EXPERIMENTAL STUDIES OF THE FRICITION PHENOMENON FOR STEEL ON OTHER MATERIALS FRICITION COUPLES AT LOW SLIDING VELOCITIES

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Abstract: The paper presents an experimental study of the friction phenomenon at low sliding velocities conducted on a test bench provided by the GUNT company. It analyses the tribological behavior in dry conditions of different friction couples for which one of the materials is steel: steel – steel, steel – aluminium, steel – gray cast iron, steel – PVC, steel – teflon, steel – bronze and steel – polyamide. The evaluated parameter was the variation of the friction coefficient as a function of the normal force and the slip rate. Finally, after comparing the results, the best pair of materials in terms of friction was determined.

Key words: friction coefficient, friction couples, low sliding velocities

1. Introduction

Tribology is the multidisciplinary science that studies the processes of friction, lubrication and wear that occur in the presence of the relative motion between two surfaces in contact.

In the tribological domain there are still many fundamental problems that have not yet been completely elucidated because of the complexity of the phenomena. Of these, we mention: the relations between the static and kinetic friction coefficients, the static friction coefficient’s dependence of idle time and the kinetic friction coefficient’s dependence of the speed and acceleration of the movement, etc. Such problems appear in the stick-slip phenomenon or in the friction phenomenon at low velocities 1.

At low sliding speeds, in dry, limit or mixed friction conditions, the movement can have intermittences or jerks. This phenomenon is called stick-slip. Typically, for the stick-slip phenomenon to occur, the static friction coefficient ($\mu_s$) between the two contact surfaces of the friction materials must be greater than the kinetic friction coefficient ($\mu_k$). In consequence, the friction force varies as shown in Fig. 1. Similar phenomena appear at low sliding velocities.

As it is known, the stick-slip phenomenon appears in friction couples with dry or limited friction regime, when the sliding speed is in the range of 0.01 – 3 mm/s or when the angular speed is somewhere in the 1 – 25 rad/s 1,2,3,4.

In the general case, $\mu_s$ and $\mu_k$ can be complicated functions of sticking time and surface
speed, respectively. Furthermore, static friction is a constraining force during sticking, while kinetic friction is an applied force during slip.\(^1,5\)

The paper aims to study the stick-slip phenomenon by analyzing the tribological behavior in dry conditions of different friction couples for which one of the materials is steel: steel – steel, steel – aluminium, steel – gray cast iron, steel – PVC, steel – teflon, steel – bronze and steel – polyamide. The evaluated parameter was the variation of the friction coefficient as a function of the normal force and the slip rate. Because the data acquisition time was high (1 sec.) the stick-slip phenomenon could not be properly highlighted in the graphic analysis of the variation of the friction coefficient.

2. The test bench

The experimental determinations have been conducted on a GUNT Tm 260.04 test bench. The test bench allows the study of the stick-slip phenomenon and the evaluation of a series of tribological parameters for different friction couples.

A general view of the test bench is presented in Fig. 2.

![Fig. 2. General view of the test bench](image)

As shown in Fig. 3, the test bench is composed of: the base frame (1); the drive system (2); friction couple module (3); scaled weights (4); measurement module (5); transducer cable connector (6); force transducer (7); spring (8); traction cable (9).

This setup allows us to highlight the variation of the friction coefficient for different pairs of materials. The friction couple is composed of a stainless steel rotating disc and a ring pad of different materials, which are loaded by placing cylindrical weights horizontally on top of them. A cable prevents the ring pad and the weights from rotating with the disc. The cable is connected to a force transducer via a tension spring. An open cup surrounds the friction disc allowing the use of different lubricants can be used.

![Fig. 3. Schematic layout of the test bench](image)

The drive module is the basis for the tests with corresponding accessories. It consists of a robust base frame made of anodized aluminum profile. The drive of the various optional modules is provided by an adjustable dc gear motor which is connected to the control unit. The rotation speed is continuously adjusted with precision by means of a 10-turn potentiometer, electronically controlled and displayed on a digital display. The friction forces are measured by strain gauges. The control unit processes these values and displays them.

The technical characteristics of the test bench are:

- Output shaft speed of the drive system: continuously variable in the 0 ... 200 rpm range;
- Maximum capable force of the force transducer: 50 N;
- Torque: 18.5 Nm;
- Interior diameter of the friction couple: \(D_i=60\) mm;
- Exterior diameter of the friction couple: \(D_e=60\) mm;

3. Description of the experimental tests

This experimental module allows the visualization of the static friction and sliding friction as well as the effects of slip-stick.

For the current experiments, the ring pad was made out of seven different materials: steel, aluminium, gray cast iron, PVC, teflon, bronze and polyamide. These seven disc pads are presented in Fig. 4.
The seven different friction couples were tested at four normal loads: 10 N, 20 N, 30 N, and 40 N. The rotation speed was increased from zero until the steady state was achieved.

Finally, we analyzed the evolution of the friction coefficient in function of time and the charge for each pair of friction. The friction coefficient was determined with Coulomb's law, as the ratio between the friction force obtained from the experimental tests and the normal load:

\[ \mu = \frac{F_f}{G} \]  

(1)

4. Results

The experimental results are analyzed graphically from the point of view of the evolution of the friction coefficient in time.

The variation of the friction coefficient for a normal load of 10 N can be observed in Fig. 5.

In Fig. 6 we can observe the evolution of the friction coefficient for a load of 20 N.

Next we have the evolution of the friction coefficient for a load of 30 N, as shown in Fig. 7.

Finally, the evolution of the friction coefficient can be observed in Fig. 8.
In terms of friction coefficient variation, the steel – PVC and steel – teflon have a very good behavior, with just a few jerks or none. These two friction couples have small values of the friction coefficient, which decreases as the load increases. For steel – teflon, we can see some frictional instability for the maximum load, 40 N, in the beginning of the tests.

5. Conclusions

After analyzing the result obtained from the experimental determinations we can conclude that the friction couple steel – gray cast iron has the lowest and most stable friction coefficient in three of the four load cases, making it the best of all seven friction couples in terms of stability of the friction coefficient at low sliding velocities. This is explained by the known fact that the two materials form an anti-friction couple.

For the lowest load, 10 N, the steel polyamide friction couple has the lowest values of the friction coefficient, but is not as stable as steel-gray cast iron.

The steel – aluminium friction couple has the highest values of the friction coefficient, this being explained by the fact that aluminium is a very ductile material.

We note that for the steel – bronze friction couple the friction coefficient has almost the same behavior for all the four loads.

The steel – steel friction couple, after aluminium, has the second weakest behavior in terms of friction coefficient variation, with high values of the friction coefficient.

For the 10 N load, the steel – polyamide pair has much lower values of the friction coefficient compared to the other three loads, which are similar with each other.

Fig. 8. Variation of the friction coefficient for a load of 40 N at low velocities

References


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