

Method of Producing Bronze-Based Sintered Bearing
Material

This invention relates to a method of producing a bronze-based sintered bearing material which
5 has higher strength than the conventional products. As is well known, for production of bronze-based sintered alloy products, there is used as starting material either powder of bronze itself or a mixture of copper and tin powders. The method
10 of the present invention has been developed for application of the latter case.

In the first place standard process for production of sintered bearing material according to powder metallurgy will be briefly described. First,
15 zinc stearate or other powdery lubricant is added in an amount of 0.3 to 2% by weight into powder of starting material, followed by sufficient mixing. Then the mixture is compacted in a die into a desired shape and thereafter the compact is sintered
20 in a sintering furnace and then subjected to sizing and oil impregnation.

Concerning the sintering step which is a most decisive factor in the quality characteristics of the sintered alloy, there are generally used
25 two types of sintering furnaces namely a batch

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type one, which is usually used for small scale sintering, and a continuous type one, which is suited for mass-production.

The continuous type furnaces are of a sidewise elongated tubular structure and are classified into several different systems according to the charge (compact) moving mechanism; namely the mesh belt system using a heat-resistant alloy-made steel belt; the pusher system in which the compact-containing sintering boxes are pushed into the furnace in succession half-continuously; the roller system, the lift beam system, etc. All of these systems have a basically similar structure comprising a compact preheating and dewaxing chamber, a sintering chamber and a cooling chamber arranged in order from the inlet side of the furnace.

Usually a reducing atmosphere such as generated by hydrogen gas or dissociated ammonia gas is used as intrafurnace atmosphere.

The sintering step is divided into two stages; dewaxing as the first stage and sintering as the second stage. In the first stage the compact is passed through the preheating and dewaxing chamber at a relatively low temperature to evaporate

away the lubricant in the compact, and in the second stage the compact is passed through the sintering chamber kept at a predetermined high temperature to effect sintering, which is followed
5 by gradual cooling down to room temperature.

The standard sintering conditions in the conventional bronze-based sintered bearing material production process are a dewaxing temperature of about 400°C; with a heating rate up to said
10 dewaxing temperature of 10 to 30°C/min; and a sintering temperature: $800 \pm 20^\circ\text{C}$.

Fig. 1 illustrates the heating curve which the compact undergoes in the sintering step. In the curve the range defined by "A" indicates
15 the dewaxing step and the range defined by "B" indicates the sintering and cooling step.

The bronze-based sintered alloy products obtained by way of such a dewaxing and sintering process in a reducing atmosphere have a radial
20 crushing strength constant of slightly above 18 kg/mm².

Since oil-impregnated bearing material is an important mechanical element in the art of technology, it is naturally desirable to elevate
25 its strength as high as possible so that an increased

degree of freedom for design is ensured.

However, strengthening of bearing material is not easily achieved. This is because essential requirements for the oil-impregnated bearings are that they not only have high wear resistance themselves, but also can minimize wear of the shafts with which said bearings are brought in contact and that they are as porous as possible, so that they can be impregnated with a large quantity of oil-lubricant. Hence the usual strengthening means available in powder metallurgy, such as addition of a strengthening element, of compaction under high pressure to achieve higher density (and thus consequent lower porosity), and as often applied to the mechanical component parts such as gears, cannot be applied.

The present invention makes possible a phenomenal increase in the strength of the bearing metal material, while maintaining their essential quality characteristics, by improving the preheating and dewaxing step that precedes sintering.

According to one aspect of the invention, there is provided a method for producing bronze-based sintered bearing material according to powder metallurgy by using powdered copper and powdered

tin as starting materials, comprising the steps of mixing powdered copper, powdered tin and a lubricant in a predetermined ratio, compacting into a desired shape, maintaining the compact in a reducing atmosphere in a first temperature range of between 415 to 710°C for a given period of time to evaporate away said lubricant, further maintaining the compact in an oxidising atmosphere in a second temperature range below said first temperature range for a few minutes to effect an oxidising reaction, and then subjecting the compact to sintering in a reducing atmosphere in a third temperature range which is conventionally used for sintering bronze-based bearing material and higher than the first and second temperature ranges.

