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ALUMINUM-SILICON BASE SINTERED POROUS BEARING METALS

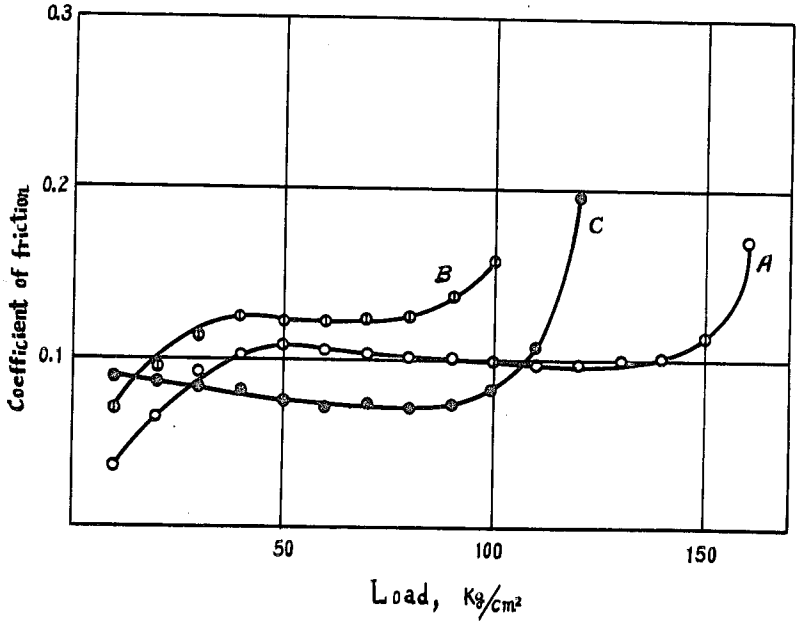
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Fig. 1.



30μ

Fig. 2.



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ALUMINUM-SILICON BASE SINTERED POROUS BEARING METALS

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ABSTRACT OF THE DISCLOSURE

Aluminum base sintered bearing metals having various advantages can be obtained from metal powders particularly including 5 to 50% by weight of silicon. It has been found that the addition of silicon substantially reduces the tendency of aluminum base metals to cause heat seizure and helps to prevent the surface clogging of the sintered product. Also, the metal mixture to be sintered including silicon powder has an improved compactibility.

This invention relates to sintered porous bearing metals and more particularly to metals formed by sintering the metal mixtures including 5 to 50% by weight of silicon powder, 0.5 to 6% by weight of copper powder, 1 to 4% by weight of tin powder, 0.3 to 2% by weight of magnesium powder, 0.3 to 2% by weight of antimony powder and the rest aluminum powder.

Heretofore, aluminum base bearing metals of different types have been proposed but unlike copper base or the like bearing metals, they wear very rapidly and their bearing surface is severely roughened. This has caused many problems in practical applications of aluminum base bearing metals despite of their merits including lightness in weight, good bearing-speed characteristics and cheapness.

To avoid such significant wear of aluminum-base bearing meals, the inventors have conducted various researches and found that highly wear-resistant bearing metals can be obtained by adding substantial amounts of silicon to aluminum base alloys.

In alloys containing aluminum as a major ingredient and particularly aluminum casting alloys, it has previousbeen known that the addition of silicon to such alloys is effective to increase the toughness of castings thereof even when added in a little amount but in such castings it has commonly been supposed that the silicon largely remains in elementary form in the metal and acts as a factor causing substantial heat of friction and thus tends to cause heat seizure to the bearings made of such metals. Accordingly the addition of silicon to aluminum casting alloys has previously been very limited in amount.

The present invention resides in preparing a uniform mixture of aluminum powder comprising 5 to 50% by weight (preferably 20 to 40% by weight) of fine silicon powder, 0.5 to 6% by weight of copper powder, 1 to 4% by weight of tin powder, 0.3 to 2% by weight of magnesium powder, 0.3 to 2% by weight antimony powder and residue of aluminum powder and compacting such mixture under the pressure ranging between 0.5 and 3.0 tons per square centimeter and then sintering at the temperature ranging between 480° C. and 550° C. in a period of 5 to 60 minutes. In the metals thus sintered, the silicon having a relatively high hardness of Vickers 1800 is intended to serve as a major load-carrying ingredient thereby to reduce the tendency of aluminum alloys to cause heat seizure, and at the same time to help to prevent the clogging of the sintered structure while improving the compactibility of the metal mixture to be sintered, for

example, so as to prevent the metal molds from being impaired in compacting operation.

