

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 produced by sintering a green compact including iron particles which are coated with copper or copper-based alloys so as to impart compressibility (i.e., easiness in compaction) to the green compact and to surely prevent the copper or copper-based alloys from segregating in the sintered alloy, the sintered alloy being excellent in any of mechanical strength, corrosion resistance, wear resistance and thermal conductivity while being considerably low in friction coefficient.

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) are standardized various kinds of the oil-retaining bearings which are employed in home electrical appliances, audio instruments, business machines, agricultural machines, automobiles, material carrying handling machines and like instruments, and assume various shapes in use. These bearings are made of various kinds of alloys, for example such as iron alloys, iron-copper alloys, iron-carbon alloys, iron-copper-carbon alloys, iron-copper-lead alloys, bronze alloys, copper alloys, lead-bronze alloys and like alloys.

Incidentally, for example, Japanese Patent Laid-Open No. 56-51554 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. On the other

hand, inventors described in this application has proposed in their Japanese Patent Laid-Open No. 60-200927 a green compact essentially composed of an iron powder, a brass powder and a German-silver powder, the green compact being sintered in a reducing atmosphere to produce an alloy.

The abovementioned conventional oil-retaining bearing, which is made of an alloy a main component of which is iron, is excellent in mechanical strength, and, therefore it can serve as a heavy-duty bearing. However, such conventional bearing is poor in corrosion resistance while being large in friction coefficient to disadvantageously increase the abrasion in the counterpart of the bearing.

In order to resolve the above disadvantage inherent in the conventional bearing, another conventional oil-retaining bearing made of a copper-base sintered alloy has been proposed. However, such another bearing made of a copper-base alloy is expensive while being poor in mechanical strength.

In order to accommodate these material properties of the conventional bearings, another conventional bearing has been proposed, which bearing is made of a sintered alloy a green compact of which is essentially composed of an iron powder, a copper powder, and at least one additional metal powder such as bronze powder, brass powder and lead powder. However, the sintered alloy of this conventional bearing suffers from the segregation of the additional metal powder. In addition, bearings made of such sintered alloy have the same disadvantages as those of bearings made of the iron-base alloy when the ratio of the iron powder is relatively large in the green compact of the alloy. On the other hand, in case that the ratio of the copper powder or the copper-base

alloy powder is relatively large in the green compact of the alloy, the bearing made of such alloy is expensive and suffers from the same disadvantages as those of the bearing made of the copper-base alloy.

5 Figure 4 is a photomicrographic illustration showing the microstructure of a conventional sintered alloy a green compact of which includes 30% by weight of a copper powder. As is clear from Figure 4, iron particles (1) and copper particles (2) are uniformly
10 mixed with each other according to their mixing ratios. As for such conventional alloy, in macrography, the copper seems to be predominant over the iron. However, in micrography, it is clear that the iron is predominant over the copper. Namely, due
15 to the presence of the copper in the alloy, a bearing made of such conventional sintered alloy is relatively good in corrosion resistance and adaptability to the counterpart of the bearing while being relatively low in friction coefficient. However, due to the presence
20 of the iron in the alloy, the above bearing suffers from the same disadvantages as those of the bearing made of the conventional iron-base alloy.

 Incidentally, a conventional powder mixture for preparing a green compact essentially consisting
25 of an iron powder is generally poor in easiness in compaction so that the mixture must be compacted in dies into the green compact under a relatively large pressure or must include a suitable powdered solid lubricant for smoothly conducting the compaction
30 process of the mixture. In case that the powder mixture is compacted in the dies under the relatively large pressure during a compaction operation, the dies have limited life. On the other hand, in case that the powdered solid lubricant is additionally mixed
35 with the mixture, the thus prepared mixture mixed with

such lubricant is compacted into a green compact which is finally sintered to produce an alloy containing the solid lubricant. However, such alloy is relatively poor in mechanical strength.

5 It is an object of the present invention to provide a sintered alloy and a method for manufacturing the same which is produced by sintering a green compact including iron particles which are coated with copper or copper based alloys so as to
10 impart easiness in compaction to the green compact and to surely prevent the copper or copper-based alloys from segregating in the sintered alloy, the sintered alloy being excellent in any of mechanical strength, corrosion resistance, wear resistance and thermal
15 conductivity while being considerably low in friction coefficient.

 We have found that the disadvantages inherent in the above conventional sintered alloys are eliminated by employing the following sintered alloys
20 for oil-retaining bearings and methods for manufacturing the sintered alloys.

 The invention accordingly provides a sintered alloy suitable as a material for an oil-retaining bearing wherein the said sintered alloy is produced by
25 sintering a green compact comprising iron particles in which the entire peripheral surface of each of said iron particles is coated with copper or copper-based alloys and wherein the sintered alloy consists of from 45% to 82% by weight of said iron and predetermined
30 percentage by weight of said non-ferrous metal and has an open porosity ranging from 15% to 28% by volume.

 It is preferred that the sintered alloy also contains an amount of at least one solid lubricant material, for example graphite or molybdenum
35 disulfide. Typically, the amount of solid lubricant,

if used, will be in the range of from 0.3 to 4.5% by weight based on the weight of the alloy.

According to one preferred embodiment of the invention, the green compact sintered to produce the sintered alloy is a compact of iron particles in which the entire peripheral surface of each of the iron particles is coated with copper and tin in which case the sintered alloy essentially consists of from 18 to 49.5% by weight of copper, from 0.5 to 6% by weight of tin and from 45 to 82% by weight of iron. According to another preferred embodiment, the particles of iron in the green compact are coated over their peripheral surface entirely with copper and zinc, in which case the sintered alloy essentially consists of from 6% to 40% by weight of copper, from 0.8% to 14.8% by weight of zinc and from 45% to 82% by weight of iron. According to yet another preferred embodiment, each particle of iron in the green compact is coated over its entire peripheral surface with copper, zinc and nickel, in which case the sintered alloy essentially consists of from 6% to 37.5% by weight of copper, from 0.8% to 14.8% by weight of zinc, from 0.8% to 9.0% by weight of nickel and from 45% to 82% by weight of iron and has an open porosity ranging from 15 to 25% by volume.

The sintered alloy of the invention may be made by a method comprising the steps of:-

mixing a predetermined amount of an iron powder with a powder of copper or a copper-based alloy to prepare a powder mixture in which the iron powder is coated with 18 to 50% by weight of said copper or copper-based alloy;

compacting said powder mixture into a green compact;

sintering said green compact to produce a

sintered alloy; and

sizing said sintered alloy to produce an alloy product.

