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SOLID LUBRICANT FILMS HAVING VITREOUS ENAMEL BINDERS

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This invention relates to the lubrication of bearings and other elements which are subjected in use to mechanical friction. More specifically, the invention is concerned with lubricants of the solid film type, that is, lubricants that take the form of a solid lubricating material permanently applied as a film to the surface to be lubricated. The general object of the present invention is to provide a solid film lubricant of this type which is specially designed and applied to withstand extremely high operating temperatures, and to retain its desired form and lubricating qualities even under such high temperatures. At the same time, the lubricant is so formulated that its lubricating characteristics may be uniform over the entire area of the film and are easily controllable by variations in the proportioning of the ingredients.

To achieve the above results, a film embodying the invention is composed of a binder formed by a ceramic material, preferably a vitreous enamel (porcelain enamel), containing a large number of minute finely divided particles of solid lubricant material distributed within the binder. The binder acts to very securely hold the lubricant particles in position within the film, and acts to tightly bond the film to the surface being treated. Both the binder and lubricant particles, as well as any other ingredients, are so chosen as to withstand without damage the high temperatures for which the film is designed. In this connection, it is preferred that these ingredients, and the ultimate film itself, be adapted to remain stable and undamaged to a temperature in excess of 650° F. and preferably to a temperature as high as or above 2200° F. With particular reference to the lubricant particles, these particles are so chosen as to retain their lubricating characteristics, preferably without substantial reduction in effectiveness, to and above the specified temperatures.

In order that the bond between the lubricant film and the bearing or other coated element may be as secure as possible, I prefer to pretreat the surface to be coated in a manner forming irregularities over its entire surface, the irregularities desirably being substantially microscopic in size and distributed in closely spaced relation over substantially the entire area of the surface. It is also preferable that the coated element be formed of a metal, such as steel, aluminum titanium, brass, or the like. The irregularities on the surface to be treated may be formed in any of various ways, as for instance by sandblasting the surface, or by a suitable irregularizing chemical treatment. A typical method of chemically irregularizing the metal surface is by a "pickling" or "acid etching" process, in which the element is immersed for a short period (say about two minutes) within an acid, such as sulfuric acid, hydrochloric acid, or hydrofluoric acid, the latter being especially desirable for aluminum, and the acid preferably being in concentrated form.

After the surface has been irregularized, I apply to the surface a coating mixture taking the form of a fusible frit which is adapted when fired to form a vitreous enamel, and containing the finely divided lubricant particles distributed within the frit. These ingredients are mixed together uniformly prior to their application to the surface, and the mixture is applied in the form of a very thin film, preferably of a thickness less than $\frac{1}{1000}$ of an inch, the ultimate lubricant film also preferably being less than $\frac{1}{1000}$ of an inch thick. The application may be by spraying, dipping, brushing, or other means, and to allow such application, the mixture may be converted to an essentially liquid form, as by forming an aqueous suspension of the various finely divided binder and lubricant ingredients. This suspension at the time of application may have a solids content between about 10 and 25 percent. In the mixture, it is found best in most cases to employ at least as much and preferably more, by weight, of the finely divided lubricant or lubricants as of the fusible material or materials for forming the vitreous enamel binder. For optimum results, the lubricant solids preferably constitute between about 65 and 90 percent, and desirably about 80 percent, of all of the solids in the coating mixture; while the fusible solids for forming the binder should constitute between about 35 and 10 percent and preferably about 20 percent of the solids.

The frit for forming the binder may be any of various conventional compositions capable of forming a vitreous enamel when fused. The ingredients of this frit are adapted to be fused into a vitreous enamel at a temperature well below the temperature at which damage would be incurred by the metal of the element being coated. The ingredients of the binder forming frit may include any of the numerous materials commonly present in such frits, such as PbO, SiO_2, Li_2O, Na_2O, K_2O, TiO_2, Sb_2O_3, B_2O_3, ZnO_2, CdO, or Na_2SiF_4.

A typical porcelain enamel frit which may be used is the product sold by E. I. du Pont de Nemours as "aluminum porcelain enamel No. L388." This frit may be used on brass, aluminum, stainless steel, and various other types of metal. The composition of this frit is approximately as follows (by weight):

	Percent
PbO	29
SiO_2	45
Na_2O	14
K_2O	3
TiO_2	8
Sb_2O_3 and B_2O_3	Traces

The lubricant particles may be of various materials capable of serving as lubricants at the temperatures previously referred to, several typical lubricant materials being:

Tungsten disulfide
Molybdenum disulfide
Boron nitride
Vermiculate
Mica
Iron oxide (e.g. Fe_3O_4 or Fe_2O_3)
Silver sulfate
Ferrous chloride
Lead oxide (e.g. PbO and Pb_2O_3)
Ferrous sulfide
Silver
Graphite (preferably "outgassed" graphite, formed at high temperature, e.g. 5000° F., in an electric furnace)

The material selected as the lubricant should preferably have a coefficient of friction at about 700° F. of not greater than about .3; and the ultimate film should also have a coefficient of friction at about 700° F. of not greater than about .3. In some cases, particles of

two or more different lubricant materials may be incorporated in the coating compositions, e.g. graphite and lead oxide mixed in equal parts by volume; or 80% graphite and 20% silver. Also, to assure optimum lubricating and wear characteristics in the ultimate film, the finely divided lubricant particles preferably are predominantly not greater than about 74 microns in size (maximum dimensions of individual particles). The frit for forming the binder should also be very finely divided, preferably consisting of small particles which are predominantly not over 74 micons in size (maximum particle dimensions).