The sintered structure may be impregnated with a few percent by weight of lubricating oil or with a soft metal such as lead or tin or with a low friction synthetic resin material such as tetrafluoroethylene resin to fill the voids in the porous structure of bearing metal whereby improving the fitting quality of the bearing structure and imparting a self-lubricating property thereto.

Some practical examples of the present invention will next be described.

EXAMPLE 1

Ingredient:	Percent by wt.
Si	5
Cu	4
Sn	3
Mg	0.5
Sb	0.5
Al	Rest
Oil content	1.0

In the above proportion, aluminum powder having a particle size of less than 20 mesh (Tyler) silicon powder having a particle size of less than 250 mesh, and copper, tin, magnesium and antimony powders having a particle size of less than 200 mesh respectively were mixed uniformly and the mixture obtained was compacted under the pressure of 1.5 tons/cm.^{2} and then sintered for a period of 60 minutes in a temperature range of from 530° C. to 540° C. in a non-oxidizing atmosphere of nitrogen gas to obtain a porous sintered alloy.

The alloy was impregnated with SAE #30 motor oil and thereafter tested for hardness and radial crushing strength constant (K). Rockwell number F110 and K=18 kg./mm.^{2} were obtained.

The bearing metal was then subjected to a cumulative load on a thrust type friction wear testing machine at the peripheral speed of 23 m./min., using a mating piece formed of structural carbon steel JIS S45C, in the condition that the load is increased every ten minutes by 10 kg./cm.^{2}. The coefficient of friction of 0.12 and the maximum load-carrying capacity as large as 60 kg./cm.^{2} were obtained.

EXAMPLE 2

Ingredient:	Percent by wt.
Si	10
Cu	4
Sn	3
Mg	0.5
Sb	0.5
Al	Rest
Oil content	2.0

The particle sizes of the ingredient powders and the sintering and testing conditions used were the same as those in Example 1. The porous alloy obtained by sintering the metal powders of the composition listed above exhibited Rockwell number F115, K=19.5 kg./mm.^{2}, coefficient of friction of 0.10 and the maximum load-carrying capacity of 80 kg./cm.^{2}.

EXAMPLE 3

Ingredient:	Percent by wt.
Si	20
Cu	4
Sn	3
Mg	0.5
Sb	0.5
Al	Rest
Oil content	3.0

The particle sizes of the ingredient powders and the sintering and testing conditions used were the same as

those in Example 1. The sintered porous alloy obtained by sintering the metal mixture of the composition listed above exhibited Rockwell number F100 K=17.5 kg./mm.², coefficient of friction of 0.10 and the maximum load-carrying capacity of 120 kg./mm.².

EXAMPLE 4

Ingredient:	Percent by wt.
Si	30
Cu	4
Sn	3
Mg	0.5
Sb	0.5
Al	Rest
Oil content	4.0

The particle sizes of the ingredient powders and the sintering and testing conditions used were the same as those in Example 1. The sintered porous alloy obtained by sintering the metal mixture of the composition listed above exhibited Rockwell number F98, K=15 kg./mm.², coefficient of friction of 0.10 and the maximum load-carrying capacity of 160 kg./cm.².

EXAMPLE 5

Ingredient:	Percent by wt.
Si	40
Cu	4
Sn	3
Mg	0.5
Sb	0.5
Al	Rest
Oil content	6.0

The particle sizes of the ingredient powders and the sintering and testing conditions used were the same as those in Example 1. The sintered porous alloy obtained by sintering the metal mixture of the composition listed above exhibited Rockwell number F70, K=10 kg./mm.², coefficient of friction of 0.12 and the maximum load-carrying capacity of 120 kg./cm.².

EXAMPLE 6

Ingredient:	Percent by wt.
Si	50
Cu	4
Sn	3
Mg	0.5
Sb	0.5
Al	Rest
Oil content	7.5

The particle sizes of the ingredient powders and the sintering and testing conditions used were the same as those in Example 1. The sintered porous alloy obtained by sintering the metal mixture of the composition listed above exhibited Rockwell number F55, K=8.0 kg./mm.², coefficient of friction of 0.12 and the maximum load-carrying capacity of 100 kg./cm.².

As observed from these examples, the porosity of the alloy metal, as represented by the weight percentage of oil impregnated and the load-carrying capacity of bearings made of such alloy increase as the percentage of silicon contained therein increases while the hardness and radial crushing strength constant value of the metal reach to their maximum one when the silicon content is about 10 percent by weight. Further, the silicon contained in the aluminum alloy is effective to make it less liable to stick while preventing the surface clogging of the alloy structure.

