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Dry-Film Lubricants from Molybdenum Disulfide Bonded With Microfibrous Boehmite

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ABSTRACT

Binders that have been tried for powdered lamellar dry lubricants have shortcomings such as hindering the realignment of the lubricant particles or encapsulating the lubricants, making a wearing-in process necessary. A microfibrous form of colloidal alumina (boehmite) is shown to act as a superior nonencapsulating binder for molybdenum disulfide in the formation of dry lubricant films. Such films exhibit lower coefficients of friction than have been reported for molybdenum disulfide or graphite films bonded with any other material. These new lubricating coatings have good load-carrying ability and durability at any temperature below the decomposition temperature of molybdenum disulfide (700°F). Optimum performance of these boehmite-bonded films is obtained when (a) the ratio of fibrillar boehmite to MoS_2 is near 0.20, (b) the film is 0.2 to 0.5 mil thick, (c) the substrate is hard and highly polished, and (d) the film is applied as an alkaline dispersion (pH = 10) and then dehydrated by baking at 550°F.

PROBLEM STATUS

This is an interim report; work on this problem is continuing.

AUTHORIZATION

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DRY-FILM LUBRICANTS FROM MOLYBDENUM DISULFIDE BONDED WITH MICROFIBROUS BOEHMITE

INTRODUCTION

A major problem in the use of graphite or molybdenum disulfide as solid lubricants for equipment operating at high temperatures or in the vacuum of space has been the difficulty of retaining adequate lubricant between moving parts. Numerous binders have been tried (1-3), including thermoplastic and thermosetting resins, sodium silicate, and ceramic compositions (4). The organic binders are either unusable or short-lived at high temperatures. The ceramic binder must be fired at 950°F to obtain adhesion; at this temperature the MoS_2 will oxidize to the more abrasive molybdenum trioxide, and under these conditions some metals undergo serious deterioration in physical properties. Sodium silicate bonding of MoS_2 or graphite (5,6) has been shown to provide effective lubrication, e.g., in some ball bearings. The glasslike sodium silicate is somewhat water sensitive, however, and has insufficient resistance to deformation or compressive shock loading for some applications. When enough of any of the above binders is present to form a durable film, the binder completely encapsulates the lubricating solid phase; therefore a wearing-in process is required to expose the lubricant at the friction interface. Such binders also fix the lubricant particles in random orientation and interfere with their realignment parallel to the shear direction, which would provide maximum reduction of friction and wear.

A recent investigation at this Laboratory has shown that a colloidal hydrated alumina will reinforce polyfluoroethylene (Teflon) films and improve their performance as dry lubricants (7). The present report describes the formation of dry lubricant films with the same fibrous colloid. Films of MoS_2 thus bonded have shown unusually low coefficients of friction, good adhesion, and good durability. While the work described below relates specifically to MoS_2 as the lubricant component, the same bonding technique and general approach is equally applicable to graphite and other powdered lamellar dry lubricants (8).

PREPARATION OF BOEHMITE-BONDED FILMS OF MoS_2 ON METAL SURFACES

The boehmite used in this work is the hydrated aluminum oxide AlO(OH), which exists as rod-shaped particles approximately 50 by 1200 angstroms.* It has a reported surface area of 293 square meters per gram (9,10). As supplied, it contains up to 10 wt-% of acetic acid and disperses in water to form stable acidic suspensions which are compatible with cationic or nonionic surfactants. The aqueous suspension forms a gel, however, on the addition of alkaline anionic materials. Thus the viscosity and thixotropy of the aqueous system can be controlled over a wide range by adjustment of solids content and pH.

The molybdenum disulfide used in this study was supplied by the McGee Chemical Company of Upper Darby, Pennsylvania, as a powder having a rather uniform maximum

*This form of alumina is at present marketed by the E.I. du Pont de Nemours and Company under the trade name "Baymal."

dimension of 0.2 micron. As the density of MoS_2 is 4.8, it is difficult to prepare a stable dilute dispersion in water or oils. Mechanical stirring is necessary to maintain reasonably homogeneous dispersions in most liquids. A dispersion in distilled water quickly develops a pH of 4, presumably as a result of hydrolysis to form H_2S.

Water-dispersed films of MoS_2 alone can be spread with a camel's-hair brush on metal plates; however, such films are readily wiped off, leaving an ultrathin layer of MoS_2 platelets which can be removed by repeated applications of a pressure-sensitive tape. The acidic character of this dispersion causes rapid corrosion of steel surfaces. Films formed from water dispersions of boehmite alone also cause corrosion of steel surfaces because of the acetic acid present. Thus, although aqueous suspensions containing boehmite and MoS_2 in suitable proportions and without pH adjustment can be brought to a paintlike consistency that permits brush coating, the acidic nature of the mixture causes prompt corrosion of steel.

Adjustment of the pH of a boehmite/MoS_2 suspension to a pH of 10 with ammonium hydroxide caused gelation of the boehmite, so that the MoS_2 particles could not settle out on standing. This pH adjustment also reduced the incidence of rust on steel surfaces in contact with the suspension. At pH 10 the presence of from 5 to 50 g of boehmite per 100 g of MoS_2 resulted in stable aqueous dispersion containing from 60 to 65 wt-% of solids. Addition of the appropriate amount of water resulted in paintlike thixotropic systems which were readily brushed onto metal surfaces to produce films with a dry thickness of 0.2 to 0.5 mil. Since, after drying, the colloidal boehmite in the coating could be redispersed in water, it was necessary to "fix" the coating by heating it sufficiently to dehydrate the boehmite. While the moisture sensitivity was much reduced at a curing temperature of 450°F, complete dehydration was best accomplished by a brief final bake at 550° F. The baked coatings so obtained were tough and durable even when rubbed or abraded under water. Microscopic examination showed that very few MoS_2 particles were loosened by rubbing vigorously with lens tissue. Continued rubbing loosened no more particles; however, the coated surfaces took on a dark burnished appearance.

MEASUREMENT OF THE FRICTIONAL BEHAVIOR OF COATINGS

The static and kinetic coefficients of friction, the stick-slip behavior, and the durability of the coatings on various metal substrates were measured with a modified Bowden-Leben stick-slip machine which has been described elsewhere (11). Ball riders were used with loads of 1000 or 10,000 g, and for the kinetic friction measurements the sliding speed of the reciprocating traverses was 0.1 cm/sec.

