The friction and wear of Fe, Mo, Ti, Al, and a nitrided 38KhMYuA steel in liquid nitrogen were studied and experimental data on the behavior of these metals in low-temperature media were obtained. The effect of the nature of the metal, normal pressure and test duration on the friction coefficients and linear wear was determined.

The problem of friction and wear at low temperatures has recently gained considerable importance. While the effect of elevated temperatures on physico-mechanical and antifriction properties of materials has been extensively studied, little is known about the effect of low temperatures.

The aim of this investigation was to study certain aspects of friction of metals in liquid nitrogen. The experimental materials included several pure metals (99.80% Fe, 99.99% Mo, 99.76% Ti, 99.97% Al) and a nitrided 38KhMYuA steel which is used in friction pairs working in low-temperature media.

The friction took place between the end faces of two hollow cylindrical specimens measuring ø16 x ø8 x 10 mm and ø15 x ø9 x 10 mm (lower and upper specimens, respectively).

Each material was tested for 1 hr at a constant sliding speed of 0.039 m/sec. The friction moment was measured with the aid of a special apparatus comprising strain sensing elements, an amplifier, and an N-700 loop oscillograph. The extent of linear wear of materials tested was measured with a UIM-21 universal measuring microscope.

Before testing, all the specimens were ground with a PP250 ø 20 x 75 EB-40 wheel on a model 3G-71 grinding machine and then polished with grade M-28 emery paper. Immediately before testing, each specimen was carefully washed in purified 95% ethyl alcohol.

When friction tests are carried out in liquid nitrogen, it is impossible to ensure the preservation and even more so the reformation of oxide films on rubbing specimen surfaces. As a result, metal surfaces in friction under these conditions tend to seize, which produces a sharp increase in the rate of wear.

Some of our experimental data are reproduced in Fig. 1 in the form of histograms showing the dependence of the friction coefficient and linear wear rate intensity on the nature of the friction pair materials. It will be seen that metals with bcc and fcc crystal lattices are subject to intense wear as a result of the onset of seizure due to their athermal plasticity. The extent of wear of metals with a hexagonal crystal lattice (Ti and the ε-phase in nitrided 38KhMYuA steel) tested under identical conditions is negligible.

![Graphs showing linear wear and friction coefficients](image-url)
Data in Fig. 1b show that the differences in the friction coefficients of metals with different crystal lattices are substantially smaller.

Among the nitriding grades of steel, the most widely used in the Soviet Union is 38KhMYuA steel (0.35–0.42% C; 0.3–0.6% Mn; 1.35–1.65% Cr; 0.7–1.2% Al; 0.15–0.25% Mo). The presence of carbon in this steel leads to the formation of carbonitride phases of the Fe$_2$(N, C) or Fe$_2$(C, N) type on its surface. Nitride Fe$_2$N ($\varepsilon$-phase) is an interstitial phase with a wide homogeneity range and a hexagonal crystal lattice. The high hardness of nitrided steel surface is attributed to a high degree of dispersion of nitride particles [1].

Investigations of friction and wear at subzero temperatures, at which the rate of diffusion is substantially reduced, make it possible to deepen our understanding of plastic deformation and strain hardening of metals. These conditions are most favorable for the manifestation of the athermal plasticity of metals, especially at slow sliding speeds at which the effect of friction-generated heat is almost completely eliminated.

The specific characteristics of friction in low-temperature media (reflected in the onset of seizure) can be explained in terms of dislocation theory. According to the fundamental concepts of the mechanism of seizure formulated on the basis of this theory by Kostetskii and co-workers [2–6], seizure cannot occur unless clean metal surfaces are brought together within the distance of action of interatomic forces. When this happens as a result of plastic deformation of metals in the actual contact zone, active dislocation centers with a sharply increased concentration of vacancies and dislocated atoms are produced [2, 4, 5]. The presence of vacancies and dislocated atoms facilitates interdiffusion of atoms of the metals in contact, this leading to the formation of interatomic bonds [2, 4, 6]. At the same time, electrons of interacting atoms become rearranged to form more stable configurations [7]. Thus, the above outlined concepts make it possible to consider the problem of the susceptibility of metals to seizure from the standpoint of their crystal and electron structures.

Analysis of the results obtained shows that the most intense seizure takes place in friction between similar metals with cubic crystal lattices which are subject to more intense wear than metals with a hexagonal lattice. The results of this investigation and data on the wear of metals in vacuum [6] lead to a conclusion that the main cause of this difference is the difference in the probability of formation of point defects in metals with cubic and hexagonal lattices.

Point defects are formed as a result of the movement of dislocations and their interaction [8]. The density of point defects is determined in the first instance by the dislocation density. Other conditions being equal, the number of dislocations formed as a result of plastic deformation depends on the number of slip planes in a given crystal, the highest dislocation density being observed in crystals oriented favorably for multiple slip, while the most favorable conditions for the interaction of dislocations exist when dislocations are moving along intersecting slip planes [9].

In the case of metals with a hexagonal lattice, the slip takes place only in one system of planes parallel to the basal plane; in the absence of bending or twinning, plastic deformation of crystals of this kind approaches the ideal laminar flow [9], as a result of which the dislocation density in metals with a hexagonal lattice is low.

The most favorable conditions for the realization of a high dislocation density exist in metals with cubic lattices in which slip can take place in several plane systems. Metals of this kind work-harden most intensely because of the large number of barriers to the movement of dislocations formed as a result of interaction between dislocations moving along intersecting slip planes [9].

Thus, point defects of the vacancy and interstitial type are formed more readily in metals with cubic lattices than in hexagonal crystals.