In the method of the invention, it is
5 preferred that the powder mixture in which the iron
powder is coated with from 18 to 50% by weight of
copper or copper-based alloy is further mixed in the
proportion of 100 parts by weight with from 11 to 240
10 parts by weight with a powder of copper or copper-
based alloys to produce a second powder mixture which
is then compacted, sintered and sized to produce an
alloy product. This second powder mixture may
additionally be mixed with 0.5% to 5% by weight of at
least one solid lubricant such as graphite, molybdenum
15 disulphide or lead.

The copper or copper-based alloys with which
said iron powder is coated may be applied to said iron
powder through any one of processes comprising
20 electroplating, hot dripping, electroless deposition,
flame spraying, and dry plating, said processes being
carried out with the use of any one of alloys a first
one of which contains any one of metals comprising
silver, copper, lead, zinc, nickel, aluminium, cobalt,
chromium, molybdenum, titanium, manganese and
25 tungsten, a second one of which alloys contains two or
more metals of said metals, and a third one of which
alloys contains phosphorus and sulfur in addition to
said metals contained in said second alloy.
Preferably, the alloy with which the iron powder is
30 coated is a brass essentially consisting of copper and
zinc, or a bronze essentially consisting of copper and
tin, or a German silver essentially consisting of
copper, zinc and nickel.

The iron powder coated with the copper or
35 copper-based alloy above may further be coated with an

additional powder of any one of additional non-ferrous metals comprising Ag, Sn, Pb, Zn, Ni, Al, Cr, Mo, Ti, Mn, W, Sb, As, Be, Bi, B and In, said additional powder further including:

- 5 a powder of an alloy essentially consisting of said additional non-ferrous metals; powders of oxides of said additional non-ferrous metals; or a
 phosphorus/sulfur powder. For instance, the iron powder coated with the non-ferrous metal may be
10 further coated with an additional powder of a brass consisting essentially of copper and zinc, or with an additional powder of bronze consisting essentially of copper and tin, or with an additional powder of German silver essentially consisting of copper, zinc and
15 nickel, e.g. containing from 3.5-8.0% by weight of nickel. Alternatively, the iron powder coated with copper or copper-based alloys may be further coated with a powder of an oxide of a non-ferrous metal which oxide is then reduced to its metal in a reducing
20 atmosphere during a sintering process. An example of a non-ferrous metal oxide that may be employed in this way is lead oxide.

 Additional objects and features of the present invention will become apparent from the following
25 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 or copper-based alloys coating formed according to the present
30 invention;

 Figure 2 is an enlarged sectional view of an irregular-shape iron particle coated with a copper or copper-based alloy coating formed according to the
35 present invention;

Figure 3 is a photomicrographic illustration of a sintered alloy of the present invention; and

Figure 4 is a photomicrographic illustration of a conventional sintered alloy the contents of iron
5 and copper of which are equal to those of iron and copper of the sintered alloy of the present invention.

Referring now to the drawings, there are illustrated; an iron particle 1; a copper particle 2;
a non-ferrous metal coating 2a; and a non-ferrous
10 metal fine particle 3.

According to the present invention, each of iron particles 1 is coated with copper or copper-based alloys and/or their alloys in preparation of a starting powder mixture which is compacted into a
15 green compact from which a sintered alloy is produced through a sintering process. In case that the iron particles 1 are coated with copper particles 2, a copper coating on each of the iron particles 1 is produced through an electroplating process an electric
20 current density and an operating time of which process are controlled to produce a desired copper coating on each of the iron particles 1. the sintered alloy of the present invention contains 18-55% by weight of copper or copper-based alloy coating, preferably 25-
25 45% by weight of such copper or copper-based alloy coating. As described later, in case that the iron particles 1 coated with the copper or copper-based alloy coating is further coated with an additional powder of non-ferrous metal, an amount of the non-ferrous metal coating may be reduced to 20% by weight.
30 As a result, according to the present invention, it is possible to coat the entire peripheral surface of each of the iron particles with a non-ferrous metal coating. Since such non-ferrous metal coating on each
35 of the iron particles is soft while being provided

with an irregular surface, a starting powder mixture from which is produced a green compact containing the iron particles coated with the non-ferrous metal is excellent in easiness in compaction.

5 Incidentally, in the present invention, although the iron particles are not specified in size, it is possible to employ iron particles in wider particle size range than a conventional particle size range of from plus 80 mesh to minus 320 mesh employed
10 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 so as to be expanded in their diameter, which makes it possible to easily treat such
15 fine iron particles coated with copper in the same manner as that of the 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
20 easiness in 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.

 In Figures 1 and 2 are shown iron particles 1
25 coated with copper through electroplating process, which copper forms the coating 2a on each of the iron particles 1. At least 85 wt.%, normally more than 90 wt.% of the iron particles 1 are effectively coated with copper. The iron particles 1 shown in Figure 1
30 assume spherical shapes with somewhat deformed coatings 2a made of copper or copper-based alloys. These iron particles 1 with such coatings 2a are so fine as to make their compaction easy. On the other hand, in case that the iron particles 1 assume
35 elongated and irregular shapes as shown in Figure 2,

such iron particles 1 are also effectively coated with copper or copper-based alloys forming the copper or copper-based alloy coatings 2a on the iron particles 1. As is clear from the photomicrographic illustration shown in Figure 2, the entire peripheral surface of each of the iron particles 1 is substantially completely coated with the copper or copper-based alloy coating 2a. Incidentally, each of the iron particles 1 shown in Figures 1 and 2 is coated with copper the proportion of which is about 30 wt.% based on the weight of each of the iron particles 1. In case that the proportion of the copper is lower than 30 wt.%, each of the iron particles is coated with the copper to the substantially same extent as that of the iron particles coated with about 30 wt.% of the copper. In general, it is possible to completely coat the entire peripheral surface of each of the iron particles with at least 18 wt.% of the copper so that a stable copper coating is provided. In this case, the proportion of the copper is preferably at least 20 wt.%, and more preferably at least 25 wt.%, based on the weight of the iron particle.

