Sintered Alloy for Oil-Retaining Bearing and Method for Manufacturing the Sintered Alloy

The present invention relates to a sintered alloy for an oil-retaining bearing and a method for manufacturing the sintered alloy, and more particularly to a sintered alloy and a method for manufacturing the same which is suitable for the bearings of audio instruments and the like. The sintered alloy has excellent adaptability to the counterpart of the bearing, causes relatively little increase in temperature when it is driving, because of the low friction coefficient, and has excellent mechanical strength.

Sintered alloys have been widely employed in oil-retaining bearings and serve as important components in most appliances. In the national standards in Japan called Japanese Industrial Standards (JIS) various kinds of industrial appliances are standardized. These bearings are made from various kinds of alloys for example, iron alloys, iron-copper alloys, iron-carbon alloys, iron-copper-carbon alloys, iron-copper-lead alloys, bronze alloys, copper alloys, lead-bronze alloys and similar alloys.

Japanese Patent Laid-Open 56-51554, for example, discloses a green compact essentially composed of an iron powder and a brass powder, which compact is subjected to a sintering process to produce a sintered alloy.

The above-mentioned conventional oil-retaining bearing, which is made from an alloy a main component of which is iron has excellent mechanical strength. Therefore, it can serve as a heavy-duty bearing. However, such a conventional bearing has a large

friction coefficient which disadvantageously causes increased abrasion in the counterpart of the bearing, and also has poor corrosion resistance.

In order to resolve the above disadvantages of conventional bearings, a copper-base sintered alloy for oil-retaining bearing has been proposed. However, such bearings made of copper-base alloy are expensive and have poor mechanical strength.

In order to accommodate these material properties of the above conventional bearings, another conventional bearing has been proposed, which bearing is made from a sintered alloy. A green compact of the sintered alloy is essentially composed of an iron powder, a copper powder, and at least one additional metal powder such as bronze powders, brass powders, lead powders and German-silver powders. However, the sintered alloy of this other conventional bearing suffers from segregation of the additional metal powders. In addition, the bearing made of such sintered alloy has the same disadvantages as bearings made of iron-base alloys when the proportion of the iron powder is relatively large in the green compact of the alloy. Furthermore, when the proportion of the copper powder or the copper-base alloy powder is relatively large, bearings made from such alloys are expensive and suffer from the same disadvantages as bearings made from copper-base alloys.

Incidentally, the conventional powder mixture mentioned-above is generally poor in ease of compaction so that the mixture must be compacted under a relatively large pressure or there must be included therein a suitable powdered solid lubricant for smoothly conducting the compaction process of the mixture. In cases where the powder mixture includes a suitable powdered solid lubricant mixed with the

mixture, the alloy has relatively poor mechanical strength, and the dies have a limited life.

Figure 3 is a photomicrographic illustration showing the microstructure of a conventional sintered iron-copper alloy a green compact of which includes 70% by weight of an iron powder and 30% by weight of a copper powder. As is clear from Figure 3, iron particles (1) and copper particles (2) are uniformly mixed with each other, and the ratio of exposed area is in proportion to the ratio of powders of the mixture.

Nowadays, one of the most important uses of oil-retaining bearings is in audio appliances, for example, the capstan axis of a tape player or a video tape deck, which axis is provided with inertial rotating fly-wheels and rotates from high speed rotation to low speed rotation. For this application, good mechanical strength, ensuring the same axis angle position, low friction coefficient, and excellent adaptability to the counterpart of axis are needed to effectively prevent wow, noise and other problems. But it is very difficult to achieve these properties effectively.

It is an object of the present invention to provide a sintered alloy for an oil-retaining bearing and a method for manufacturing the same which is suitable for the bearings of audio instruments, being excellent in adaptability to the counterpart of the bearing, causing relatively little increase in temperature because of its low friction coefficient, and having excellent mechanical strength.

According to the present invention, these disadvantages inherent in the above conventional sintered alloys are eliminated by employing the following sintered alloys for oil-retaining bearings

and method for manufacturing the sintered alloys:

1. A sintered alloy suitable as a material for an oil-retaining bearing comprising discrete particles of iron wherein the entire peripheral surface of each iron particle is coated with copper or a copper-based alloy, the sintered alloy comprising 20 to 55% by weight iron, 30 to 75% by weight copper, 2 to 12% by weight tin, 2.5 to 9% by weight lead and having an open porosity ranging from 15 to 28% by volume.

