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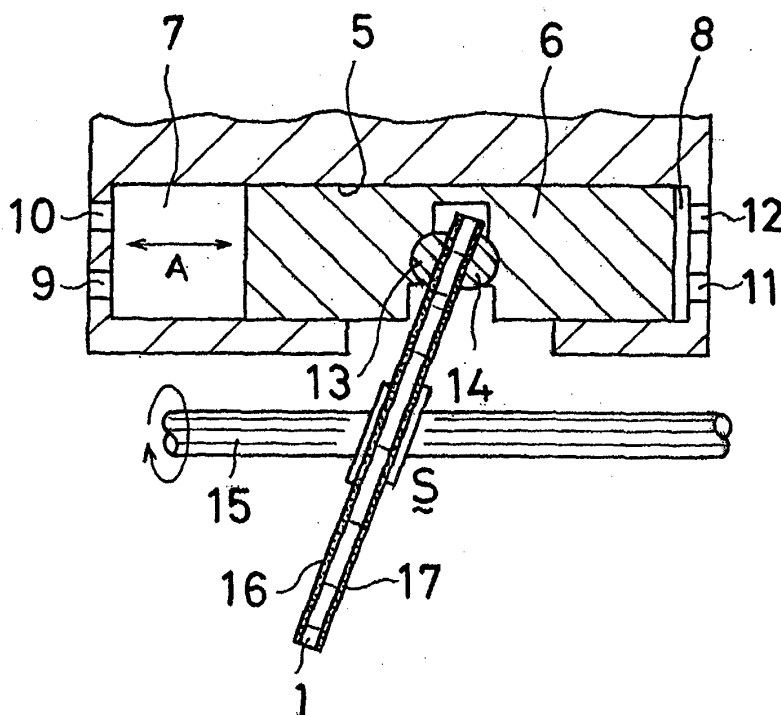
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(72) Inventors:

• **Sato, Issaku****Tokyo (JP)**• **Tadokoro, Kenzo****Mouka-shi Tochigi (JP)**(30) Priority: **18.08.2003 JP 2003294031**(74) Representative: **Schrimpf, Robert et al****Cabinet Regimbeau****20, rue de Chazelles****75847 Paris cedex 17 (FR)**(71) Applicant: **Senju Metal Industry Co., Ltd.**
Tokyo, 120-8555 (JP)(54) **Multi layer sliding part and a method for its manufacture**

(57) A multi-layer sliding part has a Cu-plated solid lubricant uniformly dispersed in the matrix of a sintered bronze powder. The sintered alloy layer is densified by pressing, and the surface of the bearing alloy layer is coated with a resin having sliding properties. In a method of manufacturing a multi-layer sliding part, a mixture of a bronze powder and a Cu-plated solid lubricant are

initially sintered, and the initially sintered mass is pulverized. The pulverized powder is sintered on both sides of a backing plate. After sintering of the pulverized powder on both sides of the backing plate to form bearing alloy layers, the bearing alloy layers are pressed and densified. After densification, the bearing alloy layers are annealed, again pressed, and then coated with a resin having sliding properties.

Fig. 2

Description

Background of the Invention

1. Field of the Invention

[0001] This invention relates to a lead-free multi-layer sliding part and to a method for its manufacture. Examples of a sliding part according to the present invention are a cylindrical sliding part such as a bushing for use in a radial sliding bearing (also called a journal bearing) and a planar sliding part for use as a swash plate in a compressor, pump, or hydraulic motor.

2. Related Art

[0002] Modern automotive air conditioning systems frequently employ what is referred to as a swash plate compressor. A swash plate compressor includes a swash plate mounted on a rotating shaft nonperpendicularly with respect to the axis of the shaft. The rotation of the shaft causes the swash plate to perform a wobbling motion, and the wobbling motion causes a piston which engages with the swash plate through one or more shoes to perform reciprocating linear motion in a cylinder and carry out intake, compression, and discharge of a refrigerant. A typical swash plate includes a disc-shaped steel backing plate, which provides the swash plate with rigidity, and a bearing alloy layer bonded to one or both sides of the backing plate to provide the swash plate with good sliding properties.