As described above, the iron particle coated with the copper or copper-based alloy is naturally employed in preparation of a starting powder mixture which is compacted into the green compact. With this respect, in order to improve the material properties of the sintered alloy of the present invention, the iron particles coated with copper or copper-based alloys are further coated with a powder of a secondary non-ferrous metal according to the present invention. In the sintered alloy of the present invention essentially consisting of iron and copper or copper-based alloys, the non-ferrous metals contained in the

alloy are consolidated so as to improve the material properties of the sintered alloy. It is natural that: the secondary non-ferrous metal coating on the iron particles may be copper; or may belong to the same group as copper; or may be an alloy of copper. In addition, the secondary non-ferrous metal may be different from copper so as to be another non-ferrous metal or an alloy thereof. In a first case that secondary non-ferrous metal is copper or belongs to the same group as copper, the sintered alloy containing such secondary non-ferrous metal is generally provided with a stable structure. On the other hand, in a secondary case that the secondary non-ferrous metal is not copper so as to be another non-ferrous metal or an alloy thereof, the sintered alloy containing such secondary non-ferrous metal may be provided with material properties different from those of the first case. For example, copper-base metals are provided with lipophilic properties, while aluminium-base metals are provided with hydrophilic properties. As for other chemical, electrical, mechanical and physical properties, the copper-base metals are different from the aluminium-base metals. Consequently, in the sintered alloy of the present invention, it is possible to combine these properties of the copper-base metals and the aluminium-base metals by employing these metals as the non-ferrous metals for coating the iron particles.

Consequently, as for the sintered alloy of the present invention, the secondary non-ferrous metals applied onto the copper or copper-based alloy coating on the iron particles may be oxides of the non-ferrous metals. Namely, since the sintering process of the green compact is generally conducted in a reducing atmosphere, the oxides contained in the green compact

are reduced to metals which are alloyed with each other. For example, in the case where the secondary non-ferrous metal coating on the iron particles coated with copper or copper-based alloys is lead oxide, such
5 lead oxide is reduced to lead or lead-base alloys contained in the sintered alloy which is suitable as a material for bearings. The lead and lead-base alloys thus added to the sintered alloy essentially consisting of iron may improve bearing properties of
10 the sintered alloy even if the contents of the lead and lead-base alloys are relatively low. In addition, during the sintering process of the green compact, it is possible to prevent such lead and lead-base alloys from oozing out of the green compact.

15 Incidentally, in the present invention, the dimensions of the green compact containing the iron particles regularly coated with copper or copper-based alloys decrease as the result of sintering process thereof. In contrast with this, the dimensions of the
20 conventional green compact in which the iron particles and the copper or copper-based alloys are simply mixed with each other increase as a result of the bulking phenomenon of the compact during its sintering process. Consequently, it is possible to control the
25 green compact in its expansion and contraction during sintering by accommodating the ratio of the iron particles coated with copper or copper-based alloys to the iron particles simply mixed with the copper or copper-based alloys in the green compact.
30 Particularly, the iron particles coated with at least 18 wt.% of copper or copper-based alloys in the green compact is considerably contracted during sintering, which enables such contraction to balance a considerable expansion of the green compact containing
35 the iron particles simply mixed with copper or

copper-based alloy particles. The iron powder employed in the green compact of the present invention may be produced through any one of powder-production processes such as atomization processes, oxide-reduction processes, electrolysis processes, carbonyl processes, and milling processes. Namely, the shapes of the iron particles vary according to their production processes. However, in case that the iron particles are substantially completely coated with copper or copper-based alloys according to the present invention, differences in shape of iron particles substantially do not affect the properties of a starting powder mixture which is compacted into a green compact from which a sintered alloy is produced.

It is easy to coat the iron particles with copper or its alloys through a suitable application process such as electroplating, hot dipping, electroless deposition, flame spraying, and dry plating. In the process of the electroplating, the coatings on the iron particles are controlled in their amount and quality by suitably controlling the electric current density and operation time of the process. In the process of hot dipping, the copper or copper-based alloy coatings on the iron particles are controlled in their amount and quality by suitably controlling the temperature of the molten copper or copper-based alloy and the preheating temperature of the iron particles. As for the remaining processes, it is also clear that the coatings on the iron particles can be controlled in their amount and quality by controlling individual operation conditions of the remaining processes.

In general, the green compact containing the iron particles coated with copper or copper-based alloys have 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. In the case where the open porosity of the green compact is less than 26% by volume, specifically less than 23% by volume and that the sintered alloy product produced from such green compact is employed in the oil-retaining bearing, it is impossible for the sintered alloy produced from such green compact to reserve a margin for sizing process and to have an open porosity for oil-impregnation process. In contrast with this, in case that an open porosity of the green compact is more than 32% by volume, specifically more than 38% by volume, the green compact suffers from its poor mechanical strength which increases damage of the green compact during handling and sintering operations thereof.

Incidentally, in the green compact of the present invention, the iron particles contained therein have the same coating ratios with each other. However, according to the present invention, it is also possible to employ a green compact in which the coating ratios 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 ratio of 10 wt.%; iron particles having a copper-coating ratio of 20 wt.%; and iron particles having a copper-coating ratio of 30 wt.%. As for the remaining non-ferrous metal coatings on the iron particles, the above coating ratios may be applied.

In general, the green compact is sintered at a sintering temperature of from 700 to 1050°C in a reducing atmosphere or in an inert atmosphere. However, in case that the green compact containing at least one of a bronze powder, a brass powder, a

German-silver powder, a manganese-bronze powder and a phosphor-bronze powder, such green compact is preferably sintered at a temperature different from the above sintering temperature. For example: the
5 green compact containing the bronze powder should be sintered at a temperature of from 750 to 900°C; the green compact containing the brass powder should be sintered at a temperature of from 800 to 950°C; the
10 green compact containing the German-silver powder should be sintered at a temperature of from 800 to 950°C; the green compact containing the manganese-bronze powder should be sintered at a temperature of from 800 to 950°C; the green compact containing the phosphor-bronze powder should be sintered at a
15 temperature of from 750 to 950°C; the green compact containing a tin powder should be sintered at a temperature of from 700 to 850°C; and the green compact containing a lead powder together with the tin powder should be sintered at a temperature of from 500
20 to 780°C, the lead powder and the tin powder being alloyed with the copper coatings on the iron particles of the green compact during sintering thereof.

When the green compact is sintered at a temperature below the above-specified sintering
25 temperature, it is impossible for the thus sintered alloy to have a desirable sintered matrix structure or alloyed matrix structure. On the other hand, when the green compact is sintered at a temperature above the above-specified sintering temperature, such sintering
30 leads to a considerable energy loss, requires an expensive sintering installation, and causes the copper or copper-based alloy coatings formed on the iron particles to be fluidized or damaged. Incidentally, the green compact is sintered for about
35 30 to

about 60 minutes.