The particle size of the silicon powder used should be as small as possible and, compared with the bearing metal obtained using a silicon powder having a particle size of from 48 to 65 mesh, the one obtained using silicon powder having a particle size of less than 250 mesh was found excellent in porosity or oil impregnation rate (by approximately 40% or more) as well as uniformity of the alloy structure.

Referring to the accompanying drawing, FIG. 1 represents a photo-micrograph of the sintered bearing metal having the composition of 20% by weight of Si, 4% by weight of Cu, 3% by weight of Sn, 0.5% by weight of Mg, 0.5% by weight of Sb, rest of Al and 3.0 by weight of oil.

The sintered porous alloy of FIG. 1 exhibits Rockwell number F100, K=17.5 kg./mm.², coefficient of friction of 0.10 and the maximum load-carrying capacity of 120 kg./mm.², silicon is represented by scattered dark areas.

FIG. 2 is a graphic diagram showing the results of the friction wear tests conducted with the bearing metal of Example 3 in comparison with an oil-impregnated sintered copper base alloy on a thrust type friction wear testing machine at the sliding speed of 23 m./min. using a mating piece of structural carbon steel JIS S45C under a cumulative load increasing every ten minutes by 10 kg./cm.².

The test speciments were each of a composition including 20% by weight of silicon as listed above in Example 3. In FIG. 2 curves A and B represent the results obtained with the bearing metals made by using silicon powder having a particle size of less than 250 mesh and silicon powder, having a particle size of 48 to 65 mesh respectively, and curve C illustrates for comparison the results obtained with oil impregnated copper base sintered alloy of the Japanese Industrial Standard B–1581, Type 1.

As observed from the diagram, the bearing metals of the present invention are slightly higher in coefficient of friction than that of oil-impregnated copper base sintered alloy but much exceed the latter in their load-carrying capacity. In addition, the wear of the mating member with the bearing metal of the present invention amounted to 0.012 gram after 160 minutes period of friction testing and that with the copper base metal amounted to as much as 0.015 gram after 120 minutes period of friction testing.

As regards the proportion of silicon in the metal mixture to be sintered, it has been found that about 10% by weight of silicon gives the maximum values of hardness and radial crushing strength constant to the bearing metal obtained and that, as the silicon percentage exceeds the optimum point, these values gradually decrease. When the silicon content reaches approximately 50% by weight, they become practically equal to the conventional values obtainable from no addition of silicon.

In contrast the oil content rises substantially linearly as the weight percentage of silicon increases up to about 10%. The increase of oil content is desirable since it causes surely reduction of the coefficient of friction, prevents heat seizure and helps to extend the bearing life and improve the load-carrying capacity of the bearing.

The silicon proportion should be determined also considering the desired mechanical strengths such as radial crushing strength constant and paying attention to the fact that any silicon percentage of less than 5% by weight is not only insufficient to prevent the significant wear pointed out hereinbefore or to avoid the tendency of heat seizure but also is ineffective to prevent the surface clogging or to obtain such an improvement in compactibility as will be described later. It is also be noted that any silicon percentage exceeding 50% by weight gives rise to strength problems and is practically unusable.

It is most recommendable to use a silicon proportion in the range of from 5 to 50% by weight and preferably from 20 to 40% by weight.

One of the conspicuous effects of adding silicon is the improvement in compactibility, that is the effect of preventing the peeling of metal molds used in compacting the metal powder mixture to be sintered. If no silicon is added, said metal powder in compacting operation tends to adhere to metal molds and to impair it severely. The addition of silicon is effective to prevent adhering of the metal molds and extend their service life. The reason why

peeling of the mold is prevented by addition of silicon, which bring rather high hardness, is not clear but such effect of adding silicon has now been confirmed experimentally and is one of its effects previously never thought in the art.

It is noted that copper when added in a proportion between one and 6% by weight is most effective to increase the strength of the sintered structure of metals but, as its proportion exceeds 6% by weight, it increases the shrinkage of compacts when sintered and makes them brittle. Addition of copper of less than one percent by weight gives no noticeable effect.

Tin has the effect of improving the fitting quality of the bearing metals and is most effective to increase its strength when added in a proportion of from one to 4% by weight. Tin of less than one percent by weight has no effect on the alloy produced and that of exceeding 4% by weight causes reduction in strength thereof.

Magnesium and antimony act to improve both the sinterability of the metal mixture and the mechanical strength of the sintered product respectively.