It is to be noted that the oxidising atmosphere used in said oxidising step may be provided by using a specific oxidising gas, but usually the object can be equally well accomplished by using the atmospheric air for such oxidising atmosphere.

According to another aspect of the invention there is provided a method of producing a bronze-based sintered bearing material according to powder metallurgy by using powdered copper and powdered

tin as starting materials, comprising the steps of mixing powdered copper, powdered tin and a lubricant in a predetermined ratio, compacting the mixture into a desired shape, heating the compact at the heating rate of higher than 50°C/min until reaching a first temperature range of between 400 to 750°C in an oxidising atmosphere and maintaining this temperature range for a given period of time to evaporate away said lubricant, and then sintering the compact in a second temperature range for a given period of time in a reducing atmosphere, said second temperature range being a range which is conventionally used for sintering bronze-based bearing material and higher than the first temperature range.

Thus the invention provides a new and unique method of producing a bronze-based sintered bearing material having excellent strength, by dewaxing in a reducing atmosphere followed by oxidising reaction in an oxidising atmosphere which is incorporated between dewaxing and sintering.

Alternatively, the invention embraces the production of bronze-based sintered bearing material having excellent strength by dewaxing in an oxidising atmosphere.

Now the present invention will be described in further detail with reference to the accompanying drawings which illustrate two embodiments thereof by way of example only, and in which:

- 5 Figure 1 is a temperature-time characteristics diagram illustrating the heating curve in the conventional dewaxing and sintering process.
- Figure 2 is a temperature-time characteristics diagram illustrating the heating curve in a dewaxing
10 and sintering process according to a first embodiment of the invention, and
- Figure 3 is a temperature-time characteristics diagram illustrating the heating curve in a dewaxing and sintering process according to a second embodiment
15 of the invention.

First, the first embodiment of the invention will be described.

- Powdered copper and powdered tin are mixed in a ratio of 91% (copper) to 9% (tin), and then
20 to this mixture is added zinc stearate as lubricant in an amount of 0.3% based on the total amount of the composition, and after completion of sufficient mixing, the mixture is compacted in a die to form many sample specimens in a cylindrical form, each
25 of which has outer diameter of 18 mm, inner diameter

of 10 mm, length of 14 mm and green density of 6.35g/cm³.

Next for sintering the specimens in different conditions they were divided into four groups I to IV and dewaxed and sintered under the dewaxing and sintering conditions as shown in Table I below.

TABLE I

Preheating and dewaxing conditions

Specimen group	Temp.	Heating rate	Radial crushing	
No.	(°C)	Atmosphere	(°C/min)	strength of sintered material (Kg/mm ²)
I	700	Reducing- Oxidising	30	30
II	400	Reducing	30	19
III	700	Reducing	30	20
IV	700	Oxidising	55	26

The specimens of Group I in the table are those prepared according to the first embodiment of the invention and they are treated by using a continuous sintering furnace of a type in which the dewaxing chamber and the sintering chamber are separate from each other but connected by a mesh belt. Each specimen is supplied into the dewaxing chamber in a reducing atmosphere, heated

to 700°C at the heating rate of 30°C/min and maintained at this temperature for a few minutes to evaporate away the lubricant. The heating rate may be suitably set by adjusting the temperature distribution in the furnace chamber and the feed rate. Then the dewaxed specimen is taken out of the dewaxing chamber into the atmospheric air (oxidising atmosphere) to oxidise the surface thereof. Although the specimen temperature drops during said operation, the sintering result is scarcely affected by such temperature drop. The specimen is then subjected to sintering in a reducing atmosphere at a temperature of 780°C for about 15 minutes, and this is followed by a normal cooling step to complete sintering.

Fig. 2 shows the heating curve of the specimen Group I in the above-described process. In the curve the range defined by "AI" corresponds to the preheating and dewaxing in a reducing atmosphere, the range defined by "AII" corresponds to the oxidising reaction step in an oxidising atmosphere and the range defined by "B" corresponds to the sintering step in a reducing atmosphere and the cooling step.