The thus sintered compact or alloy is then subjected to a sizing operation to produce a desired alloy product having a predetermined size and a predetermined open porosity. The sintered alloy has a sizing margin the proportion of which is about 20 to about 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. In this case, when the open porosity of the alloy product is less than 15 % by volume, it is impossible to conduct a successful oil-impregnation operation of the alloy product suitable as 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 its poor mechanical strength. Preferably, the alloy product has an open porosity of from 18 to 24 % by volume, which makes the alloy product good in mechanical strength and oil-impregnation properties.

The above-mentioned bronze generally consists of: about 5 - 15 wt. % tin; about 85 - 95 wt. % copper; and a suitable percentage by weight of zinc. On the other hand, the brass mentioned above generally consists of: 60 - 80 wt. % copper; 20 - 40 wt. % zinc; and 1 - 3 wt. % tin. If necessary, the tin content of the brass may be increased to about 10 wt. %, while the copper content of the same may be changed to about 90 wt. %. The German silver generally consists of: 5.5 - 32.5 wt. % zinc; and 8.5 - 19.5 wt. % nickel; the balance being copper apart from incidental impurities. The German-silver powder may be employed as it is. However, preferably the nickel content of the German silver is reduced to about 3.5 - 8.0 wt. %. For example, a German silver consisting of: 75 wt. % copper; 21 wt. % zinc; and 4 wt. % nickel is preferable. It is also possible to employ another German silver which is suitably adjusted in its zinc

content and nickel content depending upon application.

In addition to the above copper-base alloys, further employed in the secondary non-ferrous metal coatings on the iron particles are: lead; zinc; 5 aluminium; chromium; manganese molybdate; other non-ferrous metals and their alloys; and non-ferrous metals containing phosphor and/or sulfur. The secondary non-ferrous metal coatings are applied onto the copper or copper-based alloy coatings formed on 10 the iron particles, to make it possible to control the thus obtained sintered alloy in its mechanical properties, physical properties, chemical properties and electrical properties.

Incidentally, in case that a powder of an alloy such as a brass and a German silver the zinc 15 content of which alloy is considerably high is employed in the green compact, it is necessary to prevent the zinc contained in the alloy powder of the green compact from being dissipated through vaporization during sintering of the green compact. 20 In this case, it is preferable that the green compact is sintered while embedded in a carbon powder to prevent the zinc from being dissipated through vaporization during sintering. More preferably, the 25 green compact is sintered in a hermetically sealed refractory vessel. When the green compact is sintered in such hermetically sealed refractory vessel, the pressure of the vapor of zinc attains a considerable value to enhance diffusion alloying of the zinc with 30 copper and iron contained in the green compact, which makes the physical qualities of the sintered compact or alloy uniform.

When a powder of tin is added to copper coatings on the iron particles of the green compact to 35 alloy the copper coatings with the tin so as to

produce bronze coatings on the iron particles during sintering, the thus sintered compact or alloy is suitable as a material for a bearing provided with the same excellent bearing

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properties as those of a bearing made of bronze, the sintered alloy being also excellent in mechanical strength even when the iron content of the green compact is more than 50 wt. %. On the other hand, since the nickel contained in the German silver of the green compact is excellent in corrosion resistance such as oxidation resistance and alkali resistance, the sintered compact or alloy in a surface of which the nickel forms a passive-state oxide layer is excellent in corrosion resistance. As described above, the zinc contained in the green compact is alloyed with iron of the iron particles through diffusion alloying during sintering so that the sintered compact or alloy is further excellent in corrosion resistance due to the presence of the zinc. In addition, for example, when a bronze containing 10 wt. % tin is subjected to sintering, a liquid phase thereof appears at a temperature of 850 °C, which liquid phase enhances diffusion alloying of the bronze with metals of the iron particles and Cu-Zn-Ni particles, and enters spaces between the particles to improve the sintered alloy in its anti-friction 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 is smaller in specific gravity 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 a 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 problem, the solid lubricant such as graphite is mixed with the remaining starting powders in a granulated condition, the lubricant assuming

a fine-powder shape being 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 of the graphite powder employed in the present invention is within 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 starting 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.

Effects of the present invention will be now described hereinbelow.

In summary, in a starting powder mixture of the sintered alloy of the present invention, each of the iron particles is coated with copper or copper-base alloy powder so that the sintered alloy of the present invention is good in mechanical strength due to the presence of such iron particles while being also good in corrosion resistance and sufficiently low in friction coefficient due to the presence of the copper or copper-based alloy coating on each of the iron particles.

When the content of the copper or copper-based alloy of the sintered alloy of the present invention is up to 18 wt.%, it is difficult for the coating to show its effects. On the other hand, when the content of the copper or copper-based alloy of the sintered alloy is more than 50 wt.%, it is difficult for the

iron contained in the sintered alloy to impart a sufficient mechanical strength to the alloy. In addition to the above, such alloy is expensive.

5 In general, the iron particles or powder coated with copper or copper-based alloys is excellent in compressibility (i.e. easiness in compaction).

10 In the sintered alloy of the present invention, it is possible to employ any one of non-ferrous metals and their alloys comprising silver, zinc, tin, copper, lead, nickel, aluminium, chromium, manganese, molybdenum, tungsten, titanium, alloys consisting of at least two of these non-ferrous metals, and non-ferrous metal alloys further containing phosphorus and/or silicon.

15 As already described, copper powders are conventional materials in powder metallurgy. According to the present invention, each of the iron particles is coated with copper or an alloy thereof to prepare a starting material powder which is mixed with
20 the other starting material powders to prepare a powder mixture being compacted into a green compact from which a sintered alloy is produced through sintering, so that the resultant sintered alloy enjoys substantially all advantages of iron-base sintered
25 alloys and copper-based sintered alloys.

The iron particles coated with the copper-based alloy is more advantageous in effect than those coated with copper only.

30 When an additional or secondary non-ferrous metal powder or its alloy powder is further added to the powders of copper or copper-based alloy coatings on the iron particles according to the present invention, the resultant sintered alloy is further improved in material properties. For example, in case
35 that such additional or secondary non-ferrous metal

powder is a tin powder or like powders, it is possible for the resultant sintered alloy to lower its friction coefficient. In this case, however, when the amount of the additional non-ferrous metal powder such as a tin powder and the like is less than 0.5 parts by weight based on 100 parts by weight of the iron particles coated with copper or copper-based alloys, it is impossible for the resultant sintered alloy to sufficiently lower its friction coefficient. On the other hand, when the amount of the additional non-ferrous metal powder such as the tin powder and the like is more than 67 parts by weight based on 100 parts by weight of the coated iron particles, the cost of the resultant sintered alloy disadvantageously increases while a profound effect is not expected.

