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SINTERED POWDERED COPPER BASE BEARING

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This invention relates to sintered powdered copper base bearings having a high degree of wear resistance with or without subsequent cold or hot working or thermal treatment. More particularly, the invention pertains to sintered powdered copper base bearing parts containing tin and dispersed particles of aluminum oxide.

Porous metal bearings commonly have been employed in industry during recent years, but their use in many applications has been limited because of their relatively low wear resistance. Accordingly, a principal object of this invention is to provide a novel sintered powdered copper base bearing having a high degree of wear resistance due to the presence of aluminum oxide particles. A further object of the present invention is to provide a simple, inexpensive process for forming a sintered powdered copper base bearing of such a composition having close dimensional tolerances.

These and other objects are attained in accordance with my invention by the addition of aluminum oxide particles to copper base metal powder. Small proportions of tin and nickel powders are also preferably included in the powdered metal mix and serve to provide the material with greater corrosion resistance, ability to age harden, wear resistance and strength. The formed bearing part, when sintered, or when sintered and worked to a controlled degree of porosity, possesses excellent wear resistance properties due to the presence of the dispersed particles of aluminum oxide.

The resultant wear-resistant sintered powdered copper base metal may be advantageously used to form piston pin bushings, camshaft bushings, balancer shaft bushings, thrust washers and other bearing parts. Hence the word "bearing," as used herein, is intended to include all such applications in which relatively moving parts are in engagement and in which high wear resistance and good anti-score properties of the metal are desirable.

Sintered powdered copper base bearings formed in accordance with the present invention possess not only the aforementioned high wear resistance but also desirable oil-retaining properties. Moreover, these bearings, when compared with similar parts made by normal manufacturing methods, do not require the expensive machining operations otherwise frequently necessary to provide the proper tolerances. In turn, since little or no machining is necessary, scrap or waste is reduced to a minimum.

Recently, sintered powdered copper base bearings have been provided with increased wear resistance by the inclusion of either nickel-titanium or titanium-aluminum particles in the powdered metal mix. These developments are respectively disclosed in co-pending patent application S. N. 397,789, filed December 11, 1953, in the name of Robert F. Thomson and co-pending patent application S. N. 444,401, filed July 19, 1954, in the names of Robert F. Thomson and Eric W. Weinman. However, the use of aluminum oxide particles in the mix, in accordance with the present invention, affords certain advantages over the use of nickel-titanium or titanium-aluminum particles. The hard, crystalline aluminum

oxide particles are preferable from an economic standpoint since Alundum and corundum, for example, cost appreciably less than other typical nickel-titanium alloys or titanium-aluminum powders. Of course, aluminum oxide also does not contain any relatively critical materials, such as nickel or titanium.

On sintering, moreover, the high-melting aluminum oxide particles alloy with the powdered metal mix to which they are added to a negligible extent as compared with nickel-containing compounds and tend to remain in substantially the same form in which they are introduced. Maximum wear resistance normally cannot be obtained if the particles alloy excessively with the base metal of the powdered mix.

Other objects and advantages will more fully appear from the following detailed description of preferred embodiments of my invention.

The bearing is formed by initially thoroughly mixing finely pulverized aluminum oxide with a copper base powder containing tin. The tin may be alloyed with the copper, although normally it is separately added to the mix in powdered form. Other elements, such as zinc, nickel, lead, manganese, aluminum, silicon, beryllium, cobalt, iron and phosphorus, may also be included in the bearing material. Most of these elements normally may be wholly or partially alloyed with the copper. Zinc, nickel, lead and aluminum may be present in appreciable amounts and may be beneficial for particular purposes. Hence the zinc and lead contents of the copper base bearing may range as high as 45% and 30%, respectively. Likewise, up to about 15% aluminum may be included in the powdered metal mixture, a 2% to 11% aluminum content being preferred for some applications. Nickel may be present in very large quantities, as hereinafter more fully explained. Amounts of silicon and iron, preferably in the order of about 1% to 3% and 1% to 11%, respectively, may also be included. The various other elements listed above are normally present in only very small quantities.

