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Research paper

DETERMINATION OF THE PARASITIC FORCES THAT OCCUR AS A CONSEQUENCE OF THE MOVEMENT OF THE ROLLER OVER THE MINIATURE PROFILED GUIDE

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Abstract: *In order to achieve a greater efficiency degree of electrical, mechanical or other assemblies that work by consuming any form of energy, the frictional force that occurs between all moving elements of the system should be minimized. Nowadays, a lot of standard sliding and rolling pairs have been developed, which provide linear movement. Since manufacturers of these elements do not prescribe coefficient of friction when moving movable rollers on a fixed rail, it is often necessary to know the resistance to motion of these elements due to the correct selection of the drive system, and therefore it is necessary to determine them. In this paper, the resistance to motion of roller through the miniature profile guide 15 mm in width and 10 mm in height was tested.*

Key words: *frictional force, energy losses, roller, profiled guide*

1. INTRODUCTION

Ecological norms that become more stringent in recent times, tend to reduce the consumption of energy, that is, to increase efficiency degree of the same. Thus, all machines and devices produced must have a declaration indicating the efficiency degree of energy. For this reason, a lot of studies are concerned with the examination of the frictional force, which is very often undesirable, parasitic force.

When two solid bodies are in contact, there is a frictional force between them. Depending on their relative speed, friction can occur between immobile or moving bodies in contact. Thus we distinguish two types of friction coefficient: the static friction coefficient - represents the friction that opposes the onset of relative motion and the kinetic coefficient of friction - is a friction that opposes the continuation of relative motion when motion has begun [1].

The static friction coefficient is determined using the maximum frictional force, which must be overcome in order to cause relative displacement of the contact surfaces. The friction coefficient depends on the material of the solid bodies in contact, for example, in the metal contact pairs [2,3], contact pressure, temperature [4-7], surface absorption, surface finish, etc. [8,9]. The static friction coefficient increases with increasing surface roughness parameters [10], while low coefficient friction is associated with smooth surfaces [11].

Friction problems cannot be solved by performing simple experiments or by adopting the friction coefficients from the table from literature. Engineers and scientists face real problems in machines or industrial processes, created as a result of the appearance of friction whose values differ from those adopted from literature [12]. Therefore, additional friction tests must be carried out under realistic conditions. Tests can be performed on the machine itself, but it is usually followed by a series of problems and is not practical, so it is preferred by laboratory tests.

In this paper authors will show an experiment of a single contact pair, rollers and miniature profiled guides, where the values of friction and friction coefficient will be obtained.

2. THEORETICAL CONSIDERATIONS

The principle of coefficient of friction measurement over an inclined plane, figure 1, is based on the use of a gravitational force. The static coefficient of friction, as is known, is the ratio of the frictional force and the force perpendicular to the surface of the contact, where the equilibrium condition for inclined plane is given by the expression $F_\mu > m \cdot g \cdot \sin\alpha$. For the limit of sliding friction, equality applies:

$$\mu = \frac{F_\mu}{N} = \frac{m \cdot g \cdot \sin\alpha}{m \cdot g \cdot \cos\alpha} = tg\alpha \qquad (1)$$

where: μ is the size of the static coefficient of friction; F_μ is frictional force; m is body mass; g is acceleration of gravity; α is angle of inclined plane.

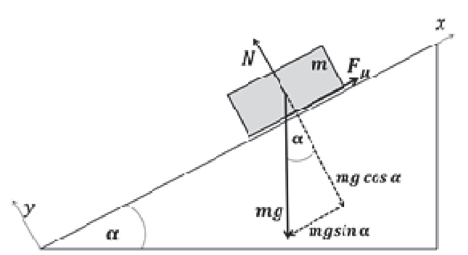

Fig.1. Equilibrium condition of the body on an inclined plane [4]

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The measuring inaccuracy of the static coefficient of friction according to this measurement principle is the result of an angle measurement error α in relation to the ideal horizontal position at the moment when the body located on an inclined plane from the static state has moved into the motion state.
According to the research [4-7], the relative percent difference can be determined by using the equation:

$$\varepsilon = \frac{tg(\alpha + \Delta\alpha) - tg\alpha}{tg\alpha} \cdot 100 \tag{2}$$

where ε (%) is the relative percent difference and $\Delta\alpha$ is the measurement error of angle α.
By analyzing equation (2) it can be shown that the errors of measuring the static coefficient of friction, even in the case of measurements of the level of sliding friction coefficient, are less than 5%, which is in the research [5,6] and figure 2 shown [13].