Even in an atmosphere of nitrogen gas of commercial purity the mixture including magnesium and antimony respectively can be sintered with extreme ease, giving a smooth and beautiful appearance on the surface of the sintered product in case that it includes 0.6% by weight of magnesium and antimony respectively. In the absence of an atmosphere of nitrogen gas, the mixture cannot be sintered satisfactorily because the aluminum oxide film is formed on the surface of metals to be sintered during sintering process.

The effects described above of these ingredients, namely magnesium and antimony, start to appear when the weight percentage of either ingredient reaches 0.3% but any proportion of these ingredients exceeding 2% by weight has a reverse effect of reducing the strength of the bearing metals produced and is less effective to improve the sinterability of the metal mixture to be sintered. As for antimony it has a further effect of preventing sweating out of the relatively low melting ingredients when sintered thereof.

As pointed out hereinbefore, the bearing metal of the present invention can be impregnated with soft metals or low friction synthetic resins as well as with lubricating oil to fill the voids in the porous structure. Impregnation of these substances is apparently effective to impart desired fitting and self-lubricating characteristics to the metal. Impregnation of solid subtsances such as mentioned above, however, naturally reduces the proportion in which lubricating oil can be impregnated, thus adversely affecting the bearing service life, and is not recommendable, for example, when the bearing metal is used without lubrication for a relatively long period.

In other words, such solid substances as soft metals and low friction synthetic resins are not to be used in place of liquid lubricants but they have the advantageous effects of improving the fitting characterisitc of the bearing metal and imparting a considerable self-lubricating characteristic thereto.

Accordingly, in impregnation of solid lubricating substances as mentioned above they should be used in an amount carefully determined to suit the intended purpose or the particular application of the bearing. In cases where the metal bearing has been impregnated with a considerably large amount of such solid substance under a high speed, it is necessary to lubricate the metal in a positive fashion.

For example, the sintered metal of the composition as described in Example 3 can be impregnated with over 10% to over 20% by weight of lead. For comparison, such sintered metal impregnated with approximately 20% by weight of lead (and having the oil content accordingly reduced to 1% by weight or less) and Phosphor bronze bar Type 2 (JIS H3741) cutting up into a shape of test specimen were tested in SAE #30 motor oil using a mating piece of structural carbon steel S45C, at sliding speed of 83.3 m./min. under the thrust load of 30 kg./cm.^{2} (as applied between the contacting end surfaces of the cylindrical pieces). After 60 hours of continuous running, the metal of the present invention exhibited a coefficient of friction of 0.05 whereas the Phosphor bronze piece exhiibted a coefficient of friction of 0.10. Also, after the same testing period, the wearing amount of the former was measured and found to be 0.015 gram whereas that of the latter was found to be 0.075 gram. In view of the fact that the former bearing metal, impregnated with 20% by weight of lead, has a specific gravity of much lower than that of the latter bearing metal and of the ratio of 1:4, it is apparent that the former or bearing metal of this invention substantially exceeds in wear resistance even if taking the difference of the specific gravity of between the former and the latter in to consideration.

From the foregoing it will be apparent that the aluminum-silicon base sintered bearing metal of the present invention has many advantages over conventional aluminum base and other bearing metals, including better compactibility of the metal mixture to be sintered elimination of the significant wear previously encountered with aluminum base metals, substantial increase in load-carrying capacity and improvement in lubricating characteristics. Further, according to the present invention, bearings suited to different applications can be easily produced by impregnating the sintered metal of the invention with appropriate solid substances such as soft metals and low friction synthetic resins.

What is claimed is:

1. Aluminum-silicon base porous bearing metal formed by sintering a compacted mixture consisting essentially of 5 to 50% by weight of silicon powder, 0.5 to 6% by weight of copper powder, 1 to 4% by weight of tin powder, 0.3 to 2% by weight of magnesium powder, 0.3 to 2% by weight of antimony and the rest aluminum powder.

2. Porous bearing metal as claimed in claim 1 characterized in that it is impregnated with a soft metal, said soft metal being selected from materials of the group consisting of lead powder and tin powder.

3. Porous bearing metal as claimed in claim 1 characterized in that it is impregnated with low friction synthetic resin, said low friction synthetic resin being tetrafluoroethylene resin.

4. A process for manufacturing aluminum-silicon base sintered porous bearing metal mixture by compacting the mixture consisting essentially of 5 to 50% by weight of silicon powder, 0.5 to 6% by weight of copper powder, 1 to 4% by weight of tin powder, 0.3 to 2% by weight of magnesium powder, 0.3 to 2% by weight of antimony powder and the rest of aluminum powder under the pressure ranging between 0.5 and 3.0 tons per square centimeter and then sintering in a temperature ranging between 480° C. and 550° C. in a non-oxidizing atmosphere.

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