The thus sintered specimens I had radial crushing strength of as high as 30 Kg/mm² (as

measured according to JIS Z2507 (ISO 2739)).

The specimens of Group II were dewaxed according to a conventional method, wherein the dewaxing chamber and the sintering chamber are connected
5 airtight to each other and a reducing atmosphere is generated in the furnace, and then temperature is raised to 400°C at the heating rate of 30°C/min to effect dewaxing, followed by sintering under the same conditions as in the case of Specimen
10 Group I. The resultant product had radial crushing strength of 19 Kg/mm².

The specimens of Group III were dewaxed according to a partly modified version of the conventional dewaxing conditions used on Group II, that is,
15 the dewaxing temperature was elevated from 400 to 700°C. The result showed a light increase in radial crushing strength due to elevated dewaxing temperature but not to any significant degree.

The specimens of Group IV were treated according
20 to the second embodiment of the invention, which will be described later. The differences of this second embodiment of the invention from the conventional method are that dewaxing is performed in a oxidising atmosphere throughout its step and that the heating
25 rate during the dewaxing operation is increased

to above 50°C/min, although the heating rate in the conventional method is 10 to 30°C/min. These improvements achieved a very high radial crushing strength of 26 Kg/mm², as compared with that obtainable from the conventional method.

These four types of specimens were subjected to sizing and oil impregnation and finished into bearings, and these bearings were then subjected to a comparison test by using a bearing performance tester. The results showed no particularly significant differences in quality among the products. Therefore it was understood that the mechanical strength of the bearing material of the invention could be improved without causing any disadvantages of performance in practical uses.

In order to maximise the improvement in radial crushing strength, the heating rate may be the same as used in the conventional process, that is, 10 to 30°C/min, but it is important to keep the dewaxing temperature within the range 415 to 710°C in which no liquid phase is produced, and the process is advanced into the next oxidising reaction step while maintaining below said temperature range, whereby a result better than obtainable from the conventional methods represented by Specimen

Groups II and III can be obtained.

As apparent from the above-described results,
the present invention provides bearing material
with higher strength than the conventional products
5 or with higher oil content where no strength improvement
over the conventional products is required. Thus,
the present invention contributes greatly to the
expansion of the scope of usage of the bronze-
based porous sintered bearings.

10 While the construction and effect of the
first embodiment of this invention have been described
above, the first embodiment of invention is
now reviewed concerning its characteristic principles.

Firstly, if the pure sintering phenomenon
15 alone is considered while supposing that the compact
contains no lubricant between the powder particles,
it is found out that sintering advances more smoothly,
when the powder surface is oxidised to a certain
extent. This is because the oxide film is reduced
20 in the course of sintering in a reducing atmosphere
to activate the particle surface.

Therefore, it is advantageous in this sense
to perform preheating and dewaxing in an oxidising
atmosphere, but this has the following disadvantage.
25 Namely, the surface and pores in the inside of

the compact are closed by the oxide generated by heating in the oxidising atmosphere, obstructing evaporation of the lubricant from the inside of the compact. Further the carbonaceous material in the lubricant composition remains in the form of soot, causing insufficient diffusive sintering of the powder particles.

This demerit is heavier than the merit caused by activated sintering, and this is the major reason for the conventional practice of preheating and dewaxing of the compact in a reducing atmosphere. Thus it will be readily understood that the first embodiment of the invention is practiced by dewaxing in a reducing atmosphere for the same reason as described above.

As mentioned above, dewaxing of the lubricant is performed smoothly according to the first embodiment of the invention, because a reducing atmosphere is used for preheating and dewaxing. Also, the heating rate may be of the standard level in the conventional practice, and therefore there is no need of giving any specific consideration to remodelling of the furnace such as extension of furnace length or the like. Further, since the compact surface oxidation is performed below

the temperature range of 415 to 710°C, which is in a solidphase region, by transferring the compact into an oxidising atmosphere after completion of dewaxing, such surface oxidisation gives no adverse effect to the structure and dimensional stability of the compact. Thus, both perfect dewaxing and activated sintering can be ensured according to the first embodiment of the invention, resulting in bearing material with higher strength than obtainable with the conventional methods.