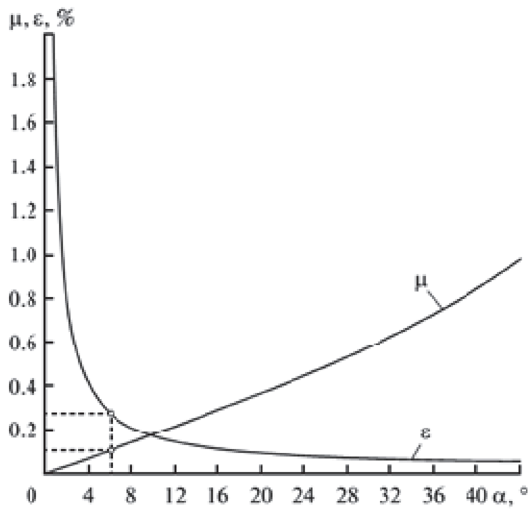

Fig.2. A graphical representation of the relative measurement error of the friction coefficient over an inclined plane [13]

3.EXPERIMENTAL EXAMINATION

Experimental examination was carried out on a specially designed tribometer, figure 3, to determine the static coefficient of friction according to an inclined plane principle. The contact pair, in this case, the profiled guide and the roller turn to one side until the moment of starting the roller move through the profiled guide. This is the moment when the driving force has reached the value of the resistive frictional force. By measuring this angle, the coefficient of friction of this contact pair is determined.
In order to achieve greater stability, the stand of the device is massive and heavy. Adjustment of the horizontality of the device is necessary especially in the case of testing the rolling coefficient of friction when extremely small angles of inclined plane are expected to cause motion. The leveling of the device is realized through the support screws, figure 4a. The horizontality of the roller at the zero value of the inclination angle was also performed, figure 4b. A level of precision 0,02 mm/m was used to leveling of the device.

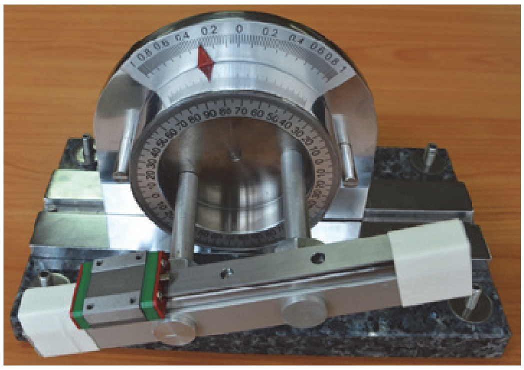

Fig.3. A device for testing the static coefficient of friction of the roller on an inclined plane

a) *b)*

Fig.4. Device leveling

After proper positioning of the device, an experiment was started, which involves rotating the contact pair until the movement of the roller through the profiled guide is made. The angle of inclined plane is achieved by translating the middle plate along the based plate, which results in rolling the front and rear discs, i.e. increasing of the angle of inclined plane. The angle is increased until the roller move along the profiled guide. The bolt with the measuring line shows the angle at which roller rolling along the slideway, while the display arrow shows the coefficient of friction.

4. RESULTS OF EXPERIMENTAL EXAMINATION

The results of experimental tests from which the values of the static friction coefficient and the frictional forces can be obtained are shown in table 1.
Given the stochastic nature of the friction coefficient, the measurement was repeated 200 times to obtain as realistic friction coefficient as possible by statistical analysis of results.