2. A method for manufacturing a sintered alloy suitable for an oil-retaining bearing, comprising the steps of:

(i) preparing a copper-coated iron powder by coating an iron powder with 25-60% by weight copper;

(ii) mixing 100 parts by weight of said copper-coated iron powder with 10-150 parts by weight of tin-lead alloy powder and/or copper-tin-lead alloy powder to form a powder mixture;

(iii) compacting said powder mixture into a green compact;

(iv) sintering said green compact at 500 to 780°C to produce a sintered alloy;

(v) sizing said sintered alloy;

the resulting alloy product comprising particles of iron coated on their entire peripheral surface with copper or a copper-base alloy and having a composition of 20 to 55% by weight iron, 30 to 75% by weight copper, 2 to 12% by weight tin and 2.5 to 9% by weight lead and having an open porosity ranging from 15 to 28% by volume.

Additional aims and features of the present invention will become apparent from the following description of the preferred embodiments of the present invention, which will be made with reference to the accompanying drawings in which:

Figure 1 is an enlarged sectional view of a spherical iron particle coated with copper which is used in the present invention;

Figure 2 is an enlarged sectional view of an irregular-shape iron particle coated with copper which is used in the present invention; and

Figure 3 is a photomicrographic illustration of a conventional sintered alloy which contains iron and copper in the ratio of 70 to 30.

Referring now to the drawings, there are illustrated: an iron particle 1; a copper particle 2; a copper coating 2a; and a fine particle 3.

According to the present invention, each iron particle 1 is coated with copper in the preparation of a starting powder mixture which is compacted into a green compact from which a sintered alloy is produced by a sintering process. A copper coating on each iron particle 1 is produced by one of the methods of electroplating, hot dipping, electroless plating, or dry plating. As shown in Figures 1 and 2, the iron particle 1 is entirely coated with copper coating 2a, and is further coated partly with fine powder 3 which results in an irregular surface on the iron particles.

The electric current density and operating time of the above processes are controlled to produce the desired copper coating on each of the iron particles 1. The iron particles used in the present invention are coated with 25-60% by weight of copper, preferably 28-45% by weight of such copper metal coating.

Figures 1 and 2 show that each of the iron particles 1 is coated with copper coating 2a. More than 95% of the surface of each iron particle 1 is effectively coated with copper. As shown from the photomicrographic illustration, the copper coating 2a

has an irregular surface 3 made of copper powder, which is so fine as to make the compaction process easy. The irregular surfaces 3 will never allow segregation and other defects in the case of the method using a mixture of iron powder and copper powder.

Incidentally, in the present invention, although the size of the iron particles is not specified, it is possible to employ iron particles in wider particle size range than a conventional particle size of 100 mesh employed in manufacturing iron-base sintered alloys. Namely, even when relatively fine iron particles are employed in the present invention, such iron particles are coated with copper such that they have increased diameters, which makes it possible to easily treat such fine iron particles coated with copper in the same way as conventional-size iron particles. In addition, due to the presence of the copper coating on each of the iron particles, such iron particles coated with copper are excellent in ease of compaction, which makes it possible to normally or easily compact oversize iron particles in the same manner as that of the conventional-size iron particles.

The tin-lead alloy powders of the present invention consist of 10-63% by weight of tin and the rest is lead. The copper-tin-lead alloys of the present invention consist of 5-12% preferably 5-8% by weight of tin, 1-15% preferably 2-8% by weight of lead, and the rest is copper. Soft properties similar to those of solder metal are obtained by alloying tin with lead, and further alloying with copper to make the alloy product having excellent adaptability to copper-coated iron particles. If the alloy material contains less than 2% by weight of tin and less than

2.5% by weight of lead, the above properties can not be obtained. On the other hand, if it contains more than 12% by weight of tin, and/or more than 7% by weight of lead, a process for sintering with iron particles which are coated with copper powder is likely to be relatively unsuitable.

The proportion of copper coated iron powder and copper-tin-lead alloy powder mentioned above in the sintered alloy product is preferably obtained by mixing 100 parts by weight of copper coated iron powder with 10-150 parts by weight of copper-tin-lead alloy powder.

In general, the green compact containing the iron particles coated with copper has an open porosity ranging from about 23% by volume to about 38% by volume, specifically ranging from about 26% by volume to about 32% by volume. If the open porosity of the green compact is less than 26% by volume, specifically less than 23% by volume, then when the sintered alloy product made from the green compact is used as an oil-retaining bearing, it is impossible for the sintered alloy produced from the green compact to reserve a margin for the sizing process and to have an open porosity for the oil-impregnation process. In contrast with this, if the open porosity of the green compact is more than 32% by volume, specifically more than 38% by volume, the green compact suffers from poor mechanical strength which increases damage to the green compact during handling and sintering operations.