EFFECT OF FILM COMPOSITION AND SUSPENSION pH ON BEHAVIOR

Variation of the proportion of boehmite in the coating changed its behavior under severe mechanical stress. When the amount of boehmite was less than 16 g per 100 g of MoS_2 present, severe rubbing with a hard rounded tool produced grainy debris. When 16 to 20 g of boehmite was present per 100 g of MoS_2, the coating appeared to be ductile under severe rubbing or when the steel specimen was bent. When more than 25 g boehmite per 100 g of MoS_2 was present, the coating was brittle and fractured when the steel plate was bent. Figure 1 shows that coatings containing near 20 g of boehmite per 100 g of MoS_2 also exhibited the lowest friction of the compositions examined, regardless of the pH of the suspension from which they were formed. Stick-slip behavior was most pronounced on coatings containing more than 25 g of boehmite per 100 g of MoS_2.

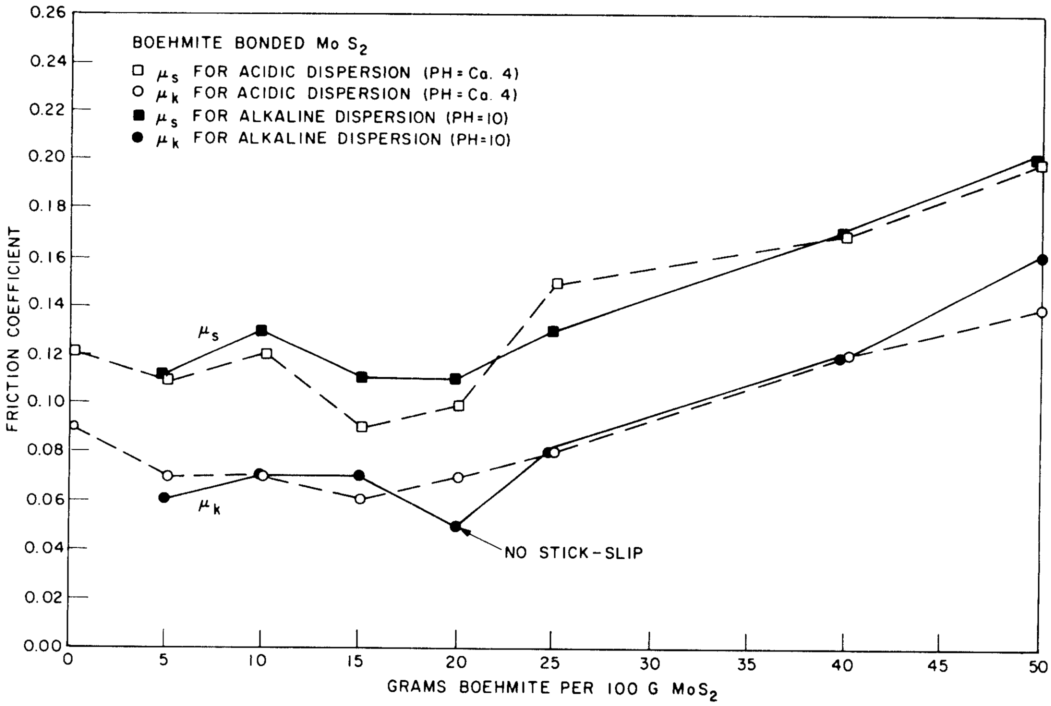


Fig. 1 - Effects of boehmite concentration and pH on friction of MoS_2 coatings at 78°F (1000-g load; 0.1 cm/sec; sandblasted SAE 1020 steel plate; SAE 52100 steel ball rider)

Figures 1 and 2 also show that films from alkaline dispersions containing 20 g of boehmite per 100 g of MoS_2 exhibited about the same static friction coefficients as those deposited from corresponding acidic dispersions. The kinetic coefficients are perhaps slightly lower for the alkaline coatings. Alkalinity also caused a more pronounced reduction in the stick-slip behavior, which disappeared completely for some of the alkaline coatings. Some degree of stick-slip behavior was found with all other bonded MoS_2 coatings examined. Except where will be otherwise stated, all of the coatings to be discussed were deposited from alkaline suspensions containing 20 g of boehmite per 100 g of MoS_2; their thickness was between 0.2 and 0.5 mil.

EFFECT OF SURFACE FINISH ON ADHESION AND PERFORMANCE

Almost all of the published data concerning the frictional behavior of bonded MoS_2 refers to coatings applied to metal surfaces which had been first prepared by chemical or mechanical roughening. Roughened surfaces appear to have been necessary to obtain satisfactory adhesion of the coating. Boehmite, however, has been found to give good adhesion on polished surfaces. Therefore, we have made some measurements on sandblasted metal specimens, but we have also compared the adhesion and performance of each composition applied to both rough and polished surfaces. Some difficulty was encountered in brushing a uniform coating on polished monel, titanium, or SAE 52100 steel. This difficulty could be corrected to some extent by increasing the solids content of the dispersion. A uniform coating could be obtained if a second coat was applied over the dehydrated first coat. The coatings stained polished brass, copper, and bronze but not aluminum, SAE 1020 steel, or rhodium.

