Evaluation of tribotechnical parameters of polymer compounds used in machine tool construction

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Abstract. The conducted research of the coefficient of friction of the polymer compound applied by printing on the guides of the grinding machine. The results were obtained using an electromechanical device developed by the authors, when changing the speed of the relative movement of the caliper along the guides, the normal pressure force, and the type of lubricant. It was found that the use of polymer material in the machine guides reduces the coefficient of friction and ensures smooth movement of the calipers at low speeds. The use of solid lubricants based on fluoropolymer allows you to further reduce the coefficient of friction in the machine guides and ensure uniform movement of the calipers throughout the speed range.

1. Introduction
The use of guides with a polymer coating based on epoxy resin and with the addition of molybdenum disulfide and other antifriction components has significantly increased the dynamic performance of machines while reducing the energy consumption of drives in the domestic machine tool industry.

Despite significant advances in the creation of polymers, work in this direction continues, in order to obtain materials that exceed the existing analogues in their antifriction properties.

The laboratory of Vladimir state University developed the polymer compound "Elatex" based on epoxy resin with the addition of solid lubricants and fillers for application to the guides of grinding mills.

2. Measurement instrumentation
The anti-friction properties of the developed compound were initially determined using the RU163380 tribometer, which allowed us to study the friction characteristics of samples moving on a metal surface that imitates guides. The research was carried out in the laboratory, since the existing tribometers are not adapted to perform measurements directly on the machine, which did not allow us to establish a complete picture of the change in the coefficient of friction of the polymer, which takes place in real operating conditions.

To eliminate this drawback, a portable measuring device was developed that made it possible to measure the coefficient of friction directly on the machine with modes that simulate the working and idling of the caliper. The design of the device allows the use of samples with various shapes and sizes. The scheme of the device for measuring the coefficient of friction is shown in figure 1. [7]
Figure 1. Scheme of a device for measuring the coefficient of friction.

The device consists of a strain-gauge sensor 2, which is connected to the carriage of the test sample 5 by a leash 1 and cantilevered in a precision guide 3 moved by an electric motor through a conductor 4. The engine control unit allows to set the movement of the engine at a fixed speed.

The sensor 2 is a plate made of 40H elastic steel with a thickness of 2 mm, a width of 30 mm and a length of 100 mm, respectively, to which are glued wire strain gauges KF5P1-10-100, connected according to the Wheatstone bridge scheme.

The signal from sensor 2 is sent to the Ni 9237 strain gauge electronic module, digitized and processed using software RU 2018613116. The measuring device works under a control program developed by the authors in the LabView software environment.

The total deviation value of the measuring device used was ±0.62%.

Research of polymer material friction

The research of the developed compound was made in pairs with the metal, and the effect of the sample speed, the normal pressure force, and the type of lubricant on the coefficient of friction was checked.

At figure 2 shows the change in the coefficient of friction of the sample depending on the speed of relative movement. As can be seen from the graph, there is a monotonous and nonlinear increase in the coefficient of friction, which can be explained by the following phenomena.

During the movement of the sample, the internal contact forces of the test pair are redistributed. At the moment of starting, the sample is exposed to the normal component of the load, and at the moment of movement, a tangential component is added. Initially, under the action of normal load, there occurs crushing of asperities of the polymer, and then cut.

As a result of the redistribution of the reference areas, the transition from an incomplete rest friction force to a full one occurs. The greatest friction force occurs at the boundary point of the transition from rest friction to sliding friction, since it is additionally necessary to overcome the intermolecular bonds that occur between the contacting surfaces. This leads to an increase in the work spent on overcoming the friction forces and as a result to an increase in the coefficient of friction. [1, 2, 3]
The effect of the normal pressure force on the coefficient of friction, at a constant rate of relative movement of the sample, is shown in figure 3.

As noted in [1, 2, 3, 6] the influence of the normal pressure force is significant. It is believed that as a result of increasing the load on a separately selected indenter the friction force increases.

In practice, this statement for the polymer – metal pair was close and the following phenomenon was observed. The normal component of the friction force acting on the actual contact area determines the normal pressure. As the contact area increased, the normal pressure decreased and the coefficient of friction decreased.

At the same time, an elastic polymer with a high degree of viscosity begins its flow, which results in the introduction of metal guides into the micronerities and increases the contact area. In this case, the appearance of adhesive forces is inevitable, however, the presence of lubricants in the polymer prevents the formation of adhesive contact, resulting in semi-liquid friction, in which the coefficient of friction acquires a certain stable value.[4,5]

In our case, this occurred at a normal pressure of 16 kPa, when the coefficient of friction reached a value of 0.65. Before that, the coefficient of friction had a maximum value and gradually decreased with increasing load until the moment of stabilization in the contact pair.
The results of the researching of the effect of lubricants on the coefficient of friction of the polymer – metal pair are shown in table 1. Analysis of the results shows that a number of lubricants significantly affect its value.

Teflon and fluoroplast belong to these lubricants. The use of «Forum» fluoroplastic lubricant allowed for a friction coefficient of 0.07-0.08 at sample speeds of 0.25 – 0.5 m/min. At the same time, there was a uniform movement and a constant coefficient of friction along the entire path of the sample.

The use of mineral anti-jump oil increased the coefficient of friction and led to the appearance of acceleration and deceleration areas when the sample was moving. The presence of a liquid film could only provide semi-liquid friction, which increased the adhesive component, which required additional effort to overcome.

| №  | Type of lubricant | Force of normal pressure, [N] | Speed of the sample, [m/min] | Rest friction force, [N] | Friction force of the movement, [N] | Coefficient of friction |
|----|------------------|-------------------------------|-------------------------------|-------------------------|-----------------------------------|-----------------------|
| 1  | «Forum»          | 50                            | 2,5                           | 3,61                    | 3,54                              | 0,0708                |
| 2  | «Bosch»          | 50                            | 2,5                           | 5,12                    | 4,95                              | 0,0990                |
| 3  | Without lubrication | 50                      | 2,5                           | 6,91                    | 6,54                              | 0,1308                |
| 4  | Gazprom lxep2    | 50                            | 2,5                           | 9,05                    | 8,86                              | 0,1772                |
| 5  | Lynx Lipyc       | 50                            | 2,5                           | 9,32                    | 9,17                              | 0,1834                |
| 6  | Gear oil, GM     | 50                            | 2,5                           | 10,90                   | 10,70                             | 0,2140                |
| 7  | SHrus-4          | 50                            | 2,5                           | 12,47                   | 12,16                             | 0,2432                |
| 8  | Mobil xhp222     | 50                            | 2,5                           | 14,42                   | 13,94                             | 0,2788                |
| 9  | Brake fluid      | 50                            | 2,5                           | 14,82                   | 14,63                             | 0,2926                |
| 10 | Toyota 90999-94161 | 50                | 2,5                           | 15,23                   | 14,78                             | 0,2956                |
| 11 | Litol            | 50                            | 2,5                           | 16,43                   | 16,00                             | 0,3200                |

The use of automotive lubricants made it possible to establish their complete unsuitability for the polymer-metal pair. The use of this type of lubricant increases the coefficient of friction, which is contrary to the requirements of the technical specification. [4]

The use of a universal measuring device for recording friction parameters made it possible to research the coefficient of friction of polymer – metal samples in the laboratory and directly on grinding machines.

It was found that the use of polymer material in the machine guides reduces the coefficient of friction and ensures smooth movement of the calipers at low speeds.

The use of solid lubricants based on fluoropolymer allows you to further reduce the coefficient of friction in the machine guides and ensure uniform movement of the calipers throughout the speed range.

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