Next, the second embodiment of the invention will be described.

As previously described, this second embodiment of the invention consists in that an oxidising atmosphere is used for the dewaxing step in the furnace, dewaxing is practiced at a somewhat higher temperature than used in the conventional process, that is, 400 to 750°C, and the heating rate in the dewaxing step is set at above 50°C/min.

The specimens used for dewaxing experiments are prepared in the same manner as in the case of the aforesaid first embodiment of the invention. Namely, powdered copper and powdered tin are mixed in a ratio of 91% (copper) and 9% (tin), and to this mixture is added zinc stearate as lubricant

in an amount of 0.3% based on the total amount of the mixture, and after completion of sufficient mixing, the mixture is compacted in a die to prepare a number of specimen in a cylindrical form, each of which has outer diameter of 18mm, inner diameter of 10mm, length of 14mm and green density of 6.35g/cm³.

Next for sintering the specimens in different conditions they were divided into five groups I to V and sintered under the dewaxing conditions shown in Table 2 below by using a continuous sintering furnace of a type in which the dewaxing chamber and the sintering chamber are separate from each other but connected by a mesh belt.

TABLE 2

Preheating and dewaxing conditions

Specimen group	Temp.		Heating rate		Radial crushing strength of sintered material (Kg/mm ²)
	No.	(°C)	Atmosphere	(°C/min)	
I		700	Oxidising	55	26
II		400	Reducing	30	19
III		400	Oxidising	30	15
IV		700	Oxidising	30	16
V		700	Reducing	30	20

The specimens of Group I in Table 2 are those

prepared according to the second embodiment of this invention. Each specimen is supplied into the dewaxing chamber in an oxidising atmosphere, raised in temperature at the heating rate of 55°C/min and maintained at this temperature for a few minutes to evaporate away the lubricant. The heating rate may be suitably set by adjusting the temperature distribution in the furnace chambers and the feed rate. After completion of dewaxing, the specimen is transferred into the sintering chamber. The temperature drop caused during this transfer gives almost no substantial influence to the sintering result. Then sintering is performed in a reducing atmosphere by maintaining the temperature at 780°C for about 15 minutes, and this is followed by a normal cooling step to complete sintering. Fig. 3 shows the heating curve of the specimen Group I in the above described process. In the curve the range defined by "A" corresponds to the dewaxing step and the range defined by "B" corresponds to the sintering and cooling step.

The thus sintered specimens I had radial crushing strength of as high as 26 Kg/mm² (as measured according to JIS Z 2507 (ISO 2739)).

The specimens of Group II in table 2 were

dewaxed in a usual way, that is, in a reducing atmosphere by raising the temperature to 400°C at the heating rate of 30°C/min, and then subjected to sintering in the same way as Specimen Group

- 5 I. The resultant product had radial crushing strength of 19 Kg/mm².

Next, the specimens of Group III and IV were dewaxed according to the partly modified version of the dewaxing conditions used for Groups II
10 and I, that is, in the case of Group III, only the atmosphere of the dewaxing chamber was changed from reducing to oxidising in the conventional dewaxing method, while in the case of Group IV, the heating rate alone was lowered from 55°C/min
15 to 30°C/min in the known method. The products obtained from these specimen groups showed far lower radial crushing strength than those from the first-mentioned two groups (Group I and II).

Next, the specimens of Group V were treated
20 in a reducing atmosphere and at a heating rate used in the conventional method but by elevating the dewaxing temperature from 400 to 700°C. The result showed a slight increase in strength over the conventional products owing to elevated dewaxing
25 temperature.

The aforesaid five types of specimens were then subjected to sizing and oil impregnation and finished into the bearings, and these bearings were subjected to a comparison test by using a bearing performance tester. The results showed no particularly significant difference in quality among the products.

