The static friction of a series of polymer—steel friction pairs has been investigated as a function of the stationary contact time at temperatures from $-150^\circ$C to $+200^\circ$C. The experimental technique is described and the results of the experiments are evaluated.

Antifriction materials based on organic polymers combined with metals are being ever more widely used in bearing assemblies operating under vacuum conditions. These materials possess a number of advantages: first, in most cases there is no question of the contact surfaces welding under vacuum at elevated loads and temperatures; secondly, these materials are capable of operating under dry-friction as well as boundary-friction conditions.

Investigations of the friction of self-lubricating materials under vacuum conditions at low contact velocities indicate that the force of friction in a vacuum is much greater than in air [1]. At the same time, it is known that the contact rheology and the variation of the coefficient of friction with the duration of stationary contact lead to a "stop effect" and the occurrence of mechanical relaxation oscillations at low sliding velocities. If one takes into account the low power of the motors of vacuum instruments and mechanisms, one can understand why it is necessary to know the static friction characteristics for bearing assemblies that operate with different stationary contact intervals and different surface temperatures.

We have investigated the static friction of a series of polymers paired with steel in a vacuum of $10^{-5}$ mm Hg. The effect of temperature, normal load, and the physico-mechanical properties of the materials were considered.

For this purpose we developed an experimental procedure and designed an instrument that enabled us to determine the static friction parameters under various test conditions.

Most instruments for investigating static friction in a vacuum incorporate an inclined plane along which the specimen slides [2]. The static force of friction is measured by rotating the vacuum chamber until the specimen starts to slide. In this case the coefficient of friction is determined with respect to the angle of inclination of the plane corresponding to this moment. Such apparatus, while making it possible to conduct a large series of experiments without resealing the vacuum chamber, does not permit a detailed study of the transition to sliding, which is most important for gaining an understanding of the contact processes.

The rejection of this method soon confronted the investigators with the problem of transmitting motion to the specimen in contact without disturbing the vacuum. In existing friction apparatus the specimens are displaced by electric motors located inside or outside the vacuum chamber. In the latter case the motion is transmitted from the motor shaft through sylphon bellows and diaphragms or through solid, liquid and gas seals [3]. In certain instruments the motion is produced by magnetic, electromagnetic, or electric fields through the chamber wall [4]. The choice of the method of transmitting the shearing force is based on the technical requirements and considerations of efficiency.

In our friction instrument, which is shown schematically in Fig. 1, the source of motion is the elongation of a heated rod introduced into the vacuum chamber. Three test specimens 1, cylindrical rods 8 mm...
In diameter with a total area of 1.5 cm², are inserted in sockets in the moving carriage 3. The legs are compressed by a load P against a flat plate 2, the lower element of the friction pair, which is secured to a fixed base 4. The shearing force Q is transmitted by means of a lever 5 through an elastic element 6, to which strain gauges are attached. The minimal convective heat transfer under vacuum conditions and the special design of the rod ends make it possible to obtain a linear shearing force. The rate of application of the load can be varied over a broad interval by regulating the stabilized voltage supplied to the heating spiral. The instrument is placed over a diffusion pump beneath a glass dome. The temperature of the friction surface is controlled by pumping a liquid heat transfer agent through the internal cavity of the base. The surfaces of the gauges and the elastic element are coated with picein in accordance with El’kin’s method [5].

The materials selected for investigation were polyamide resin (Kapron-B), Ftoroplast-4 (Teflon), low-pressure polyethylene, and the antifriction material Maslyanit* based on polyamide resin and plasticized in accordance with the method described in [6]. The lower element of the friction pair was a plate of steel 45 that had not received any heat treatment. The choice of materials was determined by the design of the instrument and was related with the need to heat the friction surface. The specimens were cleaned with organic solvents. They were then introduced into the instrument and brought into contact. After a certain time a tangential load, whose rate of increase was constant in all the experiments, was applied to the specimens. This load increased until it reached the value of the total static force of friction. By means of the strain gauges the entire transition process was recorded on the 120-mm photosensitive paper of a loop oscillograph. The transition from a state of rest to a state of motion was accompanied by a sharp decrease in load.

The tests described began at a chamber pressure not exceeding 10⁻⁵ mm Hg. For the pump employed the time required to create this vacuum was 10-15 min. In order to obtain the force of friction at zero contact time in a vacuum we investigated the sliding of the polymer over the steel. The presence of an elastic element in the system produces mechanical self-oscillations. This leads to the nonuniform displacement of one specimen over the surface of the other. The corresponding variation of the tangential force is shown in Fig. 2. In our experiments the separating force corresponding to the third or fourth oscillation was taken as the static force of friction at zero contact time. The directly measured force of friction at zero contact time in air is close to that found by the method described in a vacuum.

For all the friction pairs investigated the static force of friction increases with increase in stationary contact time, tending to a certain limit. The steady-state value of the force of friction and the time required to reach it are determined by the test conditions and the characteristics of the material itself. For materials with a lower modulus of elasticity and hardness the variation of the force of friction with time is more intense.

An increase in the normal load, which affects not only the nature of the dependence of the static force of friction on the stationary contact time but also the force of friction itself, leads to a similar result.

The vacuum has an important influence on the force of friction. By eliminating moisture condensation and the presence of air bubbles in the defects and cracks on the friction surfaces, by partially evaporating surface films and by preventing the contamination of the surfaces with dust and dirt, the vacuum not only accelerates the attainment of the limiting value of the static force of friction but also increases that

* The material was developed in the new antifriction materials laboratory of the Novocherkassk Polytechnic Institute.