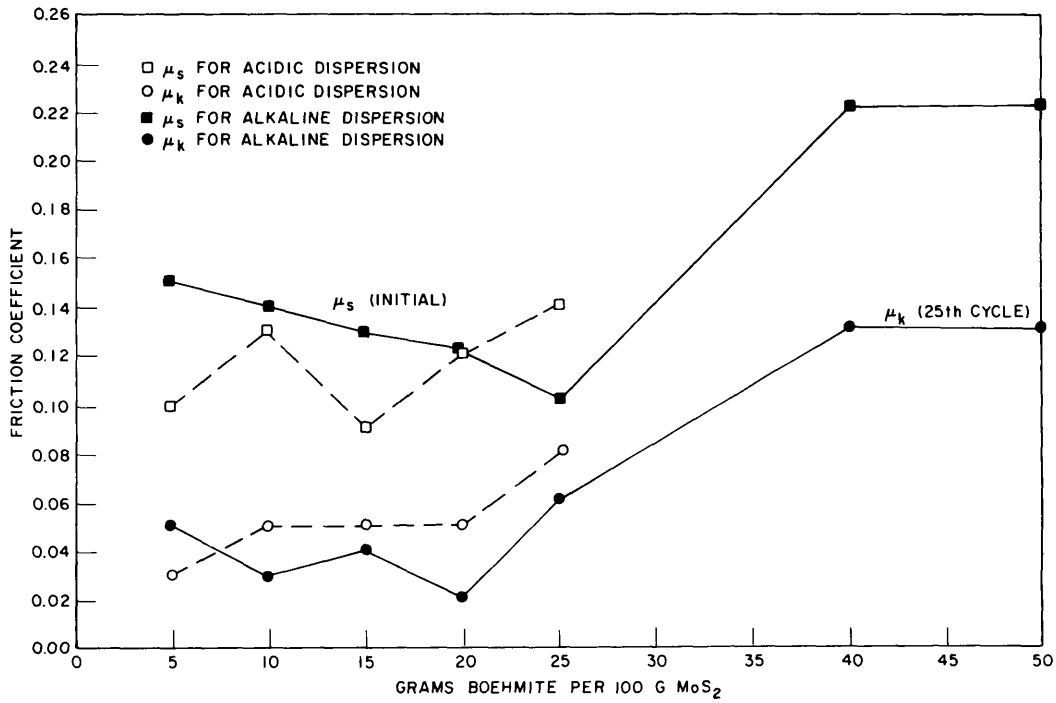


Fig. 2 - Effects of boehmite concentration and pH on friction of MoS_2 coatings at 575°F (1000-g load; 0.1 cm/sec; sandblasted SAE 1020 steel plate; SAE 52100 steel ball rider)

Coatings applied to polished surfaces appeared slightly superior to those on a sandblasted substrate. The advantage of the polished substrate was most evident at a 10,000-g load, and there was greater differences between the static frictional coefficients than between the dynamic values. More uniform coverage could be obtained with a thinner film on a polished surface than on a sandblasted surface. Experience with Teflon lubricant films (7,12) suggested that thinner films give lower friction coefficients and better durability than films over 0.5 mil thick. Polished substrates were therefore employed in the study of some of the variables involved.

EFFECT OF TEMPERATURE ON PERFORMANCE

The performance of boehmite-bonded coatings on sandblasted SAE 1020 steel at 78°F and at 575°F may be compared by reference to Figs. 1 and 2. It can be seen from these data that the coefficients of kinetic friction are distinctly lower at 575°F than at room temperature. It was not feasible to make "stick-slip" measurements at higher temperatures than those reported, but corresponding samples were heated to 700°F and to 800°F for 1 hour, after which the frictional behavior was measured at 78°C. At 700° the coating was observed to oxidize, as the color changed slowly from black to light gray. The coefficients of static and kinetic friction were then found to be about twice the values measured at 575°C. At 800°F the oxidation quickly turned the coating from black to gray-white, and the coefficients of friction were approximately three times the values at 575°F. A few coatings were heated to 1000°F for 1 hour. The resulting white film still had good cohesion and adhesion, but measurements of the friction coefficients at room temperature showed them to be as high as those of films consisting of boehmite alone.

The effect of temperatures up to 600°F on coating performance was studied in more detail using polished SAE 1020 steel, SAE 52100 steel, and SAE 52100 rhodium-plated steel. Figure 3 shows that μ_k passed through a broad minimum in the 300 to 400° F range, but even at 600° F the performance was still as good as that found at room temperature. Since the results on the three hard smooth surfaces chosen for the study were nearly equivalent, the results of measurements on the three surfaces at two loadings were averaged to obtain the graphical points shown in Fig. 3. The plotted lines are considered to be statistically significant. The static coefficient μ_s decreased between 78 and 300° F but was essentially constant above that temperature. The rise in μ_k is attributed, at least in part, to progressive oxidation above 400° F of the MoS_2 in the film. It is possible that the ball prevented access of air for rapid oxidation at the point of contact in the 400 to 600° F range; hence μ_s was not altered. However, μ_k was measured on surfaces which had already been modified by oxidation.

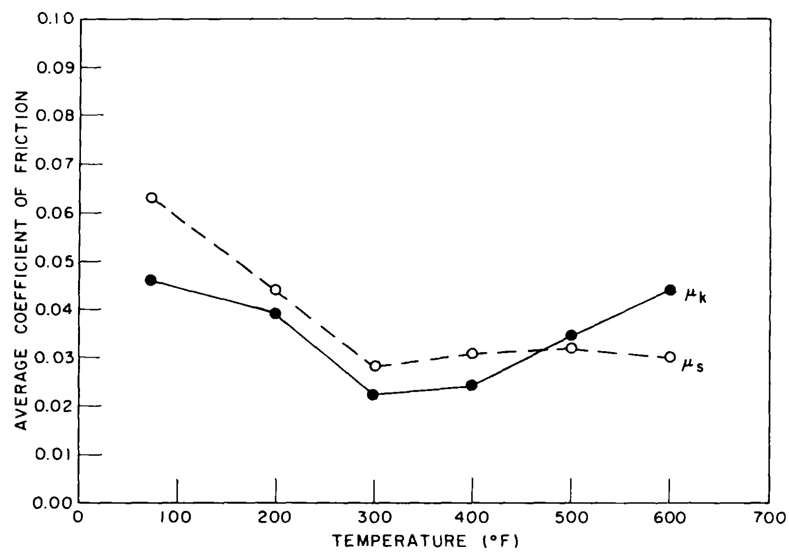


Fig. 3 - Effect of measurement temperature on the friction of boehmite-bonded coatings. Average of results on smooth SAE 1020 steel, SAE 52100 steel, and rhodium-plated SAE 52100 steel. Coefficients at 1000-g and 10,000-g loadings are included in a single averaged point. (20% boehmite bonding agent in alkaline dispersion.)

