ANTIFRICTION PROPERTIES OF BORON NITRIDE DURING DRY FRICTION IN GASEOUS MEDIA AND AT LOW TEMPERATURES

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Owing to design or technological considerations, many combinations of machine components are expected to operate without lubrication in gaseous environments, in air at reduced pressure, or at low temperatures. The usual liquid and semiliquid lubricants, which are successfully employed under normal conditions for lowering friction and wear, rapidly evaporate in air at very low pressure, and are totally unsuitable for low-temperature operation. Under such conditions, the use of conventional antifriction materials cannot secure an adequate service performance of machines and instruments because of the very high friction and wear of their components.

An urgent need has thus arisen for new antifriction materials securing low friction during unlubricated operation in a sufficiently wide range of service loads, speeds, and temperatures and having physicomechanical properties which undergo little change under the influence of low temperatures and inert gaseous environments.

According to literature data, promising antifriction materials include boron nitride, which is distinguished by high chemical resistance in corrosive media, in a vacuum, and at low temperatures. The quantitative characteristics of the friction and wear process of boron nitride were investigated in a special vacuum cryogenic installation, within which a friction unit was housed. The latter was made to rotate by an electromagnetic coupling located outside the test chamber. The friction unit operated on the principle of friction between specimens and a wear disk rotating in a horizontal plane. The coefficient of friction during testing was determined by measuring the elastic torsional strain of the specimen holding rod. Wear determination was based on measurement of the linear dimensions and weight loss of specimens.

Effect of Low Temperatures

Experiments were performed on specimens from five boron nitride grades (Nos. 1, 2, 3, 4, 5) which differed from one another in the degree of coining. The tests were conducted at temperatures of 300, 273, 195, and 77 K. The temperature of 273 K was attained by pouring distilled water with ice into a twin-walled Dewar flask, the temperature of 195 K by pouring in a mixture of ethyl alcohol and dry ice, and the temperature of 77 K by pouring in liquid nitrogen. Testing began 30 min after the filling of the flask and cessation of boiling of the low-temperature liquids as a result of heat transfer from the internal parts of the installation.

The experiments designed to determine the influence of cryogenic temperatures on the friction and wear of the materials were conducted at residual chamber pressures of 133 and 322 N/m², which ensured that the friction surfaces were protected against moisture condensing in the form of snow. Both the chamber and friction zone temperatures were measured during experiments by means of Pt/Pt-Rh thermocouples connected to EPD potentiometers.

Parts operating at liquid gas temperatures are very frequently made from brass and austenitic stainless steels, the strength and ductility characteristics of which are substantially raised under these conditions. Consequently, disks from 1Kh18N9T stainless steel nitrided to a Rockwell C hardness of 62 were used as the mating friction material. Table 1 presents comparative data on the wear of boron nitride (specimens Nos. 1 and 4), without taking into account the running-in period.

An analysis of the experimental results in Table 1 shows that environment temperature exerts a very significant influence on the wear of boron nitride: with lowering temperature, the weight loss due to wear markedly increases.

The inflection points of the curves in Fig. 1 determine the maximum permissible pressure on boron nitride operating against 1Kh18N9T steel at 77 K. Examination of the friction surfaces and observations made during the wear process demonstrated that, at pressures below the critical values, the friction surfaces of specimens are coated with a bright, polished film. When the critical value of pressure is attained, the film is stripped from the friction
Fig. 1. Effect of pressure on wear of boron nitride at liquid nitrogen temperature: 1) specimen No. 1; 2) specimen No. 2; 3) specimen No. 3; 4) specimen No. 4. Temperature 77°K.

Fig. 2. Effect of temperature on coefficient of friction of boron nitride: 1) specimen No. 1; 2) specimen No. 5.

Table 1

<table>
<thead>
<tr>
<th>Environment temperature °K</th>
<th>Wear in 2h of operation, mg</th>
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<tbody>
<tr>
<td>specimen No. 1</td>
<td>specimen No. 4</td>
</tr>
<tr>
<td>300,15</td>
<td>21</td>
</tr>
<tr>
<td>273,15</td>
<td>22</td>
</tr>
<tr>
<td>195,15</td>
<td>27</td>
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<tr>
<td>77,15</td>
<td>32</td>
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surface of the specimen, and this is probably responsible for the subsequent seizure of friction pairs. The prevalence of the seizure process during this period is indicated both by the sharp rise of the friction force (and wear) and the increase of the coefficient of friction and temperature of the friction surfaces.

Thus, at a normal wear rate, the bulk temperature of specimens exhibited only slight fluctuations about some steady-state medium; in operation under seizure conditions, however, a pronounced temperature drop was observed.

Figure 2 shows the influence of environment temperature on the coefficient of friction of boron nitride. It will be seen from these curves that, as environment temperature decreases, the coefficients of friction of specimens Nos. 1 and 5 increase approximately to the same extent. Thus, taking the extent of wear and the coefficients of friction as service performance criteria of these materials, both boron nitride compositions may be employed for operation with 1K18N9T stainless steel at liquid nitrogen temperatures.

Determination of the amount of wear and the coefficient of friction cannot, of course, provide a complete picture of the antifriction properties of these materials at low temperatures. Further studies will be required of the effect of temperature on the physicomechanical characteristics of boron nitride, the wear process of this material at low temperatures, and the characteristics of rupture of its surface layers under these conditions.

Influence of Gaseous Environments

Figure 3 shows the dependence of the weight loss due to wear of the boron nitride materials of friction velocity in various gaseous environments. Before admission into the chamber, gaseous argon, nitrogen, and helium were dried by passage through a vessel with silica gel. Prior to each experiment, the required gas was blown through the chamber of the installation to expel the remaining traces of air; next, a stream of the gas was established in the chamber at a small excess pressure due to a water seal. Initially, a series of experiments was conducted in an air atmosphere, and the results obtained were regarded as the starting data. Subsequently, using specimens and the mating friction material prepared in the same manner, experiments were carried out in chemically pure argon, nitrogen, and helium.

Negligible wear was observed in air in the friction velocity range between 0.5 and 4.4 m/sec (Fig. 3). In this range, wear is caused by the formation and crumbling out of brittle layers. As the friction velocity increases from 4.4 to 6 m/sec, the atmospheric wear rate curve rises steeply, and wear on a 1000-m path increases in this velocity range from 22 to 1000 mg, i.e., by a factor of almost 50. During operation in the friction velocity range 4.4-6 m/sec, the surface film is stripped from the specimen, and film removal is faster than film formation; this is probably responsible for the seizure of the mating materials. The subsequent increase of friction velocity to 10.5 m/sec brings about some reduction of wear. Thus, in the friction velocity range investigated, the curve of atmospheric wear of these materials vs friction velocity passes through a maximum.

A slightly different picture of the wear process is observed in the case of friction in the inert gases. During tests in argon, nitrogen, and helium, specimens exhibited much higher wear rates than in air. At a friction velocity