[0003] In a swash plate compressor, the swash plate often rotates at a high rotational speed (at least 8,000 rotations per minute), so an extremely high load is applied to the swash plate where it is contacted by the shoes of the compressor. Accordingly, during operation of the swash plate, the bearing alloy layers must not peel off the steel backing plate, and the bearing alloy layers must not be damaged or worn. Therefore, a swash plate must have a high bonding strength between the steel backing plate and the bearing alloy layers. In addition, the bearing alloy layers must have a high hardness as well as excellent sliding properties.

[0004] In the past, two methods have generally been used to bond the bearing alloy layers to the surface of the backing plate of a swash plate. There are the flame coating method and the sintering method.

[0005] A bearing alloy layer formed by flame coating does not have adequate bonding strength to a steel backing plate, and the bearing alloy layer sometimes peels off the steel backing plate during use of a swash plate. The peeling of a bearing alloy layer formed by the flame coating method is caused by the fact that the bond between the bearing alloy layer and the backing plate is a mechanical bond and not a metallurgical bond. Namely, in the flame coating method, a molten bearing alloy is blown against a steel backing plate by a high pressure gas, and due to its energy, the bearing alloy burrows into the steel backing plate and forms a mechanical bond.

[0006] With a swash plate manufactured by a conventional sintering method, the bearing alloy layer which is formed has a low density, so depressions may form in the bearing alloy layer and seizing may occur during use of a swash plate. In Japanese Published Unexamined Patent Application 2003-21056, the present inventors proposed a swash plate and a method for its manufacture in which a bearing alloy powder is sintered to the surface of a steel backing plate and the alloy density of the bearing alloy layer is increased. With that swash plate, the alloy density of the bearing alloy layer is at least 85%, which is larger than the alloy density (at most 80%) of a swash plate obtained by the conventional sintering method, so it is more difficult for seizing to occur.

[0007] A swash plate according to that patent application has a surface made only of a bearing alloy. Although that swash plate is adequate for use with swash plate compressors existing in the past, its sliding properties are not adequate for modern swash plate compressors which have higher performance requirements and which operate at higher rotational speeds and under higher loads than older compressors. Therefore, recently, in order to obtain a swash plate with better sliding properties, the surfaces of swash plates are being coated with resins having excellent sliding properties.

[0008] There have been many proposals of swash plates coated with a resin. For example, in Japanese Published Unexamined Patent Application 2002-180961, a copper alloy is sintered on the surface of a steel backing plate to form a bearing alloy layer, and a resin having good sliding properties is coated on the bearing alloy layer. In Japanese Published Unexamined Patent Application Hei 11-13638, a copper alloy layer is formed on a steel backing plate by plating, flame coating, cladding, sintering, or other method, and any of a resin having good sliding properties, molybdenum disulfide, or graphite is applied to the surface of the alloy layer to form a coating.

[0009] In Japanese Published Unexamined Patent Application 2003-21056, in order to solve the problems of the conventional sintering method, i.e., to prevent the formation of depressions and the occurrence of seizing during use of a swash plate, initial pressing of the steel backing plate is carried out after sintering to eliminate voids in a sintered bearing alloy layer. As a result, the alloy density of the bearing alloy layer is increased, and the formation of depressions and seizing no longer occur during use. However, in a swash plate like the one described in that application in which

the bearing alloy layer is formed on both sides of a steel backing plate and only initial pressing has been carried out in order to increase the alloy density, the sliding properties of the swash plate are not adequate when the swash plate is used in modern swash plate compressors.

5 Summary of the Invention

[0010] A swash plate in which a bearing alloy layer is coated with a resin having good sliding properties has superior sliding properties at high rotational speeds compared to a swash plate in which an uncoated bearing alloy is formed on a steel backing plate. However, a swash plate which is coated with a conventional resin having good sliding properties has a problem with respect to the length of time for which the good sliding properties can be maintained. Namely, a resin with good sliding properties which is coated on the surface of a bearing alloy layer is present between the bearing alloy layer and a shoe of a swash plate compressor in the initial stage of operation of the compressor, so the resin with good sliding properties initially improves sliding properties. However, with the passage of time, the resin with good sliding properties is shaved away by the shoe until it is almost entirely worn away, and a point is reached at which only a small amount of the resin remains in the surface irregularities of the bearing alloy layer. Accordingly, after the initial stage of operation of an air conditioner compressor, the shoes of the compressor contact the small amount of the resin coating remaining in the surface irregularities of the bearing alloy layer and the bearing alloy layer itself. If the bearing alloy layer has poor sliding properties, seizing of the bearing alloy layer ends up taking place.