More particularly, in case that the additional non-ferrous metal powder is a tin powder, when the amount of the tin powder is less than 0.5 parts by weight based on the total amount of copper, it is impossible for the resultant sintered alloy to lower its friction coefficient. In case that the additional non-ferrous metal powder is a bronze powder, generally speaking, when the amount of the bronze powder is less than 10 parts by weight though it depends on the tin content of the bronze, it is impossible for the resultant sintered alloy to lower its friction coefficient. On the other hand, when the amount of the tin powder is more than 7 parts by weight, the cost of the resultant sintered alloy disadvantageously increases while a profound effect is not expected. In case of the bronze powder, when the amount of the bronze powder is more than 67 parts by weight, the cost of the resultant sintered alloy disadvantageously increases while a profound effect is not expected. In case that the additional non-ferrous metal powder is a

brass powder, when the amount of the brass powder is more than 11 parts by weight based on 100 parts by weight of the iron particles coated with copper or copper-based alloys, the mechanical strength of the resultant sintered alloy increases. However, when the amount of the brass powder is more than 67 parts by weight, the cost of the resultant sintered alloy disadvantageously increases while a profound effect is not expected. In case that the additional non-ferrous metal powder is a German-silver powder, when the amount of the German-silver powder is more than 11 parts by weight, the resultant sintered alloy is improved on mechanical strength and corrosion resistance. However, when the amount of the German-silver is more than 67 parts by weight, the cost of the resultant sintered alloy disadvantageously increases while a profound effect is not expected.

In case that the additional or secondary non-ferrous metal powder added to the iron particles coated with copper or copper-based alloys is a powder of a copper-tin-lead alloy, it is possible to remarkably improve the resultant sintered alloy in its bearing properties. It is well known to improve the sintered alloy in its bearing properties by adding lead. However, when a sufficient amount of lead is added to the coated iron particles, a green compact produced from the resultant powder mixture containing the sufficient amount of lead suffers from a lead-oozing phenomenon which arises when the green compact is sintered to produce a sintered alloy which is impaired in quality under the influence of the lead-oozing phenomenon. In the present invention, the additional or secondary non-ferrous metal powder is added to the iron particles coated with the copper or copper-based alloys, which makes it possible to coat

the iron particles with a powder of a substantially
copper-tin-lead alloy, whereby the lead-oozing
phenomenon of the green compact is eliminated during
sintering. In addition, since the green compact is
5 provided with an iron matrix composed of the iron
particles, the sintered alloy of the present invention
produced from such green compact is excellent in
mechanical strength while being excellent in its
bearing properties due to the presence of such
10 copper-tin-lead alloy coatings on the iron particles.

Namely, as for the iron particles coated with

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copper according to the present invention, each of the iron particles is further coated with a powder of a tin-lead alloy so that the copper is alloyed with the tin-lead alloy to prepare the copper-tin-lead alloy with which
5 the iron particles are coated during sintering. In case that the lead component of the copper-tin-lead alloy is added to the iron particles in the form of lead oxide, the green compact is sintered in a reducing atmosphere to reduce the lead oxide to lead which is alloyed with
10 the other components of the alloy to produce the copper-tin-lead alloy coating on the iron particles. In any case, the resultant sintered alloy of the present invention enjoys a sufficient mechanical strength and improved bearing properties. Incidentally, the green compact of
15 the present invention should be sintered at a sintering temperature of from 500 to 780 °C. When the sintering temperature is lower than 500 °C, it is impossible to sufficiently sinter the green compact. On the other hand, when the sintering temperature is higher than 780 °C,
20 the resultant sintered alloy is poor in mechanical strength, and the dimensions of the green compact shrink considerably as the result of sintering. The lead content of the sintered alloy of the present invention is at least 45 wt. % so that the lead content of the alloy
25 is relatively small, which contributes to cost reduction in manufacturing the sintered alloy.

According to the present invention, one or more solid lubricants such as graphite and molybdenum disulfide are added to the starting material powders for preparing
30 the starting powder mixture to be compacted into the green compact, whereby the green compact to be sintered into the sintered alloy is improved in its compressibility (i.e., easiness in compaction). Since such lubricants remain in the sintered alloy, the sintered alloy is also
35 improved in lubricity to lower its friction coefficient. The amount of the lubricants to be added to the other

starting material powders should be at least 0.5 wt.% based on the total amount of the other starting material powders (i.e. the iron particles coated with copper or copper-based alloys and the secondary non-ferrous metal powder to be added to the copper or copper-based alloy coating on each of the iron particles). When the amount of the lubricants is less than 0.5 wt.%, a profound effect of addition of the lubricants is not expected. On the other hand, when the amount of the lubricants is more than 5 wt.%, the resultant sintered alloy is poor in mechanical strength.

In case that a component such as zinc a boiling point of which is lower than the sintering temperature of the green compact is contained in the green compact, the green compact is sintered in a reducing atmosphere in a hermetically sealed refractory vessel to control vaporization of zinc during sintering, so that a desirable sintered alloy is produced according to the present invention.

In order to give certain product precise dimensions to the thus sintered alloy, the sintered alloy is subjected to cold reduction in dies, or what is called "sizing". Through such sizing operation, the sintered alloy is released from its stresses and deformations which are produced during sintering. The size of the sintered alloy going for sizing should be 15-35 vol.% (i.e. a sizing margin) greater than the required dimensions of the final product. When the sizing margin of the sintered alloy is less than 15 vol.%, it is impossible to sufficiently release the sintered alloy from its stresses and deformations. On the other hand, when the sizing margin of the sintered alloy is more than 35 vol.%, the resultant final alloy product is damaged in its sintered matrix and open

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porosity, which impairs the alloy product in lubricity and durability when the alloy product serves as an oil-retaining bearing.

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EXAMPLE 1

Minus 100-mesh iron particles were copper plated to prepare three kinds of copper-coated iron particles which have a 20 wt. % copper coating: a 30 wt. % copper coating; and a 40 wt. % copper coating, respectively.