Even a relatively minute amount of the aluminum oxide powder improves the wear resistance of the bearing to a measurable extent, and the range of this constituent may vary from a small but effective amount to a quantity constituting approximately 15% by weight of the final mix. However, in order to provide the desired economy and strength, particularly impact strength and shock resistance, the aluminum oxide content preferably should be maintained between 0.25% and 7.5% by weight, although these physical properties normally are present to a satisfactory extent when the aluminum oxide constitutes as much as about 15% of the powdered metal mix. When more than 15% aluminum oxide is used, the tensile strength and ductility of the sintered powdered copper base bearing are appreciably reduced. The excessive brittleness of such a bearing, which precludes its effective use in many applications, is evidenced by chipping or cracking of wear test specimens when they are being ground. Optimum properties are usually obtained when the bearing contains approximately 1% to 5% of the crystalline aluminum oxide powder.

I have obtained best results when the copper constitutes between about 70% and 97% of the total mix. However, it will be understood that the terms "copper base metal," "copper base bearing" and "copper base alloy," as used herein, are intended to encompass alloys and powdered metal mixtures in which copper is the major constituent and preferably constitutes at least 50% of such a powdered metal mixture or alloy.

Finely divided graphite, preferably 80 mesh or finer, may be mixed with the metal powder to increase tool or die life and to improve frictional characteristics of the formed copper base bearing part. Small amounts of

graphite not in excess of approximately 6.5% are satisfactory, while a graphite content between about 0.3% and 4% is normally preferred.

Likewise, in order to eliminate the necessity of coating the dies with a lubricant during the briquetting operation, a small but effective amount of zinc stearate powder not in excess of about 2.5% should also be included in the powdered metal mix. In general, I have found that best results are obtained with a mix having a zinc stearate content between approximately 0.3% and 2%. Other die lubricants, such as stearic acid in powder form, can also be used in place of the zinc stearate.

The inclusion of proper amounts of tin and nickel in the powdered metal mix further increases the wear resistance and score resistance of the formed bearing part. Moreover, nickel also contributes corrosion resistance to the bearing and improves its ability to age harden. Tin melts at a low temperature and alloys with copper to form a tin-copper alloy, the latter coating the substantially pure copper particles. During the sintering operation, the elevated temperature causes the tin to diffuse through the copper. The melting point of the metal in the areas previously occupied by the tin is thus raised, thereby providing an alloy having a melting point above the sintering temperature. Since the tin brazes the copper particles together to form a bronze, the resultant metal is a better bearing material than if no tin were present and possesses better corrosion resistance. Furthermore, the tin and nickel, if included in the powdered metal mix, serve to strengthen the bearing.

Although amounts of tin as high as 18% by weight may be used, optimum results are obtained with a preferred tin content between approximately 1% and 13%. The addition of tin in quantities greater than 18% results in the formation of hard and brittle copper-tin compounds, which tend to produce galling. Alternatively, a bronze powder of similar composition may be employed. The preferred nickel range is between 2% and 15%, although this element may be substituted for copper in amounts ranging from a small but effective amount up to the point where the copper content is only slightly higher than the nickel content. In no instance, therefore, would the added nickel content exceed about 49% in this copper base bearing material.

In view of the above considerations, I have found that a sintered powdered copper base bearing having excellent wear resistance is one which comprises approximately 1% to 5% by weight of crystalline Al_2O_3 powder, 0.3% to 4% by weight of carbon, tin not in excess of 13% by weight, and the balance substantially all powdered copper. The inclusion of nickel in amounts not in excess of 15% increases the corrosion resistance of the bearing and permits it to be more satisfactorily age hardened.

The tin powder may be added in the form of tin dust, while the nickel may be introduced as nickel powder, such as electrolytic nickel powder or nickel produced from nickel carbonyl by means of the Mond process or other suitable means. Although nickel may also be used in other forms, it is desirable to add it in the form of nickel powder formed from nickel carbonyl as its commercially available fine particle size permits quicker homogenization. Electrolytic nickel powder, as commercially supplied, is somewhat coarser grained, and its use necessitates a longer period of time at an elevated temperature to sufficiently homogenize the powder metal mix.

Among the aluminum oxides which may be used are fused Al_2O_3, such as alundum, and the impure Al_2O_3 containing minor amounts of iron oxide and known as "Turkish emery." Corundum (a form of natural Al_2O_3) and tabular corundum (calcined Al_2O_3) likewise can be successfully employed in accordance with the present invention. Specific examples of these forms of crystalline aluminum oxides include the commercially available compounds identified as Alundum 600X, Alundum 320B, corundum 300, tabular corundum −100+200 and Turkish emery 320. The numerals following the alumina classification in each instance indicate the approximate particle size of the alumina particles. The proper use of appropriate amounts of any of these forms of aluminum oxides in the manner hereinafter described results in the production of a sintered powdered metal part having substantially improved wear resistance. Approxiately −100 to −600 mesh aluminum oxide powder may be used, but −250 to −350 mesh particles are preferred. Crystalline aluminum oxide particles which are too coarse are somewhat prone to cause scoring.

