MANUFACTURE AND PROPERTIES OF A FRICTIONAL MATERIAL FOR ELECTROMAGNETIC CLUTCHES

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In the last few years there has been a considerable increase in demand for frictional materials suitable for dry operation at various speeds, pressures, and temperatures. This undoubtedly applies also to sintered frictional materials for electromagnetic clutches operating without lubricant. Attempts to employ existing materials for this purpose have proved unsuccessful. Recently, a new frictional material, FMKM-1, has been formulated possessing the required qualities; a process has been developed for its manufacture, and the effect of various processing parameters on its physico-mechanical and frictional properties has been investigated. Fairly detailed descriptions of the method of manufacture of this material will be found in [1-3].

In the present work the frictional properties of sintered specimens were determined, using an I-47 friction machine, over the speed range 0.13-6.3 m/sec under a specific load of 3 kg/cm². A study of the effect of pressing pressure (in the range 2-4 tons/cm²) on the frictional characteristics and hardness of FMKM-1 material revealed that, with rise in pressing pressure, the coefficient of friction and wear resistance of the material changed only slightly, while its hardness grew. In view of this, in subsequent investigations specimens were pressed under a pressure of 3 tons/cm².

An investigation into the dependence of the frictional characteristics and hardness of the material on pressure, in the range 5-15 kg/cm², applied during sintering showed that, with rise in sintering pressure, the hardness, wear resistance, and coefficient of friction of specimens increased; however, at a pressure of 15 kg/cm² a change in specimen geometry (strain) occurred during sintering, which could not be tolerated in the manufacture of machine components. On the other hand, after sintering under a pressure of 5 kg/cm² separation of frictional elements from their steel backing plates was sometimes observed. Thus, the optimum sintering pressure was 10 kg/cm².

In further tests, designed to show the effect of sintering temperature in the range 750-850°C on the properties of the material, specimens sintered at 750°C were found to be characterized by low hardness, which had an adverse effect on their frictional properties. Specimens sintered at 850°C frequently exhibited incipient melting with loss of shape—a phenomenon which was clearly undesirable. The optimum temperature proved to be 810°C, with a holding time of 3 h.

In our sintering experiments two schedules were employed: 1) direct, uninterrupted heating to the required temperature at a rate of about 200°C/h; 2) stepwise heating with an arrest at 400°C, with the application of pressures of 5 and 10 kg/cm² before and after the arrest, respectively. Similar values of hardness were recorded after these heat treatments, 35-40 HB after direct heating and 40-50 HB after stepwise heating. The quality of adhesion of frictional elements in both cases was satisfactory.

Two types of FMKM-1 specimens were prepared: single-metal ones, for frictional pairs required to transmit comparatively small loads, and bimetallic, for pairs capable of transmitting loads in excess of those permitted by the strength of the frictional material itself.

To determine the effect of surface condition of steel backing plates and their coatings on the strength of adhesion of FMKM-1 elements after sintering, steel bases were subjected to one of the following preparatory treatments: 1) sand blasting; 2) copper plating (deposit thickness 10-15 μ) by the cyanide process, without heat treatment; 3) cyanide copper plating with annealing; 4) nickel plating. Bend tests showed that adhesion was poor after sand blasting and satisfactory after the other treatments.
A typical microstructure of a specimen produced by the above-described method is shown in Fig. 1. It will be seen that the matrix of the alloy was a copper-tin solid solution with graphite, silica, lead, and molybdenum trioxide inclusions at its grain boundaries.

The frictional properties of FMKM-1 were determined under conditions similar to those encountered in actual service. Experimental disks fitted in an ETM-071B clutch were subjected to tests in an IM-7 stand, involving rubbing against quenched 65G (0.65% C-1% Mn) steel of 43-45 HRC hardness, ground to a Class 7 finish. In Fig. 2 are shown the results of tests carried out on FMKM-1 disks in the ETM-071B clutch at a frequency of 0.3 cycle/sec. It will be seen that the coefficient of friction was 0.26-0.27 and the wear 0.2 mg/cm²-h. Included for purposes of comparison are the results of tests on a standard frictional material, MK-5. A marked superiority of FMKM-1 alloy to MK-5 (ENIMS data) is evident.

In electromagnetic clutches, frictional materials operate at various frequencies, and a study was therefore made, in an IM-7 stand (ENIMS), of the effect of frequency of operation on the coefficient of friction and wear of the material. The variation of these service characteristics and frequency of operation is illustrated in Fig. 3. As can be seen, increasing the frequency of operation from 0.3 to 20 cycles/sec did not have a pronounced effect on the operating characteristics investigated.

In order to find a suitable mating material for FMKM-1, tests were carried out on 65G and 4Kh13 (0.4% C-13% Cr) steel specimens provided with satin chromium (SCr), hard chromium (HCr), and electroless nickel (ENi) deposits. Tests were performed in a high-speed ETM-071B electromagnetic clutch with external disks at a frequency of engagement of 10 cycles/sec. The highest wear resistance was found to be exhibited by a pair consisting of FMKM-1 and ground 65G steel (HRC 43), with which 10.7 million engagements were successfully performed at a coefficient of friction $f = 0.26-0.27$.

Good wear resistance was exhibited also by an FMKM-1 + 65G (SCr) steel pair, which enabled 9.14 million cycles of operation to be performed at $f = 0.2-0.3$, A 4Kh13 steel + FMKM-1 pair withstood 9.0 million cycles of engagement at $f = 0.22-0.26$. A small but stable value of coefficient of friction was recorded for an FMKM-1 + 65G (Scr) steel pair, with which 7.29 million cycles of operation were obtained at $f = 0.2$.