In order to produce ring-like oil-retaining bearings made of the sintered alloy, these three kinds of the copper-coated iron particles were compacted into green compacts (1), (2) and (3), respectively. These green compacts (1) to (3) constitute a first compact group. On the other hand, a 1.8 wt. % tin powder, a 2.7 wt. % tin powder and a 3.6 wt. % tin powder were added to these three kinds of the copper-coated iron particles, respectively, to prepare three kinds of copper/tin-coated iron particles which were compacted into green compacts (4), (5) and (6), respectively. These green compacts (4) to (6) constitute a second compact group. In like wise, a 25 wt. % bronze powder was added to the above three kinds of the copper-coated iron particles, respectively, to prepare three kinds of copper/bronze-coated iron particles which were compacted into green compacts (7), (8) and (9), respectively. The bronze was composed of copper and 12 wt. % tin. These green compacts (7) to (9) constitute a third compact group. Likewise, a 25 wt. % brass powder was added to the copper-coated iron particles, respectively, to prepare three kinds of copper/brass-coated iron particles which were compacted into green compacts (10), (11) and (12), respectively. The brass was composed of copper, 30 wt. % zinc and 2 wt. % tin. These green compacts (10) to (12) constitute a fourth compact group. Further, a 25 wt. % German-silver powder was added to the copper-coated iron particles, respectively, to prepare three kinds of copper/German silver-coated iron particles which were compacted into green compacts (13), (14) and (15), respectively. The German silver was composed of copper, 21

wt. % zinc and 4 wt. % nickel. These green compacts (13) to (15) constitute a fifth compact group. Chemical compositions, compact density ratios, sintering temperatures, open porosities after sizing, squeezing points, friction coefficients, and temperature raises in operation of these green compacts (1) to (15) of the present invention and their resultant sintered alloys of the present invention are shown in the following Table 1. In each of the compact groups, three kinds of the green compacts with the compact density ratios of from 70 to 75 % were prepared. Any of the green compacts (1) to (15) was sintered at a predetermined sintering temperature within a range of from 700 to 1050 °C. In each of the compact groups: a difference in sintering temperatures of adjacent green compacts in the Table 1 was 50 °C; and a difference in open porosity (after sizing) of adjacent sintered alloys in the Table 1 was 2 vol. %, the open porosity of any of the sintered alloys was within a range of from 18 to 24 vol. %.

Fig. 3 is a photomicrographic illustration of the sintered alloy of the present invention having been subjected to sizing, which alloy was produced by sintering the green compact (3) shown in Table 1. As is clear from Fig. 3, at least 90 % (about 98 %, on the average) of the iron particles are coated with copper to give the alloy a rough surface. On the other hand, Fig. 4 is a photomicrographic illustration of a conventional sintered alloy which was produced by sintering a green compact composed of an iron powder which was not coated with copper while simply mixed with 30 wt. % copper powder, the conventional sintered alloy having been subjected to sizing. As is clear from Fig. 4, most of the iron particles are not coated with copper, and, therefore, the area of the iron particles appearing in Fig. 4 is simply proportional to the iron content of the sintered alloy. In Fig. 3, most of the iron particles are coated

with copper so that the copper is predominant over iron in appearance. In contrast with this, in Fig. 4, iron is predominant over the copper in appearance as well as in chemical composition of the alloy. The rough surface of the sintered alloy of the present invention shown in Fig. 3 is excellent in oil-retaining properties, which rough surface being composed of the irregular-shape iron particles coated with copper shown in Figs. 1 and 2.

In the Table 1, the temperature raises in operation and the friction coefficients of the sintered alloys of the present invention were measured under conditions where the alloys were formed into oil-retaining bearings which were operated for 40 minutes at a PV value of 1000 kg/cm²·m/min.

TABLE 1

Sample No.	Material (wt. %)	Composition (wt. %)						
		Fe	Cu	Sn	Zn	Ni	Mn	P
5	(1) 20(Fe-20%Cu)	80	20	-	-	-	-	-
	(2) 30(Fe-30%Cu)	70	30	-	-	-	-	-
	(3) 40(Fe-40%Cu)	60	40	-	-	-	-	-
	(4) 20 + 1.8%Sn	78.59	19.65	1.77	-	-	-	-
	(5) 30 + 2.7%Sn	68.16	29.21	2.63	-	-	-	-
	(6) 40 + 3.6%Sn	57.92	38.61	3.47	-	-	-	-
10	(7) 20 + 25%bronze	64	33..6	2.4	-	-	-	-
	(8) 30 + 25%bronze	56	41.6	2.4	-	-	-	-
	(9) 40 + 25%bronze	48	49.6	2.4	-	-	-	-
	Bronze = Cu-12%Sn			-				
15	(10) 20 + 25%brass	64	29.6	0.4	6	-	-	-
	(11) 30 + 25%brass	56	37.6	0.4	6	-	-	-
	(12) 40 + 25%brass	48	45.6	0.4	6	-	-	-
	Brass = Cu-30%Zn-2%Sn							
20	(13) 20 + 25%German silver	64	31		4.2	0.8	-	-
	(14) 30 + 25%German silver	56	39		4.2	0.8	-	-
	(15) 40 + 25%German silver	48	47		4.2	0.8	-	-
25	German silver = Cu-21%Zn-4%Ni							

TABLE 1-continued.

	Sam- ple No.	Compact density ratio	Sin- tering temper- ature (°C)	Porosity after sizing (vo. %)	Squeez- ing point (kg/mm ²)	Friction coeffi- cient	Operating temper- ature (°C)
5	(1)	70-75	800 - 1050	18-24	12-28	0.104	30.2
	(2)	70-75	800 - 1050	18-24	12-30	0.103	29.9
10	(3)	70-75	800 - 1050	18-24	12-28	0.110	31.8
	(4)	70-75	700 - 850	18-24	18-32	0.078	20.3
	(5)	70-75	700 - 850	18-24	20-33	0.073	20.9
15	(6)	70-75	700 - 850	18-24	20-35	0.073	19.1
	(7)	70-75	750 - 900	18-24	19-32	0.077	20.0
20	(8)	70-75	750 - 900	18-24	19-37	0.074	19.1
	(9)	70-75	750 - 900	18-24	19-39	0.072	18.2
	(10)	70-75	800 - 950	18-24	18-25	0.080	21.2
25	(11)	70-75	800 - 950	18-24	18-27	0.078	21.4
	(12)	70-75	800 - 950	18-24	18-30	0.077	20.7
30	(13)	70-75	800 - 950	18-24	18-27	0.077	20.8
	(14)	70-75	800 -	18-24	18-32	0.072	18.8

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		950				
(15)	70-75	800 -	18-24	18-34	0.073	18.2
		950				

Note: The squeezing point means Radial crushing strength.