[0011] The bearing alloy used in conventional swash plates was lead bronze such as LBC-3. Lead bronze has metallic lead dispersed in a matrix of bronze. The lead functions as a solid lubricant and provides superior sliding properties. However, if lead is accumulated in the human body, it may cause lead poisoning, so its use has come to be regulated. Therefore, even in swash plates, lead bronze has come to no longer be used. As a replacement for a lead bronze bearing alloy, a lead-free bronze bearing alloy comprising Cu and Sn has come to be used in swash plates. A lead-free bronze bearing alloy has inferior sliding properties compared to a lead bronze bearing alloy, so a swash plate in which a bearing alloy layer of bronze powder is coated with a resin having good sliding properties is conceivable. However, even if such a swash plate provides good sliding properties in the initial stage of operation of the swash plate due to the resin with good sliding properties, subsequently, when the resin with good sliding properties is worn away, seizing of the swash plate will soon take place.

[0012] The present invention provides a multi-layer sliding part and a method for its manufacture which, in spite of using a lead-free bronze bearing alloy, can maintain superior sliding properties over a long period even after a resin with good sliding properties has worn away. In addition, depressions are not formed in portions of the sliding part which are contacted by a sliding member, such as a shoe of a compressor, during use of the sliding part. In a preferred embodiment, the sliding part comprises a swash plate for a swash plate compressor.

[0013] In a swash plate using a lead-free bronze bearing alloy, it is known that good sliding properties can be obtained by employing a solid lubricant instead of lead. However, if graphite or molybdenum disulfide, which is a solid lubricant for a bearing alloy, is mixed with bronze and sintered, since the solid lubricants are not metal, they are not metallurgically bonded to the bronze powder, so they are simply dispersed in an unstable state in the matrix of the bronze. In a swash plate in which a solid lubricant is dispersed in an unstable state in a bronze matrix in this manner, during operation, the solid lubricant peels from the bronze and is easily worn away, the sliding properties are lost, and seizing takes place. The present inventors perceived that if a solid lubricant can be metallurgically bonded to bronze powder, the solid lubricant achieves a stable state in the bronze matrix, so after the initial stage of operation of a swash plate compressor, even if a shoe of the compressor contacts a bearing alloy of a swash plate, the solid lubricant does not readily peel off, and if a bearing alloy layer having a high alloy density is coated with a lubricating resin, even if the lubricating resin wears away, it is difficult for depressions to form in the bearing alloy.

[0014] According to one form of the present invention, a multi-layer sliding part is prepared by sintering a mixed powder comprising 100 parts by volume of an alloy powder comprising 5 - 20 mass per cent of Sn and a remainder of Cu uniformly mixed with 1 - 50 parts by volume of a Cu-plated solid lubricant powder on a backing plate to form a bearing alloy layer, densifying the bearing alloy layer, and coating the surface of the bearing alloy layer with a resin having sliding properties.

[0015] The alloy density of the bearing alloy layer is preferably at least 85%.

[0016] The Cu-plated solid lubricant powder is preferably either graphite powder or molybdenum disulfide powder.

[0017] The resin having good sliding properties is preferably at least one material selected from a polyamide, a polyimide, a polyamideimide, and polytetrafluoroethylene.

[0018] The resin having good sliding properties preferably contains at least one material selected from graphite powder, molybdenum disulfide, and polytetrafluoroethylene as a solid lubricant.

[0019] According to another form of the present invention, a method of manufacturing a multi-layer sliding part comprises (a) mixing 1 - 50 parts by volume of a Cu-plated solid lubricant powder with 100 parts by volume of a Cu-based alloy powder comprising 5 - 20 mass % of Sn and a remainder of Cu to form a mixed powder, (b) sintering the mixed

powder in a reducing atmosphere at 750 - 850°C to form a sintered mass, (c) pulverizing the sintered mass to form a powder with a particle size of at most 300 µm, (d) dispersing the powder formed by pulverizing on a backing plate, (e) sintering the dispersed powder in a reducing atmosphere at 800 - 880 °C to bond grains of the dispersed powder to each other and to the backing plate to form a bearing alloy layer on the backing plate, thereby forming a multi-layer material, (f) pressing the multi-layer material to densify the bearing alloy layer, (g) annealing the multi-layer material after pressing in a reducing atmosphere at 840 - 880°C, (h) pressing the annealed multi-layer material to increase the strength and hardness of the multi-layer material, and (i) coating the bearing alloy layer with a resin having sliding properties.