Incidentally, in the green compact of the present invention the iron particles contained therein have the same coating proportions as each other. However, according to the present invention, it is also possible to employ a green compact in which the

coating proportions of the iron particles are different from each other. For example, according to the present invention, the green compact may be composed of: iron particles having a copper-coating proportion of 10 wt.%; iron particles having a copper-coating proportion of 20 wt.%; and iron particles having a copper-coating proportion of 30 wt.%. They are mixed with each other and further mixed with the copper alloy powders of the present invention.

The green compact of the present invention is generally compacted under a pressure of about 2-3 ton/cm^2 by the metal pattern. This compacting pressure is 70-85% of conventional compacting pressures for iron powders.

In general, the green compact is sintered at a sintering temperature of from 500 to 780°C preferably 550 to 700°C and for a sintering time of about 30 to 60 minutes in a reducing atmosphere or in an inert atmosphere.

The thus sintered compact of the alloy is then subjected to a sizing operation to produce the desired alloy product having a predetermined size and a predetermined porosity. The sintered alloy has a sizing margin the proportion of which is about 20 to 35% based on the open porosity of the green compact. The sintered alloy is subjected to sizing to produce an alloy product which has an open porosity of from 15 to 28% by volume. If the open porosity of the alloy product is less than 15% by volume, it is impossible to conduct a successful oil-impregnation operation for the alloy product such as is suitable for a material for an oil-retaining bearing. On the other hand, when the open porosity of the alloy product is more than 28% by volume, the alloy product suffers from poor

mechanical strength. Preferably, the alloy product has an open porosity of from 18 to 23% by volume, which gives the alloy product good mechanical strength and oil-impregnation properties.

A solid lubricant such as graphite and molybdenum disulfide is mixed with the other starting powders in a pulverized condition to prepare a powder mixture which is compacted into the green compact. However, the pulverized solid lubricant such as graphite has a lower density than any of the remaining starting powders of iron, German-silver and bronze so that such lubricant powder tends to float on the powder mixture so as to segregate therefrom during transportation, handling in press hopper, and compaction treatment of the mixture, which makes it difficult to uniformly mix the lubricant powder with the remaining starting powders. In order to resolve such segregation problems, the solid lubricant such as graphite is mixed with the remaining starting powders in a granulated condition, the lubricant assuming a fine-powder shape removed, which is found effective against the segregation problem. Namely, the size of a commercially available graphite powder is within the range of from 1 to 30 microns, or from 1 to 50 microns. In contrast with this, a preferable size for the graphite powder employed in the present invention is with the range of from 10 to 150 microns, more preferably within the range of from 20 to 100 microns in which a graphite powder up to 10 microns, preferably up to 20 microns in size is removed, whereby the graphite powder may be uniformly mixed with the other staring powders to resolve the above segregation problem. Separation of the graphite powder up to 10 microns, preferably up to 20 microns in size is effectively conducted in a liquid which

prevents the graphite powder from producing dust. And in case a solid lubricant is coated with copper, it is possible to strip off the coating though the compacting and sizing processes.

The effect of the present invention will be now described below.

Due to the sintered alloys of the present invention being comprised of more than 20% by weight of iron particles, the sintered alloys of the present invention have excellent mechanical strength, specifically to pressure resistance, and when employed in oil-retaining bearings will effectively prevent the rotary shaft of the oil-retaining bearing from shaking.

In the case of sintered alloys comprising less than 55% by weight of iron, each of copper, tin and lead can preferably be added and the resulting sintered alloy of this invention has good adaptability to the counterpart of bearing a low friction coefficient and maintains the bearing within a relatively low temperature range.

In order to effectively coat the iron particles of the present invention and obtain corrosion resistance, the sintered alloys of this invention comprise more than 30% by weight of copper. In order that the final sintered alloy contains sufficient iron, tin and lead, less than 70% by weight of copper should be used.

In order to obtain excellent adaptability to the counterpart of the bearing and a low friction coefficient, the sintered alloys of this invention should comprise more than 2% by weight of tin, and more than 2.5% by weight of lead. The cost of the product is kept low by restraining the upper limit of tin to 12% by weight, and restraining the upper limit

of lead to 9% by weight, specifically 7% by weight. These limits provide a suitable balance between iron, copper, tin and lead, and due to these limits, the products of the present invention obtain the above properties to a sufficient extent.

In order to achieve the preferred oil-impregnation of the bearing and lubricating operations, the alloy product of the present invention has an open porosity of more than 15% by volume. By restricting the upper limit of the open porosity of 28% by volume, the alloy product of the present invention retains good mechanical strength.