EFFECT OF SUBSTRATE AND OF RIDER HARDNESS ON PERFORMANCE

Figures 4 and 5 present data on the relation found between metal substrate hardness and friction coefficients when the rider was a hardened steel ball. The hardness parameter correlated data for polished substrates, including aluminum, magnesium, copper, bronze, brass, monel, titanium, and two steels of different hardness, along a single characteristic curve for a given load. (Monel at a 10,000-g load appears to be an exception to this correlation. The anomaly is attributed to the unusual difficulty experienced in getting a good coating on polished monel.) The curve for the 10,000-g load falls about 0.01 unit below that for the 1000-g load, and the curve for the kinetic friction coefficient is lower than that for the static coefficient under similar conditions. Both friction coefficients appear to be nearly independent of hardness above a Vickers hardness of 200. Below this hardness the coefficients rise sharply to values near 0.10 for aluminum

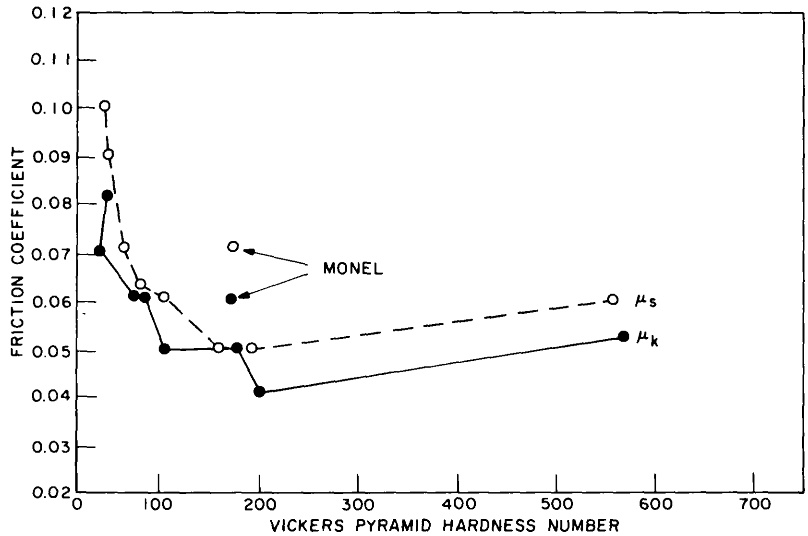


Fig. 4 - Effect of substrate hardness on kinetic and static friction (SAE 52100 steel ball rider; polished substrates; 78°F; 1000-g load)

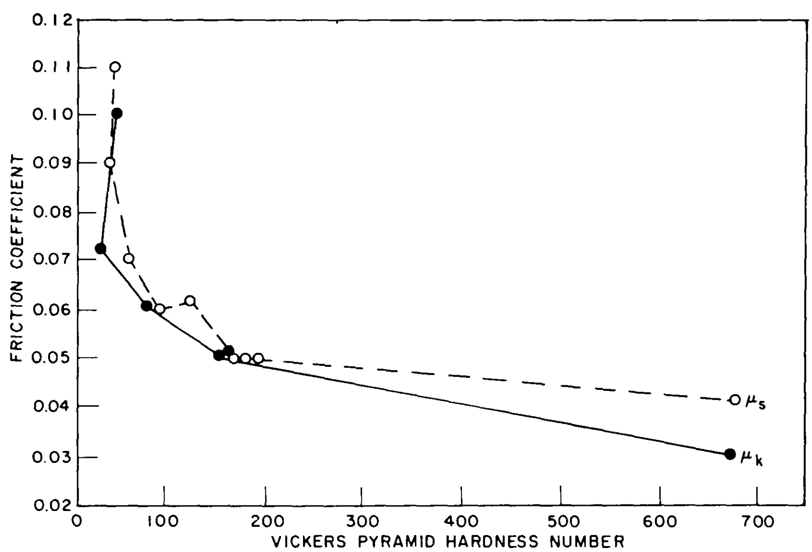


Fig. 5 - Effect of substrate hardness on kinetic and static friction (SAE 52100 steel ball rider; polished substrates; 78°F; 10,000-g load)

(VPHN = 29.8). The materials softer than Vickers 200 tended to deform and work-harden even under the 1000-g load. The coating may then fail either as a direct result of deformation or by sloughing off work-hardened fragments. Copper, brass, and bronze, in which the coating particles may have been embedded by excessive loads, did not fail catastrophically; the friction coefficients, while high, were not very sensitive to load magnitude. With substrates harder than Vickers 200, the friction coefficients were low and the stick-slip behavior was less marked at a 10,000-g load than at a 1000-g load.

Variations in the hardness of the slider ball did not give as straightforward a correlation between hardness and friction behavior. The measurements recorded in Fig. 6 were made with uncoated balls of aluminum, brass, monel, and SAE 52100 steel. The friction coefficients for the aluminum ball were much lower than would have been expected from the results on a coated aluminum substrate. This may have occurred because the rapid wear of the slider ball reduced the true unit loading in the zone of contact between ball and coating below the plastic yield strength of the aluminum.

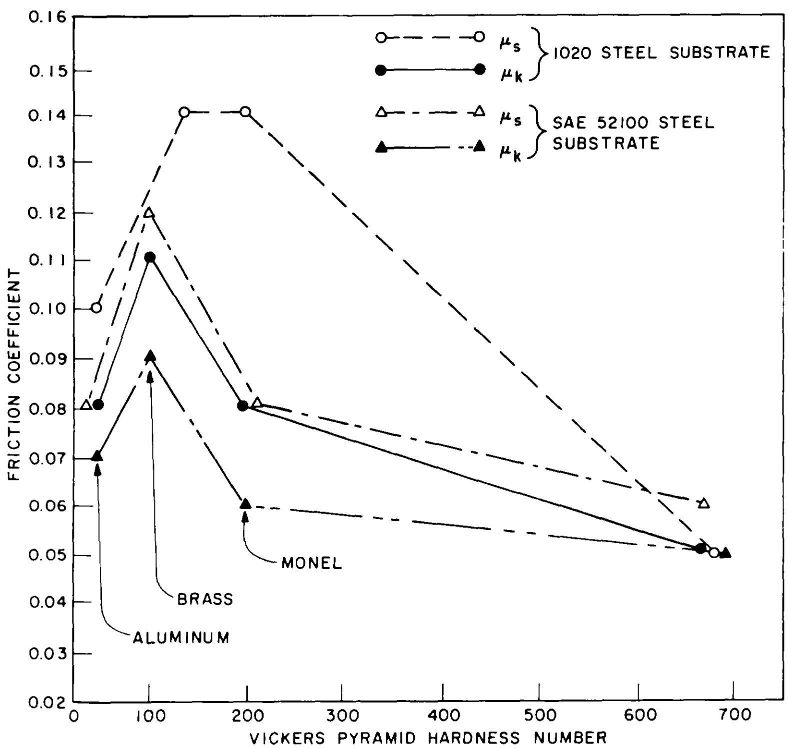


Fig. 6 - Effect of the hardness of an uncoated ball rider on friction coefficients (78° F; 1000-g load)

BONDING AGENTS OTHER THAN BOEHMITE

For purposes of comparison, friction measurements were made on samples of a commercially available MoS_2 coating having an inorganic bonding agent of a ceramic (glassy) type. It was observed that μ_s and μ_k of the ceramic-bonded coating exceeded those of boehmite-bonded coatings by a factor of approximately two. Other commercial coatings containing MoS_2 as the solid lubricant exhibited intermediate values of the friction coefficients, and none were found which would exhibit lower values than those reported here for boehmite-bonded films.