In addition to the lubricant and binder materials, the coating mixture may contain an appropriate addition agent for improving the adhesion characteristics of the binder, and preventing "tearing" of the film. This addition agent may typically be any of various water soluble silicates or oxides, such as sodium silicate, potassium oxide, silicon dioxide, sodium oxide, boron trioxide (B_2O_3), silicon oxide, or calcium oxide, or in some instances boric acid, and the addition agent may be added to the mixture in the form of a water solution.

After the coating mixture has been applied to the surface, preferably to a thickness under $\frac{1}{1000}$ of an inch, the coating and the coated element are fired to a temperature and for a period sufficient to burn or fuse the binder ingredients to a vitreous enamel form (usually to a temperature in excess of 850° F.). This vitreous or porcelain enamel binder then tightly retains the lubricant particles in place on the surface being treated. The firing of the binder also forms a tight fuse bond between the coating film and the base material, which bond holds the film permanently in place on that material. Further, the actual embedding of the film binder and lubricant particles within the irregularities in the surface being treated greatly enhances the tightness and permanency of the bond between the film and that surface.

As illustrations of specific examples of processes performed in accordance with the invention, the following are given:

Example I

An aqueous suspension was formed of aluminum porcelain enamel frit No. L388 manufactured by E. I. du Pont de Nemours, the suspension being 80 percent frit and 20 percent water (these proportions and all others in this application being by weight unless otherwise designated). This suspension was ball milled until substantially all of the frit solids (at least 99%) would pass through a 200 mesh screen, and were therefore not greater than about 74 microns in size. This suspension was mixed with molybdenum disulfide lubricant particles in proportions to give a mixture in which the solids were 80 percent solid lubricant particles and 20 percent porcelain enamel frit solids. To this was added a 25 percent solution of du Pont addition agent L389, which is composed approximately as follows:

	Percent
Potassium oxide	54.2
Boron trioxide (B_2O_3)	11.2
Sodium oxide	19.3
Silicon dioxide	15.2
Calcium oxide	.1

The resultant mixture was thinned to spraying consistency with water. The composition of the mixture at the time of application was:

80 parts molybdenum disulfide
20 parts du Pont L388 porcelain enamel frit
2 parts du Pont L389 addition agent
725 parts water

The bearing surface of an aluminum bearing was roughened by sandblasting, to form a large number of minute irregularities in the surface, distributed in very closely spaced relation over the entire bearing surface. The above mixture was then sprayed onto the irregularized bearing surface to a thickness of .00035 of an inch. The coated bearing was dried in a 200° F. oven for 10 minutes, following which it was raised in temperature to 1000° F. for 2 minutes. This fused the frit into a porcelain enamel binder tightly fuse bonded to the roughened bearing surface and having the molybdenum disulfide lubricant particles firmly held in place by the binder. The bearing coated in this manner was tested under frictional load at 700° F. for 40 hours, and functioned very effectively with little if any wear.

Example II

A stainless steel bearing was roughened by submersion in concentrated hydrochloric acid for 2 minutes, and was then coated as in Example I, but utilizing tungsten disulfide, as the solid lubricant instead of molybdenum disulfide, and with the proportions of the ingredients in the mixture at time of spraying being:

90 parts tungsten disulfide
12½ parts du Pont L388 frit
1½ parts du Pont L389 addition agent
725 parts water

This bearing performed extremely well under load at a temperature of 1000° F., and without substantial wear.

Example III

A stainless steel bearing was roughened by sand blasting and was then coated, in the same manner as was the bearing of Example I above, except that in the coating mixture, graphite and lead oxide (PbO) (in equal proportions) were substituted for the molybdenum disulphide as the lubricant material. The composition of the mixture at the time of spraying was

40 parts outgassed graphite formed at high temperature in an electric furnace
40 parts lead oxide (PbO)
20 parts du Pont L388 porcelain enamel frit
2 parts du Pont L389 addition agent
725 parts water

The graphite and lead oxide were in the same finely divided form as was the molybdenum disulfide in Example I. This bearing functioned as well under test as did the other two.

I claim:

1. The process of lubricating the irregularized friction surface of a bearing or like metallic element to be subjected to mechanical friction at high temperatures that comprises coating said surface with a uniform mixture of (1) finely divided particles of an inorganic frit fusible to form a binder, and (2) finely divided solid lubricant particles including sufficient graphite to impart lubricity to the subsequently fused film, the weight percentage of lubricant particles in said mixture being in excess of the frit particles therein, heating the coating to a temperature at which the frit particles fuse to form an essentially glassy binder which bonds the graphite-containing lubricant particles therein to the metal surface in a coating in which the graphite has stable lubricity at temperatures in excess of 650° F.

2. The process of claim 1, in which said lubricant particles include also lead oxide.

3. The process of claim 1, in which said lubricant particles include also molybdenum disulfide.

4. The process of claim 1, in which said lubricant particles include also tungsten disulfide.

5. A metallic bearing or like element having an irregularized friction surface coated by the process of claim 1.

6. The process of claim 1, in which the solid lubricant

particles in said mixture are between about 65 and 90 weight percent of the combined lubricant and frit particles.

7. A metallic bearing or like element having an irregularized friction surface coated by the process of claim 6.

8. The process of claim 6, in which said lubricant particles consist essentially of graphite and lead oxide.

9. A metallic bearing or like element having an irregularized friction surface coated by the process of claim 8.

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