In order to coat the iron particles effectively, to obtain good corrosion resistance and easy compacting operation, iron particles are coated with copper metal powders of more than 25% in proportion by weight. By restricting the upper limit of coating copper powders to 60% by weight, tin and lead are effectively included in an amount which produces a suitable alloy of the present invention.

Each of the compacting iron particles coated with copper retain mechanical strength, and the alloy product of the present invention, when used as a bearing, prevents the rotary shaft of the bearing from shaking, has good adaptability to the counterpart of the bearing, and sufficient mechanical strength can be obtained because of the properties of mixed metals. Since a considerable amount of iron powder is contained in the present invention, the cost of the alloy product of the present invention is kept relatively low.

As for the iron particles coated with copper according to the present invention, each of the iron particles are further coated with powders of tin-lead alloy or copper-tin-lead alloy, and when the alloy

product of the present invention is employed in a bearing material, it imparts improved adaptability to the counterpart of the bearing, low friction coefficient of the alloy, and improved thermal conductivity through sintering conducted at a relatively low temperature. Tin-lead-copper alloy powders improving the sintering properties of the iron particles coated with copper powders, and the green compacts of the present invention are preferably sintered at a relatively low sintering temperature of from 450 to 750°C.

In cases where the amount of tin-lead-copper alloy powder is less than 10 parts by weight based on 100 parts by weight of copper coated iron particles, it is possible to obtain the above effects. On the other hand, when the amount of tin-lead-copper alloy powder is more than 150 parts by weight, the cost of the sintered alloy product increases whilst any improvement in mechanical strength is not expected.

Copper powder coating formed on iron particles, and further coating formed by tin-lead-copper alloy powders will make the compacting process easy.

EXAMPLE

Minus 100-mesh iron particles were copper plated to prepare a copper-coated iron particles which have a 40% by weight of copper coating. Tin-lead-copper alloy powder comprising 5% by weight of tin and 5% by weight of lead, and molybdenum disulfide (MoS_2) powder coated slightly with tin-lead alloy powder and copper powder, including 63% by weight of tin and 37% by weight of lead were prepared, and the powders were mixed as shown in Table 1, from No 1 to No 7.

TABLE 1

Testing Number	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
40% Copper plated Iron Powder	50 %	60 %	40 %	50 %	90 %	85 %	86 %
50% Tin - 5% Lead - Copper alloy Powder	45 %	35 %	60 %	40 %	——	——	——
Copper coated MoS_2 Powder	——	——	——	4 %	——	——	4 %
63% Tin - 37% Lead - Copper alloy Powder	5 %	5 %	——	6 %	10 %	15 %	10 %

Table 2 shows compositions and theoretical specific gravities of No 1 to No 7 shown in Table 1.

TABLE 2

Testing Number	No 1	No 2	No 3	No 4	No 5	No 6	No 7
Fe	30.00 %	36.00 %	24.00 %	30.00 %	54.00 %	51.00 %	51.60 %
Cu	60.50 %	55.50 %	70.00 %	58.00 %	36.00 %	34.00 %	36.40 %
Sn	5.40 %	4.90 %	3.00 %	5.78 %	6.30 %	9.45 %	6.30 %
Pb	4.10 %	3.60 %	3.00 %	4.22 %	3.70 %	5.55 %	3.70 %
MoS_2	—	—	—	2.00 %	—	—	2.00 %
Theoretical Density	8.565	8.479	8.638	8.714	8.280	8.287	8.189

Each of these powders are compacted to make the products about 6.02mm in outer diameter, about 12.07mm in inner diameter and about 10mm in length. These products are further sintered at a sintering temperature of 650°C in a continuous sintering furnace at a speed of 7mm/minute. Table 3 shows compact densities, densities after sintering, outer diameters, changes in outer diameters through sintering, squeezing points and hardness of these products.