DURABILITY OF BOEHMITE-BONDED COATINGS

The durability of these boehmite-bonded coatings on SAE 52100 steel was investigated in the same friction machine used for the other measurements. The speed of sliding, however, was increased by a factor of 150 from 0.1 cm/sec to 6.0 in./sec to reduce the time required for the measurements. The friction coefficient μ_k is recorded in Table 1 as a function of the number of reciprocating traverses. The 150-fold increase in sliding velocity raised μ_k to about twice the value found at 0.1 cm/sec. The coefficient of kinetic friction decreased very slightly during the first thousand traverses and then remained constant through termination of the measurements after 6000 traverses. Although μ_k and the wear scar diameter were significantly greater for the coating containing 40 g of boehmite per 100 g of MoS_2 than for that with the optimum 20 g of boehmite, the durability and the downward trend in μ_k were similar for both.

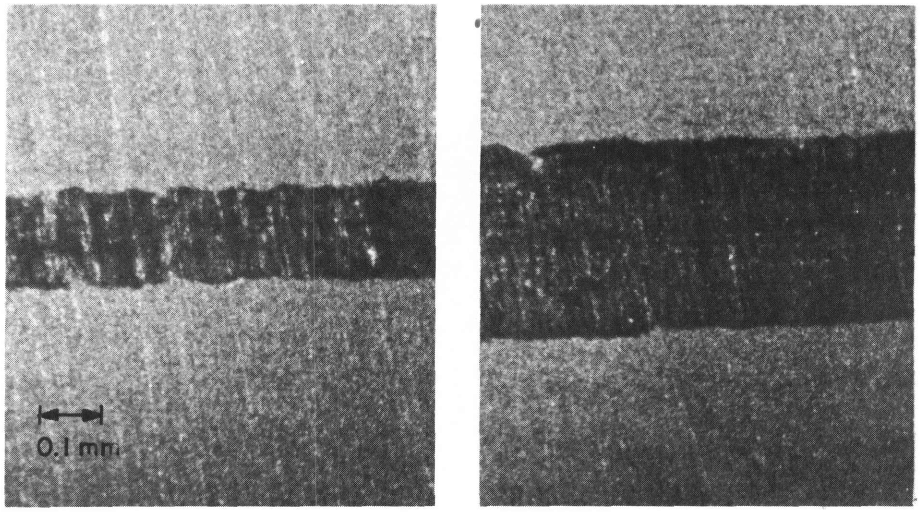
Table 1
Durability of Beohmite-Bonded MoS_2 Coatings on SAE 52100 Steel Under Conditions of Reciprocating Friction
(1000-g load on a 0.5-in. uncoated SAE 52100 steel ball; 6.0 in./sec; 77° F)

Boehmite Binder (%)	Average Coefficient of Kinetic Friction					
	1st Traverse	900th Traverse	1800th Traverse	2700th Traverse	3600th Traverse	6000th Traverse
20	0.10	0.10	0.10	0.09	0.09	0.09
40	0.18	0.18	0.16	0.16	0.16	0.16

At the conclusion of the durability tests a shiny metallic-looking line was observable at the bottom of the ball track. This was at first taken to indicate that the coating had been worn through, but microscope examination showed that the reflecting material was an extremely thin film of MoS_2 wear products overlying the undamaged gray-black coating beneath.

VISUAL CHARACTERISTICS OF WEAR TRACKS

The appearance of the wear tracks on the coated surfaces was highly indicative of the meaning of the friction coefficients recorded in this report. Selected micrographs of wear tracks magnified 100X are presented in Figs. 7 through 16. Figures 7 and 10 show especially well that the coating film was so thin that polishing marks on the substrate were still evident and that these marks were not obliterated in the ball track. The films were able to follow the elastic deformation of steel (or titanium) without rupture during at least 100 traverses. Figure 8 shows the same kind of behavior at 600° F. Figure 9 shows the reduced area of contact when the substrate was rough. Figures 11 through 13 illustrate the film behavior over deformable substrates of brass, copper, magnesium, and aluminum. Figures 11a and 12 are examples of mild substrate deformation without rupture of the lubricant film. Figures 11b and 13 show metal damage in the center of the track as a result of the plastic deformation of the substrate. Figures 14 through 16 show the wear on ball riders formed from different metals. Note that for the hardest pair of surfaces (Fig. 14) a 10,000-g load produced only slight wear on the uncoated ball. The other wear scars shown were formed at one-tenth this load. Figure 15 also shows the greater rider wear on a rough surface.



(a) 1000-g load (b) 10,000-g load

Fig. 7 - Wear tracks on boehmite-bonded MoS_2 films after 100 cycles at 78°F (polished 52100 steel substrates; uncoated 52100 steel ball rider). Note the visibility of the original polishing lines through both the virgin coating and the friction track. (100X.)

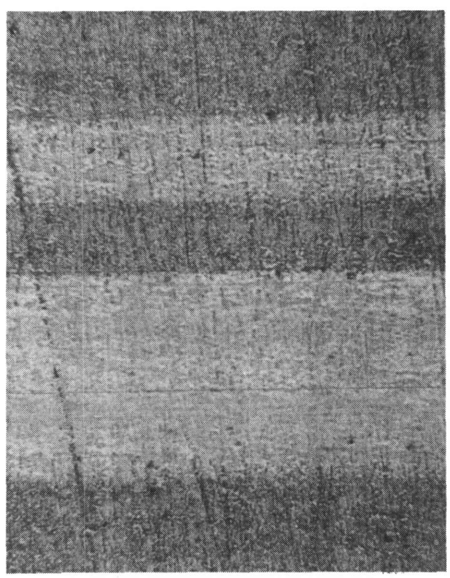


Fig. 8 - Wear tracks on boehmite-bonded coating after 100 cycles at 600°F with (upper track) a 1000-g load and (lower track) a 10,000-g load (ball rider and polished substrate of SAE 52100 steel). (100X.)