[0020] A sliding part according to the present invention uses a lead-free bronze alloy, so there is no concern whatsoever of lead pollution. In addition, a sliding part according to the present invention is formed by mixing a bronze alloy powder and a Cu-plated solid lubricant and performing sintering, so the surfaces of the bronze alloy powder and the solid lubricant are metallurgically bonded to each other, and not only is there no peeling of the solid lubricant during use, but due to the presence of a stabilized solid lubricant, good sliding properties are obtained over long periods. In addition, a sliding part according to the present invention has a bearing alloy layer formed by mixing a bronze alloy powder and a Cu-plated solid lubricant and performing sintering and which has undergone densification treatment, so even if another member, such as a shoe of a swash plate compressor, directly contacts the bearing alloy layer, depressions are not formed by the pressure of the other member against the bearing alloy layer. In addition, a sliding part according to the present invention has a coating of a resin with good sliding properties on the surface of a bearing alloy layer having good sliding properties, so it exhibits excellent sliding properties at the start of operation.

[0021] In a method of manufacturing a sliding part according to the present invention, a solid lubricant can be uniformly dispersed without uneven distribution and the solid lubricant can be strongly adhered to the lead-free bearing alloy powder. In addition, a method of manufacturing a sliding part according to the present invention can increase the alloy density of a bearing alloy including a solid lubricant, and a surface having a high alloy density is coated with a lubricating resin, so a sliding part is obtained with good sliding properties not only in the initial stage of operation but over a long period during subsequent operation.

Brief Description of the Drawings

[0022]

Figure 1 is an axonometric view of an embodiment of a multi-layer sliding part according to the present invention in the form of a swash plate.

Figure 2 is a cross-sectional view of a portion of a compressor for an automotive air condition employing a swash plate according to the present invention.

Description of Preferred Embodiments

[0023] A multi-layer sliding part according to the present invention is not restricted to any particular form. For example, it can be in the form of a cylindrical sliding member such as a bushing for use in a radial sliding bearing (a journal bearing) or a planar sliding member for use as a swash plate in a compressor, pump, or hydraulic motor.

[0024] Figure 1 is an axonometric view of an embodiment of a multi-layer sliding part according to the present invention in the form of a swash plate S for an automotive air conditioner. The swash plate S includes bearing alloy layers 2 and 3 formed on opposite sides of a disc-shaped steel backing plate 1. A hole 4 into which a rotating shaft can be inserted is formed at the center of the swash plate S. The backing plate 1 may also include a plurality of unillustrated mounting holes surrounding the central hole 4 through which bolts or other fastening members can be passed to secure the backing plate 1 to a shaft or other member.

[0025] Figure 2 is a cross-sectional view of a portion of a typical swash plate compressor for an automotive air condition employing the swash plate S of Figure 1. The compressor includes a piston 6 slidably disposed for reciprocating movement inside a cylinder 5. The cylinder 5 is divided by the piston 6 into a left cylinder chamber 7 and a right cylinder chamber 8. A left intake valve 9 and a left discharge valve 10 communicate with the left cylinder chamber 7, and a right intake valve 11 and a right discharge valve 12 communicate with the right cylinder chamber 8. At the center of the piston 6, the swash plate S is sandwiched between a left shoe 13 and a right shoe 14, with bearing alloy layer 2 in sliding contact with the left shoe 13 and bearing alloy layer 3 in sliding contact with the right shoe 14. The swash plate S is mounted on a rotating shaft 15 nonperpendicularly with respect to the axis of the shaft 15.

[0026] When the shaft 15 is rotated during the operation of the compressor, because the swash plate S is installed nonperpendicularly on the rotating shaft 15, the rotation of the swash plate S causes the piston 6 to reciprocate as shown by arrow A to perform a pumping action in a well-known manner.

[0027] In a sliding plate according to the present invention, a mixture of a powder of a bronze alloy comprising Cu

and Sn and a Cu-plated solid lubricant is sintered on a backing plate of steel, for example, to form a bearing alloy layer. The bearing alloy layer undergoes densification treatment, and then the bearing alloy layer is coated with a resin having sliding properties. The bronze alloy powder used in the present invention does not have sufficient hardness if the Sn content of the bronze alloy is smaller than 5 mass percent, while it becomes brittle if the Sn content exceeds 20 mass percent.