Commercially pure copper and tin may be used or, as hereinbefore explained, a bronze powder of appropriate composition may be used in place of the mixture of copper and tin. Hydrogen reduced copper of approximately −150 mesh has provided excellent results, although the particle size of the copper or bronze may vary from −60 to −325 mesh and still produce a satisfactory bearing. Other metal powders in the base material preferably also should have particle sizes within this range.

The sintered powdered copper base bearing may be formed by first briquetting a mixture of the pulverized aluminum oxide, tin, nickel and copper, together with zinc stearate and graphite powder, if its is desired to add the latter constituents, at an appropriate pressure in a die having a contour which is complementary to the bearing surface to be formed. Although a briquetting pressure between approximately 20,000 and 120,000 pounds per square inch has proved to be satisfactory, 40,000 to 60,000 pounds per square inch appears to be the optimum pressure range for most applications. Before briquetting, it is important that the powdered metal constituents be thoroughly mixed in order to provide uniformity of structure and properties to the resultant bearing.

The green briquette is then sintered under suitable conditions of time, temperature and atmosphere into a structure having a controlled degree of porosity. Sintering temperatures between 1300° F. and 1950° F. and sintering times between fifteen and thirty minutes appear to be highly satisfactory for these powdered copper base briquettes. The above sintering times are not critical, however, and sintering times as short as four minutes and as long as two hours produce satisfactory wear test results. Excellent results have been obtained by sintering the briquette at approximately 1500° F. for twenty minutes under a non-oxidizing furnace atmosphere, such as dissociated ammonia, dry "Drycolene" gas, or a gaseous mixture of "Neutralene" and a small amount of natural gas.

The dry Drycolene gas normally is composed of approximately 20% carbon monoxide, 3% hydrogen and 77% nitrogen. The Neutralene atmosphere mentioned above is a closely related gaseous mixture which usually consists of approximately 1.5% carbon monoxide, 1.5% hydrogen and 97% nitrogen. It has proved advantageous to use a mixture of 100 parts of Neutralene and one part of natural gas. Of course, other furnace atmospheres, such as hydrogen, mixtures of nitrogen and hydrogen or methane, etc., can be used, but Drycolene and Neutralene are readily available and each provides a highly effective protective atmosphere.

If an appreciable amount of nickel has been separately included in the powder metal mix, heat treatment subsequent to sintering is beneficial. Thus a solution treatment for one to eight hours in a non-oxidizing atmosphere at a temperature between approximately 600° F. and 1400° F. may be used to provide greater hardness and homogeneity. A two-step process is preferably employed, however, such as an initial heat treatment for five hours in a non-oxidizing atmosphere at 1400° F. followed by a water or oil quench and a low-temperature heat treatment or aging in a similar atmosphere for five hours at 600° F. The bearing may also be beneficially aged at room temperature following the solution step.

It will be understood that a sintered powdered copper base bearing containing dispersed particles of aluminum oxide in accordance with this invention may be manufactured under the usual porous metal techniques as disclosed in a number of patents, such as Patents Nos. 1,738,163, 2,097,671, 2,075,444, etc. Also, instead of briquetting the metal powder as hereinbefore explained, it may be molded to shape prior to sintering as suggested in Koehring Patent No. 2,198,702.

Likewise, the powdered metal mix may be merely spread on or otherwise placed in contact with a supporting surface and subsequently sintered. This supporting surface may be a non-porous metal backing strip, such as a steel strip, and the powdered metal may be bonded to the back on sintering. When this latter procedure is used, it may be desirable to first electro-deposit a suitable metal plate on the surface of the back to improve the strength of the bond. This type of process is disclosed in Koehring Patents Nos. 2,187,086 and 2,198,253. After sintering, the composite of spongy copper base alloy on the back may be rolled to increase the density of the powdered metal bearing and then resintered or annealed. Additional rolling and annealing treatments can be employed to further increase the density of the bearing. In this manner a highly wear-resistant sintered bronze bearing layer, for example, can be formed on a steel back.

All of the above modifications are understood to be within the scope of the present invention, which broadly comprehends the provision of a sintered powdered copper base bearing containing tin and/or nickel and dispersed particles of aluminum oxide.

