	0,561
24	10,5	19,65	2,246	10,726	0,540
Friction coupling 3: Chrome steel/OLC45					
25	4	12,8	1,555	5,902	0,461
26	5,5	16	1,555	8,115	0,507
27	6	18,2	1,555	8,853	0,486
28	6,75	19,65	1,555	9,96	0,501
29	4,75	12,8	1,900	5,734	0,448
30	6	16	1,900	7,243	0,452
31	7	18,2	1,900	8,450	0,464
32	7,75	19,65	1,900	9,356	0,471
33	6	12,8	2,246	6,129	0,478
34	7,75	16	2,246	7,916	0,494
35	9	18,2	2,246	9,193	0,505
36	10	19,65	2,246	10,215	0,514
Friction coupling 4: Oţel inoxidabil 440/OLC45					
37	4	12,8	1,555	5,902	0,461
38	5,5	16	1,555	8,115	0,507
39	6.5	18,2	1,555	9,591	0,526
40	7,5	19,65	1,555	11,066	0,557
41	5,25	12,8	1,900	6,338	0,495
42	6,5	16	1,900	7,847	0,490
43	7,75	18,2	1,900	9,356	0,514
44	8,5	19,65	1,900	10,261	0,516
45	6,5	12,8	2,246	6,64	0,518
46	8,25	16	2,246	8,427	0,526
47	9,5	18,2	2,246	9,704	0,533
48	10,5	19,65	2,246	10,726	0,540

For the friction coupling tool steel /OLC45, the friction coefficient values varied in the range 0,432-0,597 with a medium value of 0,5315.

For the friction coupling chrome steel /OLC45, the friction coefficient values varied in the range 0,461-0,514with a medium value of 0,48175.

For the friction coupling stainless steel 440/OLC45, the friction coefficient values varied in the range 0,461-0,557 with a medium value of 0,51525.

Comparing the friction coefficient obtained with research in the field, the friction coupling of mild steel/mild steel were obtained values of 0.57 to 0.59 for friction coefficient, using a pin /disc tribometer for between 10-30 minutes testing time. For sliding speeds between 0.1 to 2.5 m/s, in the presence of vibration of 10μm, friction coefficient reached values of 0.56 to 0.72, the vibration of 100 μm to 0.53 to 0.67, and 200 μm amplitude from 0.45 to 0.63. In the presence of 5-15N load and amplitude of 10 μm, friction coefficient has values between 0.254 to 0.293, at amplitude of 100 μm has values between 0.247 to 0.285 and from 200 μm amplitude, friction coefficient varies between 0.242 to 0.282 [3].

For the friction coupling materials mild steel /mild steel with polished surface, at 1.51 m/s speed, the friction coefficient reached values from 0.3 to 0.6, at speed of 0.874 m/s, friction coefficient varied in the range 0.25 to 0.64. For mild steel/mild steel surface turning, at a speed of 0.874 m/s, the friction coefficient reached values of 0.14 to 0.36. [2]

5. CONCLUSION

Analyzing the experimental values obtained by taking into account the factors that have made experimental measurements (load and sliding speed), was observed the friction coefficient increase with increasing of sliding speed and load.

Experimental results are close to that value results from the literature [2], [3].

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Încercări experimentale realizate cu ajutorul tribometrului cu trei bile

Rezumat: *În lucrarea de faţă sunt redate determinările experimentale în ceea ce priveşte determinarea coeficientului de frecare, cu ajutorul tribometrului cu trei ştifturi, pentru patru tipuri de oţeluri, în regim de alunecare, în cazul frecării uscate. Încercările s-au realizat pentru patru încărcări diferite şi trei viteze de alunecare.*

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