[0028] In a swash plate obtained by simply sintering a bearing alloy powder on the surface of a steel backing plate, an annular depression resembling the wheel rut of a vehicle ends up forming in the portion of the swash plate contacted by a shoe of a compressor. This is because with a swash plate having a bearing alloy layer which is only sintered, the bearing alloy layer is porous, so the porous portions end up being crushed by a shoe of a compressor which contacts the bearing alloy layer at a high speed and with a high pressure. With a sliding part in the form of a swash plate according to the present invention, after sintering, densification is carried out in which the porous portions of the bearing alloy layer are crushed, so a depression is not formed in the bearing alloy layer by contact with a shoe. The porous portions formed by sintering alone have an alloy density of at most 80%, and with this alloy density, a depression forms during use of a swash plate. Depressions no longer form during use if the alloy density of the bearing alloy layer of a swash plate is at least 85%.

[0029] The solid lubricant used in a sliding part according to the present invention is graphite powder, molybdenum disulfide powder, or a mixture thereof which is plated with Cu. The amount of the solid lubricant which is used is 1 - 50 parts by volume with respect to 100 parts by volume of the bronze alloy powder. If the proportion of the solid lubricant is smaller than 1 part by volume, adequate sliding properties are not obtained, and seizing occurs at an early stage of operation. If the proportion of the solid lubricant exceeds 50 parts by volume, the bearing alloy will not have adequate mechanical strength.

[0030] The resin having sliding properties used in the present invention can be any resin as long as it has excellent sliding properties. Preferred resins having sliding properties for use in the present invention are polyamide resins, polyimide resins, polyamideimide resins, and polytetrafluoroethylene (PTFE). One of these or a mixture of more than one of these can be used.

[0031] Sliding properties are further improved if a solid lubricant is contained in the resin having good sliding properties. Preferred solid lubricants for use in the present invention are 20-60 vol% of PTFE, 5-10 vol% of molybdenum disulfide, 30-70 vol% of graphite, and the like in a total amount of 5-80 vol%. It is permissible to use just one of these solid lubricants, but if two or more are mixed, the sliding properties are further improved.

[0032] If the temperature in the initial sintering step in the method of manufacturing a sliding part according to the present invention is lower than 750° C, the bonding strength between powder particles is not sufficient. On the other hand, if the initial sintering temperature is higher than 850° C, the Cu-plated solid lubricant disperses in the bronze alloy powder and ends up being consumed, the bronze alloy powder and the solid lubricant cannot be bonded to each other, and they end up separating from each other.

[0033] The sintered mass which is obtained by this initial sintering is pulverized into the form of a powder by a pulverizing apparatus such as a mill. The Cu-plated solid lubricant and the bronze alloy powder have different specific gravities, so with just mechanical mixing, the Cu-plated solid lubricant and the bronze alloy powder are not uniformly mixed. However, if the mixed powder is pulverized after initial sintering, the solid lubricant is uniformly present throughout the pulverized powder. The particle size of the pulverized powder is at most 300 micrometers. If the particle size of the powder is larger than 300 micrometers, it cracks and ends up falling from the bronze matrix. The preferred size of the pulverized powder used in the present invention is approximately 100 micrometers.

[0034] If the temperature of the sintering which is carried out after dispersing the pulverized powder on a steel backing plate is lower than 800° C, the bonding strength between the alloy powder particles and between the alloy powder particles and the steel backing plate is insufficient, while if it exceeds 880° C, intermetallic compounds of iron and copper are formed and the bonding strength decreases.

[0035] In a manufacturing method for a sliding part according to the present invention, a reducing atmosphere is preferably used when mixing the bronze powder and the Cu-plated solid lubricant and performing initial sintering and when sintering the pulverized powder of the sintered mass which is obtained by the initial sintering on a steel backing plate because at the time of heating, the surfaces of the bearing alloy powder and the steel backing plate oxidize, and an oxide film is formed which interferes with metallic bonding. If the initial sintering and sintering are carried out in a reducing atmosphere, oxidation of the bearing alloy powder and the steel backing plate during heating are prevented, and oxides on the metal surface which formed prior to heating are reduced and removed, so bonding of the alloy powder particles to each other and to the steel backing plate is carried out with certainty. An example of a reducing atmosphere used in the present invention is an atmosphere of hydrogen gas or ammonia decomposition gas (75% hydrogen, 25% nitrogen) or the like.