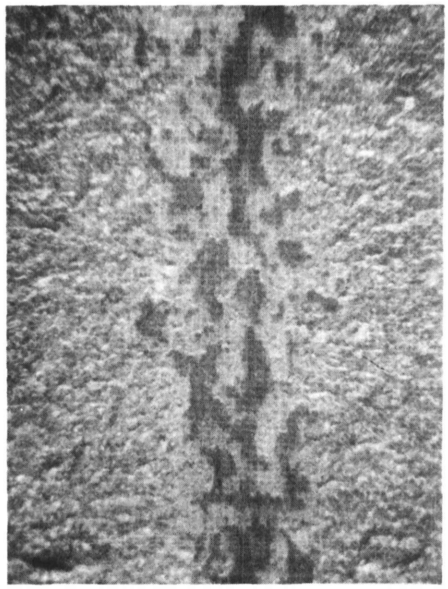
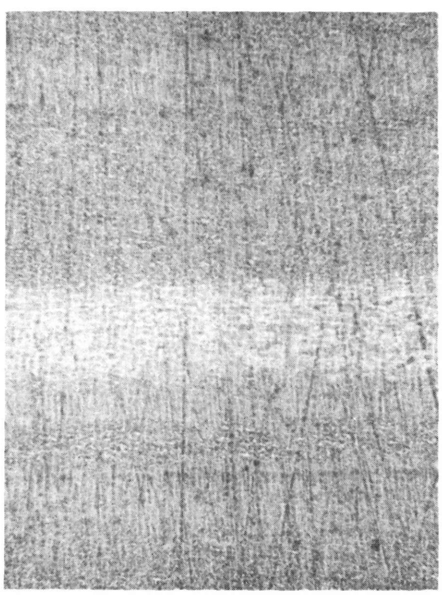
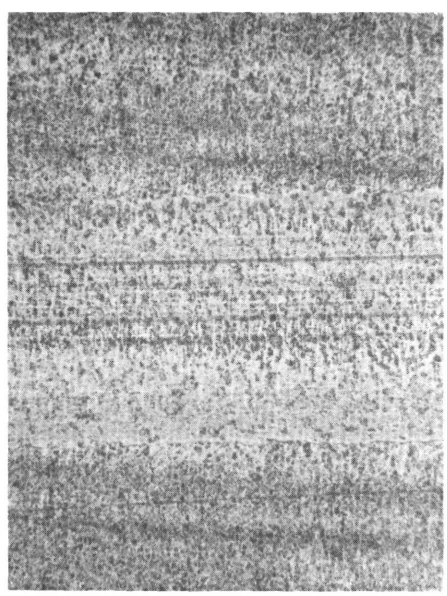


Fig. 9 - Wear track on a roughened surface after 100 cycles at 78°F with a 1000-g load (boehmite-bonded MoS_2 on sandblasted SAE steel; ball rider of SAE 52100 steel). (100X.)

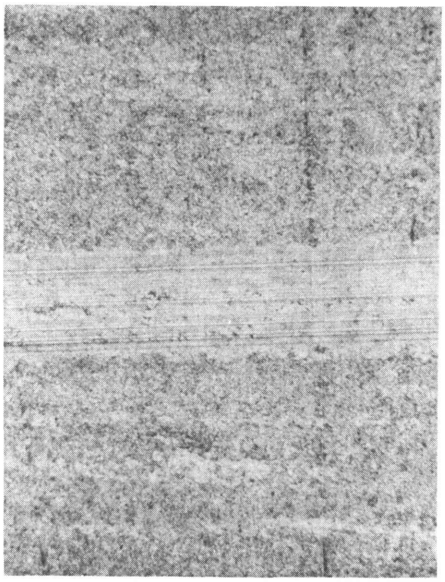


(a) 1000-g load

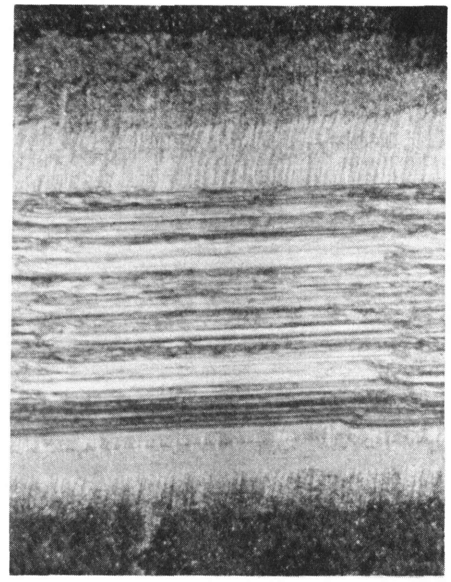


(b) 10,000-g load

Fig. 10 - Wear tracks on polished titanium after 100 cycles at 78°F (ball rider of SAE 52100 steel). (100X.)



(a) 1000-g load



(b) 10,000-g load

Fig. 11 - Wear tracks on polished brass after 100 cycles at 78° F (ball rider of SAE 52100 steel). In (a) the boehmite-bonded coating has matched the deformation of the brass substrate but has maintained its integrity; in (b) the extensive substrate deformation has ruptured the coating and has led to galling in the center of the track. (100X.)