In the light of the above mentioned results of the comparison tests and in relation to the limit conditions for producing the aforesaid prominent difference in radial crushing strength, and it has been found that an obviously significant influence is given when the heating rate is above 50°C/min, and that, although the optimum dewaxing temperature is around 700°C, a better result than obtainable from the conventional methods represented by specimen Group II can be obtained when the dewaxing temperature is within the range of 400 to 750°C. However, rising of temperature over 750°C may cause oxide film separation from the surface of powder surface to rather lower the product strength.

As apparent from the above described results, the second embodiment of the present invention also ensures bearing material with higher strength than the conventional products, or with higher

oil impregnation where no strength improvement over the conventional products is required.

According to the second embodiment of the invention both dewaxing of the lubricant and oxidisation
5 of the compact are performed in such a manner that first heating is conducted in an oxidising atmosphere under the aforesaid conditions, then there proceeds dewaxing of the lubricant and then oxidisation of compact advances. Thus, both elimination
10 of the lubricant and promoted sintering by activation can be ensured at the same time, resulting in bearing material with higher strength than obtainable from the conventional methods.

As described above, either the first embodiment
15 or the second embodiment of the present invention can provide bearing products having a substantially higher strength than those obtainable from the hitherto known methods. In case the strength of the bearing material is maintained at the same
20 level as that of the conventional one, more porosity may be allowed. Thus bearing products with higher oil impregnation can be produced.

Claims

1. A method of producing bronze-based sintered bearing material according to powder metallurgy by using powdered copper and powdered tin as starting materials, comprising the steps of mixing powdered copper, powdered tin and a lubricant in a predetermined ratio, compacting the mixture into a desired shape, maintaining the compact in a reducing atmosphere in a first temperature range of between 415 to 710°C for a given period of time to evaporate away said lubricant, further maintaining the compact in an oxidising atmosphere in a second temperature range below said first temperature range for a few minutes to effect an oxidising reaction, and then subjecting the compact to sintering in a reducing atmosphere in a third temperature range which is conventionally used for sintering bronze-based bearing material and higher than the first and second temperature ranges.
2. A method of producing a bronze-based sintered bearing material as set forth in Claim 1, wherein atmospheric air is used for said oxidising atmosphere.
3. A method of producing a bronze-based sintered bearing material according to powder metallurgy by using powdered copper and powdered tin as starting



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- materials, comprising the steps of mixing powdered copper, powdered tin and a lubricant in a predetermined ratio, compacting the mixture into a desired shape, heating the compact at the heating rate of higher
5 than 50°C/min until reaching a first temperature range of between 400 to 750°C in an oxidising atmosphere and maintaining this temperature range for a given period of time to evaporate away said lubricant, and then sintering the compact in a
10 second temperature range for a given period of time in a reducing atmosphere, said second temperature range being a range which is conventionally used for sintering bronze-based bearing material and higher than the first temperature range.
- 15 4. A method of producing a bronze-based sintered bearing material as set forth in Claim 3, wherein atmospheric air is used for said oxidising atmosphere.



range which is conventionally used for sintering bronze-based bearing material and higher than the first temperature range.

9. A method of producing a bronze-based sintered bearing material as set forth in any of Claims 5 6 to 8, wherein atmospheric air is used for said oxidising atmosphere.

10. A method of producing a bronze-based sintered bearing material according to powder metallurgy by using powdered copper and powdered tin as starting materials, comprising the steps of mixing powdered copper, powdered tin and a lubricant in a predetermined ratio, compacting the mixture into a desired shape, heating the compact at the heating rate of higher than 50°C/min until reaching a first temperature range in an oxidising atmosphere and maintaining this temperature range for a given period of time to evaporate away said lubricant, and then sintering the compact in a second temperature range for a given period of time in a reducing atmosphere.

11. A method of producing a bronze-based sintered bearing material as set forth in Claim 10, wherein said first temperature range is from 400 to 750°C.

12. A method of producing a bronze-based sintered bearing material as set forth in Claim 10 or 11,



wherein said second temperature range is a temperature range which is conventionally used for sintering bronze-based bearing material and higher than the first temperature range.

- 5 13. A method of producing a bronze-based sintered bearing material as set forth in any of Claims 10 to 12, wherein atmospheric air is used for said oxidising atmosphere.

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