[0036] In a manufacturing method for a sliding part according to the present invention, first pressing of the bearing alloy layer on a steel backing plate is performed in order to densify the bearing alloy surface. A pressing force on the bearing alloy surface of 150 - 250 tons is suitable.

[0037] After the bearing alloy surface is densified, annealing is carried out at 840 - 880° C. The annealing at this time reduces the hardness of the bearing alloy layer which underwent excessive work hardening by the first pressing step to a suitable level, and it resinters peeled portions formed during the first pressing step and increases the bonding strength. Sufficient annealing cannot be carried out if the annealing temperature is lower than 840° C, while if it is

higher than 880° C, the hardness of the steel backing plate decreases and the mechanical strength ends up decreasing. **[0038]** After annealing, a second pressing step is carried out on the bearing alloy layers. The second pressing increases the hardness which decreased too much during the annealing step to a prescribed hardness, and it also adjusts the thickness of the bearing alloy layers. A hardness of Hv 100 - 140 in the second pressing step is suitable. If a desired thickness can be obtained just by the second pressing step, it is possible to proceed directly to the next step. However, when it is difficult to obtain a desired thickness in the second pressing step, the thickness in the second pressing step may be left at slightly larger than the desired thickness, and machining may be subsequently performed with a lathe to adjust the thickness.

[0039] In order to obtain strong adhesion between the surface of the bearing alloy layer and the resin having sliding properties, the surface of the bearing alloy layer is preferably roughened so as to have small surface irregularities. If the surface of the bearing alloy layer is roughened, its surface area increases and the adhesion strength increases, and the resin having sliding properties becomes engaged with the roughened bearing alloy surface and produces stronger adhesion by an anchoring effect. An example of a method for roughening the surface of the bearing alloy is machining of the surface with a lathe as described above. If the bearing alloy layer is machined with a lathe, the lathe will form surface marks resembling the grooves in a phonograph record. Examples of other possible methods of roughening the surface of the bearing alloy layer are sandblasting and etching.

Examples

[0040] The present invention will be further described by the following examples.

Example 1 and Comparative Examples 1 - 4

[0041] Example 1 of a swash plate according to the present invention having a resin coating on both sides thereof was prepared by the following steps (a) - (i). Steps (d) and (e) were first performed on one side of a disk-shaped backing plate, and then they were repeated on the opposite side of the backing plate prior to proceeding to step (f). Steps (f) - (i) were performed on both sides of the backing plate at the same time.

(a) Mixing: 4 parts by volume of Cu-plated graphite powder were mixed with 100 parts by volume of brass alloy powder made from 10 mass percent of Sn and a remainder of Cu.

(b) Initial sintering: The mixed powder obtained in step (a) was heated at 800°C in a reducing atmosphere to form a sintered mass.

(c) Pulverizing: The sintered mass formed in step (b) was pulverized in a hammer mill to form a powder with a particle size of approximately 100 micrometers.

(d) Dispersion: The pulverized powder obtained in step (c) was uniformly dispersed to a thickness of 0.8 mm on one side of a steel backing plate (S45C) having a thickness of 5.0 mm and a diameter of 80 mm.

(e) Sintering: The steel backing plate on which the pulverized powder was dispersed was heated in a heating furnace containing a reducing atmosphere at 860°C to sinter the powder particles to each other and to the steel backing plate to form a multi-layer member having a bearing alloy layer.

(f) First pressing: The multi-layer member obtained in step (e) was pressed with a load of 200 tons to densify the bearing alloy layers.

(g) Annealing: The densified bearing alloy layers were heated for 15 minutes in a heating furnace containing a reducing atmosphere at 860°C to perform annealing.

(h) Second pressing: The annealed bearing alloy layers were pressed in a press with a load of 180 tons. After pressing, the hardness of the bearing alloy layers was Hv 100. Machining was performed with a precision lathe to give the bearing alloy layers a uniform thickness and to give the surface of the bearing alloy layers a suitable roughness.

(i) Resin coating: A suspension comprising polyamideimide, which is a resin having sliding properties, and solid lubricants in the form of a dispersion containing PTFE, MoS₂, and graphite was applied to the surface of both of the bearing alloy layers, and then baking was carried out in a heating furnace at 180°C.

[0042] Comparative Example 1 of a swash plate was prepared in the same manner as was Example 1 except that step (i) of forming a resin coating on the bearing alloy layers was omitted.