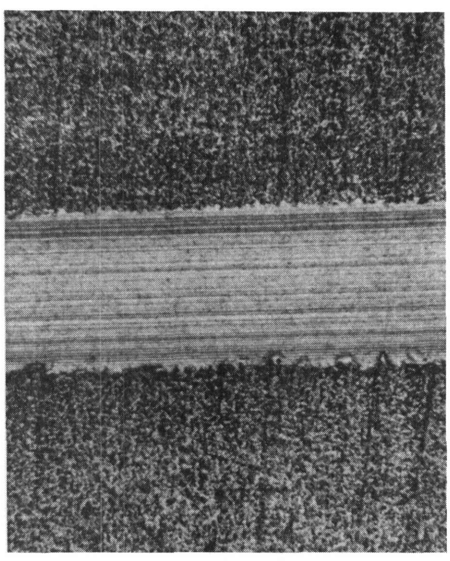
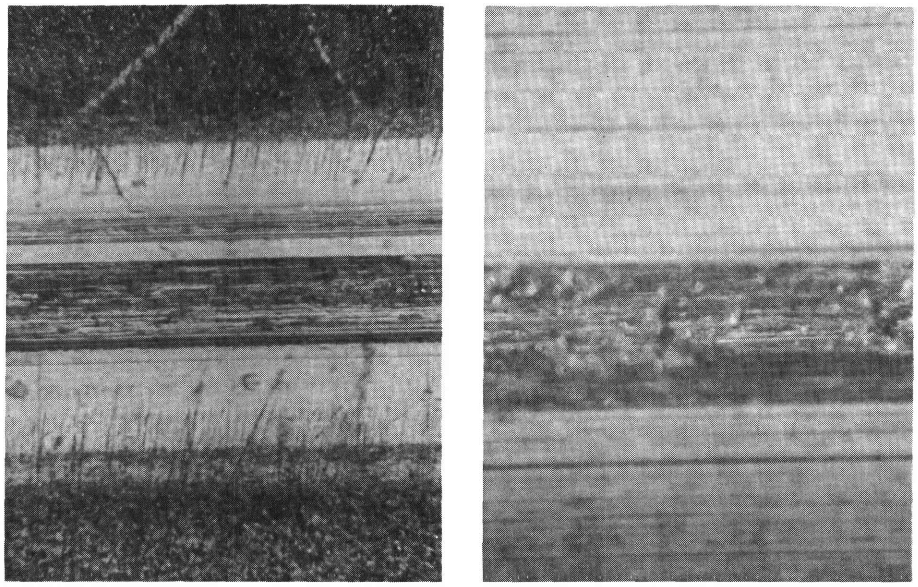


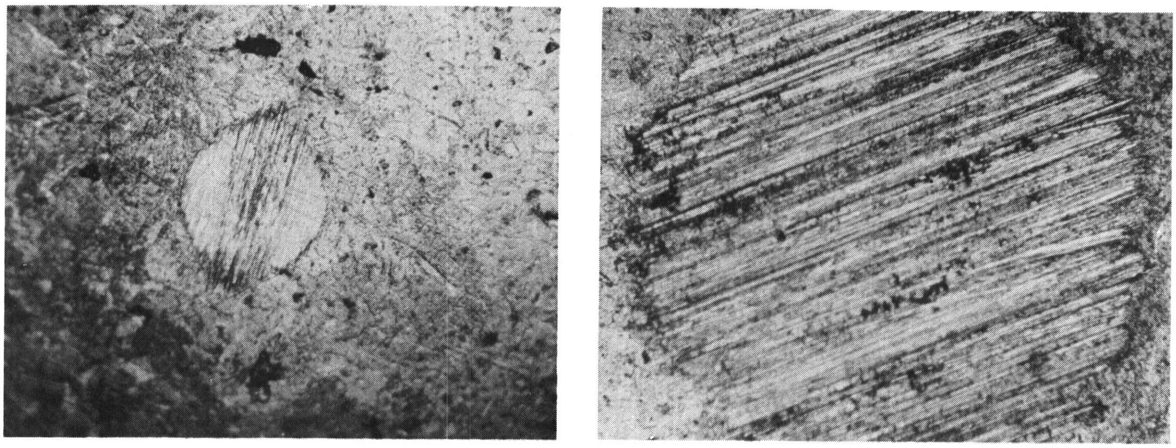
Fig. 12 - Wear track on polished copper after 100 cycles at 78°F with a 1000-g load (SAE 52100 steel ball rider). The coating has deformed with the substrate but remains continuous. (100X.)



(a) (b)

Fig. 13 - Wear tracks on boehmite-bonded MoS_2 coating after 100 cycles at 78°F with a 1000-g load (SAE 52100 steel ball rider). The coating has failed over the center of the track and has allowed galling. Note that the wear track on the soft aluminum substrate extends beyond the edges of the micrograph, although galling occurred only at the center; (a) polished magnesium substrate, (b) polished aluminum substrate. (100X.)

Fig. 14 - Wear scar on an uncoated SAE 52100 steel ball rider after 100 cycles with a 10,000-g load (boehmite-bonded MoS_2 coating; SAE 52100 steel substrate). 100X.)



(a) (b)

Fig. 15 - Effect of substrate finish on the wear of a brass ball rider after 100 cycles at 78°F with a 1000-g load (boehmite-bonded MoS_2 coating; substrate of SAE 1020 steel), (a) polished substrate, (b) sandblasted substrate. (100X.)

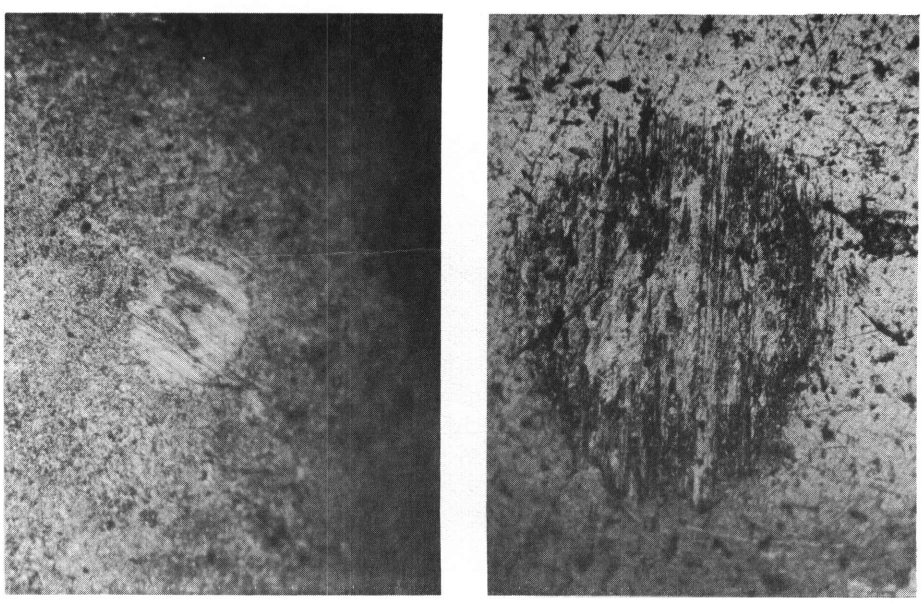
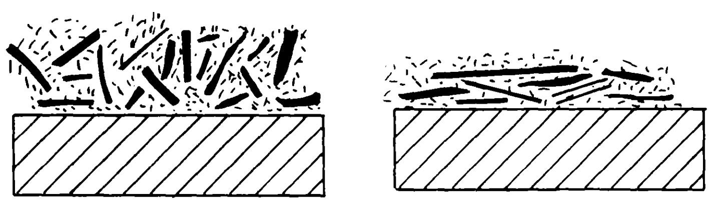


Fig. 16 - Wear on ball riders on boehmite-bonded MoS_2 coatings on polished SAE 1020 steel at 78°F; (a) Monel rider after 100 cycles, (b) aluminum rider after 10 cycles. (100X.)