Table 1. Results of experimental examination

Number of measurements	angle of inclined plane [°]	Number of measurements	angle of inclined plane [°]
1	13	101	9
2	11	102	8
3	11	103	10
4	10	104	7
5	12	105	8
6	11	106	10
7	12	107	9
8	5	108	9
9	12	109	11

Number of measurements	angle of inclined plane [°]	Number of measurements	angle of inclined plane [°]
10	12	110	10
11	11	111	9
12	12	112	8
13	9	113	8
14	14	114	9
15	9	115	9
16	6	116	7
17	10	117	5
18	10	118	9
19	9	119	8
20	9	120	11
21	9	121	8
22	12	122	9
23	9	123	6
24	9	124	8
25	11	125	10
26	8	126	10
27	11	127	6
28	10	128	9
29	9	129	9
30	8	130	10
31	8	131	9
32	10	132	10
33	11	133	10
34	10	134	7
35	14	135	8
36	9	136	14
37	10	137	9
38	9	138	7
39	12	139	7
40	9	140	10
41	10	141	9
42	9	142	10
43	9	143	8
44	9	144	7
45	13	145	13
46	12	146	10
47	6	147	9
48	10	148	7
49	10	149	7
50	9	150	8
51	7	151	7
52	9	152	10
53	11	153	7
54	12	154	14
55	12	155	10
56	9	156	7
57	12	157	13
58	5	158	8
59	8	159	9
60	9	160	7
61	9	161	9
62	10	162	11
63	9	163	9
64	9	164	11
65	11	165	8
66	10	166	11
67	11	167	10
68	13	168	7
69	8	169	10
70	14	170	12
71	9	171	11
72	10	172	8
73	8	173	8
74	13	174	11
75	14	175	8
76	11	176	9
77	8	177	10
78	9	178	8
79	12	179	10
80	9	180	11
81	9	181	9
82	10	182	10
83	9	183	7
84	8	184	9
85	8	185	11
86	9	186	11
87	9	187	11
88	8	188	7
89	6	189	13
90	9	190	8
91	9	191	8
92	8	192	10
93	12	193	11
94	9	194	14
95	8	195	7
96	13	196	12
97	9	197	11
98	9	198	8
99	9	199	10
100	8	200	9

All the experimental results are divided into 10 classes to form the Gaussian distribution and the angle, as realistic as possible, at which the roller is moved by the profiled rail, table 2.

Table 2. Processing of experimental results

Angle (°)	Number of repetitions	Relative frequency
5	3	0,015
6	5	0,025
7	17	0,085
8	32	0,160
9	55	0,275
10	34	0,170
11	24	0,120
12	15	0,075
13	8	0,040
14	7	0,035

Based on table 2, Gaussian distribution is shown in figure 6.

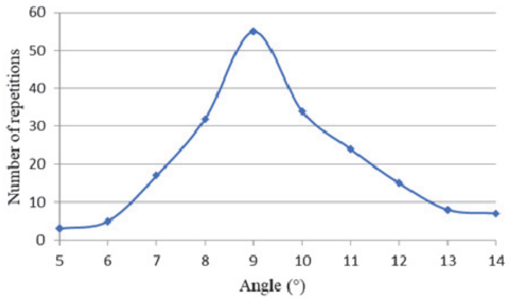

Fig.6. Gaussian distribution of experimental results

5. DISCUSSION OF THE EXAMINATION RESULTS

By analysing the experimental results (table 2) it can be seen that statistically observed the highest probability that the angle value that makes the roller motion per profiled guide is 9° and that probability is 27.5%. This is confirmed by Gaussian normal distribution constructed on experimental data and shown in figure 5.

By knowing this angle and the mass of the roller it is possible to calculate the frictional force of roller per profiled guide.

$$F_\mu = m \cdot g \cdot \sin\alpha \quad (3)$$

$$F_\mu = 0{,}059\,(kg) \cdot 9{,}81\,(m/s^2) \cdot \sin 9^\circ = 0{,}0905\,(N) \quad (4)$$

From the equation (3) and (4) it is seen that the frictional force of this contact pair is small, but it should certainly not be forgotten in the construction of the small power drive unit where it can occupy a large relative part.

6. CONCLUSION

More stringent regulations on the energy efficiency of machines and devices force designers to maximize energy use. To this end, the knowledge of all the parasitic forces that must exist in any kind of movement is crucial to the proper design of the driving system. The study carried out in this paper shows that the resistance to motion of roller is less than 0,1 (N). Since this is a miniature profiled guide that usually finds its application in low-powered driving systems, this resistance can take up a large relative part of the available system power, so as such must be taken into when dimensioning the driving system.

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