[0043] Comparative Examples 2 - 4 were examples of conventional swash plates. Comparative Example 2 of a swash

plate did not include a solid lubricant in its bearing alloy layer, the bearing alloy layer was not subjected to densification by pressing, and a resin coating was not formed atop the bearing alloy layer.

[0044] Comparative Example 3 of a swash plate did not include a solid lubricant in its bearing alloy layer, and a resin coating was not formed atop the bearing alloy layer, but the bearing alloy layer was subjected to densification by pressing.

[0045] Comparative Example 4 of a swash plate did not include a solid lubricant in its bearing alloy layer, and the bearing alloy layer was not subjected to densification by pressing, but it did have a resin coating formed atop the bearing alloy layer.

[0046] The coefficient of friction and durability of each of these examples and comparative examples were tested in the following manner.

[0047] Coefficient of friction: A swash plate was mounted horizontally on the base of a thrust testing machine with one of its surfaces facing upwards. The testing machine had a horizontal rotating disk facing the top surface of the swash plate. Three shoes for use in a swash plate compressor like the shoes 13 and 14 shown in Figure 2 were secured to the lower side of the disk opposing the top surface of the swash plate, each at a radial distance of 34.5 mm from the center of the disk. The disk was rotated at 4000 rpm, and an axial force of 20 kg was applied to the disk to press the shoes against the top surface of the swash plate. The torque required to rotate the disk at 4000 rpm with the shoes pressed against the swash plate was measured and was used to calculate the coefficient of friction of the swash plate by the following formula:

$$\begin{aligned} \text{coefficient of friction} &= \text{torque applied to disk} / [\text{axial load applied by shoes to} \\ &\text{swash plate} \times \text{moment arm of load (= distance of shoes from center of disk)}] \\ &= \text{torque} / 20 \text{ kg} \times 34.5 \text{ mm} \end{aligned}$$

[0048] Durability: During the measurement of the coefficient of friction, with the disk rotating at 4,000 rpm and the shoes contacting the top surface of the swash plate, the temperature of the swash plate was measured, and the number of minutes (rounded down to the nearest whole number) until the temperature of the swash plate reached 200°C was measured. A value of 0 minutes means that the temperature of the swash plate reached 200°C before the elapse of 1 minute.

[0049] The manufacturing methods used for these examples and comparative examples and the results of measured are shown in the following table.

Example No.	Bearing alloy layer contains solid lubricant	Densification of bearing alloy layer	Resin coating on bearing alloy layer	Coefficient of friction	Durability (minutes to reach 200°C)
Example 1	Yes	Yes	Yes	0.137	26
Comp.Ex.1	Yes	Yes	No	0.193	8
Comp. Ex. 2	No	No	No	0.295	0
Comp.Ex.3	No	Yes	No	0.216	5
Comp. Ex. 4	No	No	Yes	0.143	1

[0050] From a comparison of the results for Comparative Examples 2 and 4, it can be seen that although the provision of a resin coating on a conventional bearing alloy layer of a swash plate significantly decreases the initial coefficient of friction of the swash plate, it produces only a minor increase in durability (from 0 minutes to 1 minute) because the resin coating soon wears off, and the underlying bearing alloy layer does not have good sliding properties.

[0051] In contrast, from a comparison of Example 1 of the present invention and Comparative Example 1, it can be seen that the provision of a resin coating on the bearing alloy layer of a swash plate according to the present invention provides not only a significant decrease in the initial coefficient of friction, but also an enormous increase in durability (from 8 minutes to 26 minutes). Thus, the combination of a bearing alloy layer according to the present invention and a resin coating provides a synergistic effect which cannot be predicted from the prior art.

[0052] A multi-layer sliding part according to the present invention has excellent sliding properties, not only at the initial stage of operation but over a long period, so when the sliding part is used as a swash plate, it can provide excellent performance in modern swash plate compressors for automotive air conditioners which operate under more severe

conditions of higher speeds and higher loads.