DISCUSSION

The superior performance experienced with these coatings with regard to low frictional coefficients, high load-carrying ability, and remarkable durability result in large part from the physical nature of the boehmite matrix in which the solid MoS_2 particles are embedded. After the coating was baked, the binder fibrils formed a feltlike structure through which the molybdenum disulfide particles were rather uniformly distributed (Fig. 17a). Although the orientations of the MoS_2 particles may have been nearly random in the original porous film, the compression of this film under load caused the particles to be arranged in an overlapping or shingle pattern with the longest dimensions of the particles more or less parallel to the surface of the substrate (Fig. 17b). The boehmite fibrils served as mortar to tie the lubricant platelets to each other and to the substrate. These fibrils have lengths of 1200 Å, and as a result of their much smaller 50-Å diameter they deformed easily to make molecular contact with the substrate, the lubricant particles, and with each other. The baking produced a partial dehydration of these fibrils; it must have formed many Al-O-Al linkages between contacting fibrils, so that the MoS_2 platelets became enmeshed in a three-dimensional network of strongly bonded alumina fibers. Because of this structure the coating can deform or compress under load without loss of adhesion or integrity, as was observed experimentally. After evaporation of the water in the original coating suspension, the binder will have a discontinuous structure which does not completely encapuslate the MoS_2 platelets as a sodium silicate or ceramic glass or organic resin binder may be expected to do. Hence low friction was observed from the first traverse of the surface without a requirement that the binder be worn away to expose the surface of the lubricant platelets.



(a) (b)

Fig. 17 - Models of boehmite-bonded MoS_2 film; (a) wet coating, (b) coating after drying and compressive loading.

Metal substrate hardness has the effect to be expected of any surface covered with a softer thin film of dry lubricant (13, 14). The lowest coefficients of friction and the greatest durability were obtained (for the loadings reported here) on substrates having a Vickers hardness of 200 or higher. Such hard metal substrates carried the load transmitted through the thin coating with little or no plastic deformation, and the coating remained intact. As would be expected, softer metal substrates were deformed plastically by the pressure of the hardened steel rider, so that the coating cracked and sloughed off to expose bare metal to the rider. Both the static and the kinetic coefficients of friction were higher on softer metals (Figs. 4 and 5). Soft metals may also work-harden during deformation, and fragments of the hardened metal may be detached and plowed along the friction track. The boehmite-bonded coatings, like other solid lubricant films, show little or no ability to heal over or re-cover the spots where bare metal has once been exposed.

No systematic effort was made to study film thickness as a major variable. Earlier work on Teflon lubricating films on steel showed that if the film thickness was allowed to exceed 18 microns (0.0007 inch), the deformation of the film by the slider increased the force needed to overcome friction and also contributed to early failure of the coating. The same considerations apply to bonded MoS_2 films, for it was observed qualitatively that thick films were even more liable to slider damage and peeling than were the polytetrafluoroethylene coatings.

The facts that μ_s decreased with rising temperature and that μ_k passed through a distinct minimum in the neighborhood of 300 to 400°F suggest that some physical or chemical property responsible for the lubricating characteristics of these MoS_2 coatings is temperature sensitive. This property change with rising temperature might be the decrease in shear strength of the MoS_2 platelet or might be the increase in chemical reactivity of the MoS_2 which reduces cohesion within the lamellar structure. The rise in μ_k above 400°F is attributed to progressive oxidation of the MoS_2 to MoO_2, which causes higher friction and exceeds the initial beneficial effect of higher temperatures.

CONCLUSIONS

A microfibrous form of colloidal alumina (boehmite, AlO(OH)) has been shown to act as a superior nonencapsulating binder for molybdenum disulfide platelets in the formation of dry lubricant films. The boehmite-bonded films exhibited lower coefficients of friction than have been reported for either MoS_2 or graphite films bonded with any other agent. These new films have good load-carrying ability and durability. They are useful at any temperature below 700°F, which is the decomposition temperature of MoS_2.

The static and kinetic coefficients of friction decreased with rising temperature in going from 77°F to 300°F. Exposure of the coatings to temperatures above 400°F caused the friction coefficients to rise because of progressive oxidation of the MoS_2.

Optimum results with these new dry film lubricants will be obtained only when bearing conformation, bearing hardness, dry lubricant, and bonding agent are designed as a system. In general, boehmite-bonded MoS_2 coatings will give best results if the bearing surfaces are polished and have a hardness in excess of 200 Vickers, the coating is 0.2 to 0.5 mil thick, the microfibrous boehmite-MoS_2 suspension in water has a pH of 10, and the boehmite to MoS_2 ratio is 20/100.

RECOMMENDATION

It is recommended that these boehmite-bonded MoS_2 coatings be evaluated by the Naval Air Engineering Center in the special equipment used at that activity to qualify commercial MoS_2 coating materials for military usage as dry film lubricants.

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13. ABSTRACT

Binders that have been tried for powdered lamellar dry lubricants have shortcomings such as hindering the realignment of the lubricant particles or encapsulating the lubricant, making a wearing-in process necessary. A microfibrous form of colloidal alumina (boehmite) is shown to act as a superior nonencapsulating binder for molybdenum disulfide in the formation of dry lubricant films. Such films exhibit lower coefficients of friction than have been reported for molybdenum disulfide or graphite films bonded with any other material. These new lubricating coatings have good load-carrying ability and durability at any temperature below the decomposition temperature of molybdenum disulfide (700°F). Optimum performance of these boehmite-bonded films is obtained when (a) the ratio of fibrillar boehmite to MoS_2 is near 0.20, (b) the film is 0.2 to 0.5 mil thick, (c) the substrate is hard and highly polished, and (d) the film is applied as an alkaline dispersion (pH = 10) and then dehydrated by baking at 550°F.

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Sulfur compounds						
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