Wear tests were conducted to compare sintered copper base metal samples formed in accordance with my invention with sintered copper base samples containing no aluminum oxide particles. These samples were prepared as tensile bars briquetted at a pressure of 60,000 pounds per square inch. They were then sintered for 25 minutes in a dissociated ammonia atmosphere at a temperature of 1575° F. and subsequently cooled in this atmosphere. None of the samples was forged. Each specimen to be tested was machined to prepare a ⅛ inch by 1⅛ inch rubbing surface. The specimens were next successively locked in a fixture of the wear test machine and placed in contact with a rotating smooth-surfaced cast iron wheel having a face width of one inch. Increased wear resistance was measured by decreased weight loss in grams and in decreased volume loss in cubic inches.

A wear test using this apparatus was conducted in which the specimen load was increased to 512 pounds and retained at this figure for a total test period of five hours. At the end of this time the sintered copper base test specimens which did not contain aluminum oxide particles showed an average weight loss of 0.341 gram, while copper base samples containing crystalline Al_2O_3 particles lost an average of only 0.0426 gram. Similarly, while the former specimens underwent a volume loss averaging 269×10^{-5} cubic inches, the test specimens formed in accordance with the present invention changed on the average only approximately 11×10^{-5} cubic inches. The results of these tests, which show the relatively low weight and low volume loss of my new sintered powdered copper base bearing material under severe wear test conditions, illustrate its high wear resistance.

While the present invention has been described by means of certain specific examples, it is to be understood that the scope of the invention is not to be limited thereby except as defined in the following claims.

I claim:

1. A highly wear-resistant sintered powdered metal comprising approximately 0.25% to 15% Al_2O_3 particles, 2% to 15% nickel, and the balance substantially all a metal selected from the class consisting of copper and copper base alloys.

2. A wear and corrosion-resistant sintered powdered metal bearing consisting essentially of approximately 0.25% to 7% aluminum oxide, 2% to 15% nickel powder, 0.3% to 6.5% carbon, and the balance substantially all powdered bronze.

3. A highly wear-resistant sintered powdered metal bearing consisting essentially of about 0.25% to 7.5% aluminum oxide in the form of dispersed finely divided particles, tin not in excess of 18%, 2% to 15%, and the balance substantially all copper.

4. A sintered powdered metal bearing characterized by high wear resistance, said bearing being formed from a powdered metal mixture consisting essentially of 1% to 5% crystalline Al_2O_3 particles, carbon not in excess of 6.5%, 1% to 13% tin, 2% to 15% nickel, and the balance substantially all powdered copper.

5. A sintered powdered metal bearing characterized by oil-retaining properties and high wear resistance, said bearing formed from a mixture consisting essentially of about 1% to 13% tin powder, 2% to 15% nickel powder, 1% to 5% Al_2O_3 powder, 0.3% to 4% carbon, 0.3% to 2% die lubricant, and 70% to 97% copper powder.

6. A sintered powdered metal bearing characterized by high wear resistance, said bearing being formed from a powdered metal mixture consisting essentially of about 0.25% to 15% dispersed, hard particles of crystalline aluminum oxide, 2 to 11% aluminum, 0.3% to 6.5% carbon, and the balance substantially all copper.

7. A sintered powdered metal bearing characterized by high wear and score resistance, high strength and good frictional properties, said bearing being formed from a powdered metal mixture consisting essentially of 1% to 5% aluminum oxide in the form of dispersed finely divided particles, 1% to 13% tin powder, 2% to 11% aluminum powder, and the balance substantially all a metal powder selected from the class consisting of copper and copper base alloys.

8. A sintered powdered metal bearing characterized by high wear and score resistance, high strength and good frictional properties, said bearing consisting essentially of 0.25% to 7.5% dispersed hard particles of crystalline Al_2O_3, 2% to 11% aluminum, nickel not in excess of 15%, 0.3% to 6.5% carbon, and the balance substantially all a metal selected from the class consisting of copper and copper base alloys.

9. A sintered powdered metal bearing characterized by high wear and score resistance, high strength and good frictional properties, said bearing being formed from a powdered metal mixture consisting essentially of 1% to 5% pulverized aluminum oxide, 0.3% to 6.5% graphite powder, 2% to 15% nickel powder, 2% to 11% aluminum powder, tin powder not in excess of 18%, 0.3% to 2% die lubricant, and the balance substantially all copper powder.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,831,243 April 22, 1958

Robert F. Thomson

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 11, after "15%" and before the comma insert --nickel--.

Signed and sealed this 8th day of July 1958.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents

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