Claims

1. A multi-layer sliding part prepared by sintering a mixed powder comprising 100 parts by volume of an alloy powder comprising 5 - 20 mass per cent of Sn and a remainder of Cu uniformly mixed with 1 - 50 parts by volume of a Cu-plated solid lubricant powder on a metal backing plate to form a bearing alloy layer, densifying the bearing alloy layer, and coating the surface of the bearing alloy layer with a resin having sliding properties.
2. A multi-layer sliding part as claimed in claim 1 wherein the density of the bearing alloy layer is at least 85%.
3. A multi-layer sliding part as claimed in claim 1 or 2 wherein the Cu-plated solid lubricant powder is selected from graphite powder and molybdenum disulfide powder.
4. A multi-layer sliding part as claimed in any one of claims 1 to 3 wherein the resin having sliding properties comprises at least one material selected from a polyamide resin, a polyimide resin, a polyamideimide resin, and polytetrafluoroethylene.
5. A multi-layer sliding part as claimed in any one of claims 1 to 4 wherein the resin having sliding properties contains at least one material selected from graphite powder, molybdenum disulfide, and polytetrafluoroethylene as a solid lubricant.
6. A method of manufacturing a multi-layer sliding part comprising:
 - (a) mixing 1 - 50 parts by volume of a Cu-plated solid lubricant powder with 100 parts by volume of a Cu-based alloy powder comprising 5 - 20 mass % of Sn and a remainder of Cu to form a mixed powder,
 - (b) sintering the mixed powder in a reducing atmosphere to form a sintered mass,
 - (c) pulverizing the sintered mass to form a powder with a particle size of at most 300 μm ,
 - (d) dispersing the powder formed by pulverizing on a backing plate,
 - (e) sintering the dispersed powder in a reducing atmosphere at 800 - 880°C to bond grains of the dispersed powder to each other and to the backing plate to form a bearing alloy layer on the backing plate, thereby forming a multi-layer material,
 - (f) pressing the multi-layer material to densify the bearing alloy layer,
 - (g) annealing the multi-layer material after pressing in a reducing atmosphere at 840 - 880°C,
 - (h) pressing the annealed multi-layer material to increase the strength of the multi-layer material and obtain a prescribed hardness; and
 - (i) coating the bearing alloy layer with a resin having sliding properties.
7. A method as claimed in claim 6 wherein the solid lubricant of the Cu-plated solid lubricant powder is selected from graphite, molybdenum disulfide, tungsten disulfide, and mixtures of these.
8. A method as claimed in claim 6 or 7 wherein the resin having sliding properties comprises at least one material selected from a polyamide resin, a polyimide resin, a polyamideimide resin, and polytetrafluoroethylene.
9. A method as claimed in any one of claims 6 to 8 wherein the resin having sliding properties contains at least one material selected from graphite powder, molybdenum disulfide, and polytetrafluoroethylene as a solid lubricant.

Fig. 1

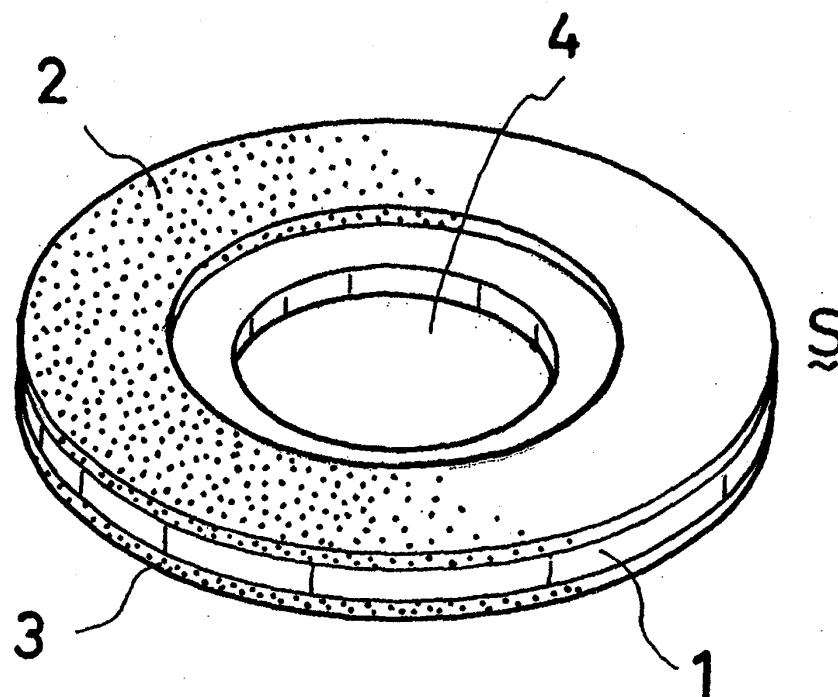


Fig. 2