5 Of the data shown in the above Table 1, the data of the sample Nos. (1) to (3) are shown in the following Table 2 in detail.

- 34

TABLE 2

Investigation item			Compact density (g/cm ³)	Density after sintering (g/cm ³)	Oil content (vol. %) after sintering	
Sample						
5	Sintering at 730 °C	20 wt. % Cu content	X Max Min 0	6.005	6.005	23.50
10		30 wt. % Cu content	X Max Min 0	5.970	6.020	25.30
15		40 wt. % Cu content	X Max Min 0	5.955	6.050	25.70
20	Sintering at 800 °C	20 wt. % Cu content	X Max Min 0	6.005	6.060	23.35
25		30 wt. % Cu content	X Max Min 0	5.970	5.995	25.20
30		40 wt. % Cu content	X Max Min 0	5.955	6.070	25.35
35	Sintering at 850 °C	20 wt. % Cu content	X Max Min 0	6.005	6.135	23.00
		30 wt. % Cu content	X Max Min	5.970	6.135	23.75

			δ			
		40 wt. % Cu content	X Max Min δ	5.955	6.250	23.20
5	Sintering at 1000 °C	20 wt. % Cu content	X Max Min δ	6.005	6.135	22.80
10		30 wt. % Cu content	X Max Min δ	5.970	6.235	22.85
15		40 wt. % Cu content	X Max Min δ	5.955	6.345	21.95

Outside

TABLE 2-continued

Investigation item				Outer diameter after sin- tering (mm)	Change in di- men- sion through sin- tering (%)	Squeez- ing point (kg/mm ²)	Hard- ness in inner diameter surface (H _{Rh})
5	Sample						
15	Sintering at 730 °C	20 wt. % Cu content	X	12.0720	+0.016	12.51	58.4
			Max	12.09		12.91	60
			Min	12.06		12.11	57
			δ	0.00979		0.299	1.28
		30 wt. % Cu content	X	12.0595	-0.086	12.89	49.0
			Max	12.08		13.33	50
			Min	12.05		12.51	47
			δ	0.00630		0.280	0.89
		40 wt. % Cu content	X	12.0422	-0.230	11.94	41.5
			Max	12.05		12.28	46
			Min	12.03		11.48	39
			δ	0.00651		0.339	2.25
25	Sintering at 800 °C	20 wt. % Cu content	X	12.0652	-0.039	15.65	65.8
			Max	12.09		16.35	71
			Min	12.04		14.74	62
			δ	0.01024		0.467	2.44
		30 wt. % Cu content	X	12.0600	-0.082	14.50	56.9
			Max	12.08		15.06	61
			Min	12.04		14.26	51
			δ	0.01000		0.305	2.59
		40 wt. % Cu content	X	12.0254	-0.369	12.85	47.9
			Max	12.05		14.31	52
			Min	12.00		8.37	47
			δ	0.01169		2.010	1.87
35	Sintering at 850 °C	20 wt. %	X	12.0032	-0.553	23.18	68.4
		Cu content	Max	12.01		23.58	70

Of the data shown in the above Table 1, the data of the sample Nos. (4) to (6) are shown in the following Table 3 in detail.

TABLE 3

Sample	Investigation item			Compact density (g/cm ³)	Density after sintering (g/cm ³)	Oil content (vol. %) after sintering
5	Sintering at 730 °C	20 wt. %	X	5.970	6.090	23.35
		Cu content	Max			
		+1.8 wt. %	Min			
10		30 wt. %	X	5.915	6.060	24.60
		Cu content	Max			
		+2.7 wt. %	Min			
15		40 wt. %	X	5.935	6.160	24.60
		Cu content	Max			
		+3.6 wt. %	Min			
20	Sintering at 800 °C	20 wt. %	X	5.970	6.100	23.10
		Cu content	Max			
		+1.8 wt. %	Min			
25		30 wt. %	X	5.915	6.080	24.40
		Cu content	Max			
		+2.7 wt. %	Min			
30		40 wt. %	X	5.935	6.230	23.85
		Cu content	Max			
		+3.6 wt. %	Min			
35	Sintering at 850 °C	20 wt. %	X	5.970	6.215	21.90
		Cu content	Max			
		+1.8 wt. %	Min			
		30 wt. %	X	5.915	6.285	21.60
		Cu content	Max			
		+2.7 wt. %	Min			

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5			δ	0.01036		0.315	1.37
	40 wt. %	X	11.9267	-1.187	23.45	70.4	
	Cu content	Max	11.96		25.39	72	
		Min	11.88		21.84	69	
		δ	0.01555		0.987	1.20	
10	Sintering at 850 °C	20 wt. %	X	11.9727	-0.806	31.90	80.1
		Cu content	Max	11.99		32.45	82
			Min	11.96		31.63	79
			δ	0.00865		0.347	1.14
		15		30 wt. %	X	11.8885	-1.503
Cu content	Max			11.91		32.85	84
	Min			11.85		31.51	78
	δ			0.01605		0.443	1.30
				40 wt. %	X	11.8237	-2.040
		Cu content	Max	11.87		34.40	80
			Min	11.77		32.21	75
			δ	0.01906		0.681	1.62

Note: The squeezing point means Radial crushing strength.

EXAMPLE 2 (a comparative example)

60 parts by weight of iron particles coated with 40 wt.% copper was mixed with 40 parts by weight of a bronze containing 9 wt.% tin to prepare a starting material powder theoretically consisting of: 36 wt.% iron; 60.4 wt.% copper; and 3.6 wt.% tin. The thus prepared starting material powder was compacted at a compact density ratios of 65%, 70% and 75%, respectively, to prepare three kinds of green compacts. The green compacts of each of the kinds were sintered at a temperature of 800°C or 850°C, to produce two kinds of sintered alloys the material properties of which are shown in the following Table 4.

Table 4

Compact density ratio (%)	Sintering temperature (°C)	Compact density (g/cm ³)	Outer diameter of sintered alloy (mm)	Change rate in dimensions of sintered alloy through sintering (%)
65	800	5.551	11.9315	1.14
	850	5.551	11.6920	-2.16
70	800	5.913	11.944	1.44
	850	5.913	11.738	-1.71
75	800	6.350	11.974	1.67
	850	6.350	11.760	-1.81

Table 4-continued

Compact density ratio (%)	Sintered density (g/cm ³)	Open porosity of sintered alloy (vol. %)	Hardness in end face of sintered alloy (H _{Rh})	Squeezing point in end face of sintered alloy
65	5.770	32.10	25.90	11.1
	6.058	27.82	55.90	27.1
70	6.100	27.46	47.60	18.7
	6.442	23.36	67.90	31.9
75	6.520	22.46	62.80	23.57
	6.843	18.65	79.10	40.42

Note: The squeezing point means Radial crushing strength.