TABLE 3

	Compact density	Density after Sintering	Open Porosity	Outer-diameter	Change in Outer diameter through Sintering	Squeezing point	Hardness (HRB)
Average	5.954	6.080	28.86	12.007	- 0.522	14.34	36.4
Maximum	5.970	6.100	29.20	12.020	- 0.414	14.87	40.0
Minumum	5.940	6.060	28.60	12.000	- 0.580	13.65	31.0
Difference	0.030	0.040	0.60	0.200	0.166	1.22	9.0
Av.	5.918	6.064	28.48	11.990	- 0.663	15.11	42.0
Max.	5.930	6.090	28.60	12.000	- 0.580	15.53	45.0
Min.	5.900	6.030	28.30	11.980	- 0.746	14.13	38.0
Dif.	0.030	0.060	0.30	0.020	0.166	1.40	7.0
Av.	6.042	6.184	28.42	12.006	- 0.530	13.97	28.4
Max.	6.050	6.220	28.70	12.010	- 0.497	14.12	31.0
Min.	6.030	6.160	28.00	12.000	- 0.580	13.83	26.0
Dif.	0.020	0.060	0.70	0.010	0.083	0.29	5.0
Av.	6.082	6.188	27.48	12.017	- 0.439	15.22	48.8
Max.	6.100	6.200	27.80	12.020	- 0.414	15.56	50.0
Min.	6.070	6.170	27.40	12.010	- 0.497	14.95	48.0
Dif.	0.030	0.030	0.40	0.010	0.083	0.61	2.0
Av.	5.784	5.984	27.48	11.948	- 1.011	12.44	55.6
Max.	5.850	6.070	28.90	12.000	- 0.580	13.17	60.0
Min.	5.740	5.860	26.50	11.895	- 1.450	11.43	52.0
Dif.	0.110	0.210	2.40	0.105	0.870	1.74	8.0
Av.	5.826	6.148	25.86	11.874	- 1.624	12.51	73.0
Max.	5.850	6.270	26.70	11.940	- 1.077	12.99	81.0
Min.	5.800	6.070	24.50	11.810	- 2.154	12.18	64.0
Dif.	0.050	0.200	2.20	0.130	1.077	0.81	17.0
Av.	5.696	5.846	29.42	11.988	- 0.679	12.64	53.6
Max.	5.710	5.860	29.60	11.990	- 0.663	12.91	57.0
Min.	5.680	5.840	29.20	11.980	- 0.746	12.27	52.0
Dif.	0.030	0.020	0.40	0.010	0.083	0.64	5.0
UNIT	g/cc	g/cc	Vol%	mm	%	Kgf/mm²	deg.

These sintered products are further sized to make the oil-retaining bearings of inner diameter of about 0.08mm, open porosity of about 25% by volume, and outer diameter of about 12.00mm.

These bearings of the present invention were tested for temperature increase by using them as a rotary axis rotating at 1500 rpm or at 5000 rpm. 40 minutes from the start of the test (in general, the temperature of bearings increased for 30 minutes, after 30 minutes there was no temperature increase). The temperature increase was 15-16°C for the 1500 rpm test, and 24-25°C for the 5000 rpm test. The results of these tests illustrate the advantageous property of bearings of the present invention.

The inventors of the present invention have examined the sintering properties of said testing powders No 1 to No 7, through batch sintering at a sintering temperature of 600°C, and continuous sintering at temperatures of 650°C and 700°C for 1 hour. The results of these texts are almost the same as the results described in Table 3 except the changes of squeezing point of 2-6 kg/mm^2, and hardness of 2-25 HRH.

As described above, in the sintered alloys of the present invention, a copper coating is formed on the iron particles so as to prevent the iron from lowering the friction coefficient of the alloy, and improve the adaptability of the alloy to the counterpart or journal when the alloy serves as a bearing. In addition, the sintered alloy of the present invention is also excellent in thermal conductivity and may be produced through sintering conducted at a relatively low sintering temperature. Namely, it is possible to easily produce the sintered alloy of the present invention. Consequently, we believe that the present invention contributes much to industry.

CLAIMS

1. A sintered alloy suitable as a material for an oil-retaining bearing comprising discrete particles of iron wherein the entire peripheral surface of each iron particle is coated with copper or a copper-based alloy, the sintered alloy comprising 20 to 55% by weight iron, 30 to 75% by weight copper, 2 to 12% by weight tin, 2.5 to 9% by weight lead and having an open porosity ranging from 15 to 28% by volume.

2. A method for manufacturing a sintered alloy suitable for an oil-retaining bearing, comprising the steps of:

(i) preparing a copper-coated iron powder by coating an iron powder with 25-60% by weight copper;

(ii) mixing 100 parts by weight of said copper-coated iron powder with 10-150 parts by weight of tin-lead alloy powder and/or copper-tin-lead alloy powder to form a powder mixture;

(iii) compacting said powder mixture into a green compact;

(iv) sintering said green compact at 500 to 780°C to produce a sintered alloy;

(v) sizing said sintered alloy;

the resulting alloy product comprising particles of iron coated on their entire peripheral surface with copper or a copper-base alloy and having a composition of 20 to 55% by weight iron, 30 to 75% by weight copper, 2 to 12% by weight tin and 2.5 to 9% by weight lead and having an open porosity ranging from 15 to 28% by volume.

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