Incidentally, the samples shown in the above

Tables 1 to 4 are given for the purpose of

illustration of the present invention and are not

intended as limitation of the present invention. the

most important feature of the present invention

consists in a copper or copper-based alloy coating

with which each of the iron particles is substantially

completely coated so as to be prevented from rusting.

The sintering temperature of a green compact containing aluminium or tin is lower than that of a green compact containing copper. In addition, the green compact containing aluminium or tin is also good in compressibility (i.e. easiness in compaction), mechanical strength and adaptability to the counterpart of a bearing made of a sintered alloy produced from such green compact, which good properties are substantially identical with those of a green compact in which each of the iron particles is coated with copper and those of the resultant sintered alloy produced therefrom.

As described above, in the sintered alloy of the present invention, iron of the iron particles forms a strong matrix excellent in mechanical strength, while the copper or copper-based alloy coatings formed on the iron particles effectively prevent the iron from rusting, lower a friction coefficient of the alloy, and improve the alloy in its adaptability 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 so much to the industries.

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CLAIMS

1. A sintered alloy material suitable for an oil-retaining bearing having an open porosity ranging from 15-28% by volume, characterized in that said sintered alloy has a sintering structure comprising discrete regions of iron in which the entire peripheral surface of each of the iron particles is coated with copper-based alloy; essentially consists of 45-82% by weight of iron and 18-55% by weight of copper-based alloy.
2. A sintered alloy material as claimed in claim 1, wherein said copper-based alloy is a copper-tin alloy and the sintered alloy consists of 45-81.5% by weight of iron, 18-49.5% by weight of copper and 0.5-6% by weight of tin.
3. A sintered alloy material as claimed in claim 1, wherein said copper-based alloy is a copper-zinc alloy and the sintered alloy consists of 50-82% by weight of iron, 6-40% by weight of copper and 0.8-14.8% by weight of zinc.
4. A sintered alloy material as claimed in claim 1, wherein said copper-based alloy is a copper-zinc-nickel alloy and the sintered alloy consists of 45-82% by weight of iron, 6-47.5% by weight of copper, 0.8-14.8% by weight of nickel.
5. A sintered alloy material as claimed in claim 1, wherein said sintered alloy further contains 0.3-4.5% by weight of at least one solid lubricant.
6. A sintered alloy material as claimed in claim 5, wherein the solid lubricants include graphite or molybdenum disulphide.
7. A method for manufacturing the sintered alloy of claims 1 to 4, comprising the steps of:
 - (i) mixing 100 parts by weight of iron



powder coated with copper or copper-based alloy with 11-82 parts by weight of additional non-ferrous metal alloy powder;

5 (ii) compacting said powder mixture into a green compact;

(iii) sintering said green compact to produce a sintered alloy; and

(iv) sizing said sintered alloy to produce an alloy product.

10 8. A method for manufacturing the sintered alloy of claim 5 or claim 6 comprising the steps of:

(i) mixing 100 parts by weight of iron powder coated with copper or copper-based alloy with 11-82 parts by weight of additional non-ferrous metal alloy powder and further mixing the resulting powder mixture with 0.5-5% of at least one solid lubricant;

15 (ii) compacting said powder mixture into a green compact;

(iii) sintering said green compact to produce a sintered alloy; and

20 (iv) sizing said sintered alloy to produce an alloy product.

9. A method for manufacturing a sintered alloy as claimed in claim 8, wherein the solid lubricants include graphite, molybdenum disulphide and lead.

25 10. A method for manufacturing a sintered alloy as claimed in claim 7, wherein said copper or copper-based alloy with which said iron powder is coated is applied to said iron powder through any one of process comprising electroplating, hot dipping, electroless deposition, flame spraying and dry plating, and wherein said copper-based alloy coating on the iron powder contains two or more metals selected from metals comprising silver, copper, lead, zinc, nickel, 30 aluminium, cobalt, chromium, molybdenum, titanium,



manganese and tungsten, and wherein said copper-based alloy may additionally contain phosphorus and sulfur.

11. A method for manufacturing a sintered alloy as claimed in claim 10, wherein said iron powder is
5 coated with a brass essentially consisting of copper and zinc.

12. A method for manufacturing a sintered alloy as set forth in claim 10, wherein said iron powder is
10 coated with a bronze essentially consisting of copper and tin.

13. A method for manufacturing a sintered alloy as claimed in claim 10, wherein said iron powder is
15 coated with German-silver essentially consisting of copper, 15-35% by weight of zinc and 3.5-35% by weight of nickel.

14. A method for manufacturing a sintered alloy as claimed in any one of claims 7 to 13, wherein said iron powder coated with copper or copper-based alloy is
20 further mixed with an additional powder of any one of additional non-ferrous metals comprising Ag, Cu, Sn, Pb, Zn, Ni, Al, Cr, Mo, Ti, Mn, W, Sb, As, Be, Bi, B and In, said additional non-ferrous metals; powders of oxides of said additional non-ferrous metals; or a phosphorus/sulfur powder.

25 15. A method for manufacturing a sintered alloy as claimed in claim 14, wherein said iron powder coated with said copper or copper-based alloy is further mixed with an additional powder of a brass essentially consisting of copper and zinc.

30 16. A method for manufacturing a sintered alloy as claimed in claim 14, wherein said iron powder coated with said copper or copper-coated alloy is further mixed with an additional powder of bronze essentially consisting of copper and tin.

35 17. A method for manufacturing a sintered alloy as



claimed in claim 14, wherein said iron powder coated with said copper or copper-coated alloy is further mixed with an additional powder of German-silver essentially consisting of copper, 15-35% by weight of zinc and 3.5-35% by weight of nickel.

18. A method for manufacturing a sintered alloy as claimed in claim 17, wherein the content of said nickel in German-silver is in the range of 3.5-8.0% by weight.

19. A method for manufacturing a sintered alloy as claimed in claim 7, wherein said iron powder coated with copper or copper-based alloy is further mixed with an additional powder of an oxide of an additional non-ferrous metal, said additional powder of said oxide being reduced to metal in a reducing atmosphere during a sintering process.

20. A method for manufacturing a sintered alloy as claimed in claim 19, wherein said oxide of said additional non-ferrous metal is lead oxide.

