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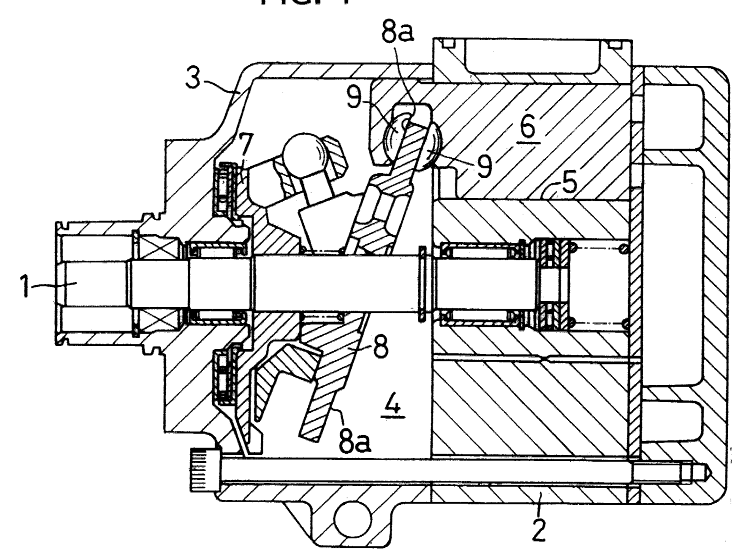
(54) Piston for swash-plate type compressor and manufacturing method of the same

(57) The manufacturing of a piston (6) for a swash plate compressor comprises the following steps: An Al-Si alloy containing 7 to 18wt% of silicon is die casted and therefore needs not to be melted in a sand mold to refine (finely disperse) the eutectic Si phase in order to increase shock resistance. The die casting includes quenching (rapid cooling) of the aluminium alloy, to influence the shape of the eutectic silicon particles. Before the step of the quenching of the molten alloy, Na or Sr are added in quantities ranging from 20 to 1000ppm either simultaneously or independently. The spherically shaped silicon particles increase wear resistance of the piston, because stress concentrations in the material can be avoided during piston operation.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] This invention relates to a manufacturing method of piston for a swash-plate type compressor and a piston manufactured by the manufacturing method.

Related Background Art

[0002] A swash-plate type compressor is mainly used for an air conditioner of a vehicle. It is classified into a single-headed piston type and a double-headed piston type, or a fixed-capacity type and variable-capacity type, depending on construction thereof. As one example, a variable-capacity type swash-plate compressor of a single-headed piston type is shown in Fig. 1, and a single-headed type piston constituting the swash-plate compressor is shown in Fig. 2.

[0003] A drive shaft 1 is supported at both axial ends thereof by a cylinder block 2 and a front housing 3 via bearings. An axially intermediate portion of the drive shaft 1 is disposed in a crank chamber 4 formed by the cylinder block 2 and the front housing 3. In the cylinder block 2, plural bores 5 are formed around the axial end of the drive shaft 1 to receive single-headed type pistons 6 reciprocately. In the crank chamber 4, a swash plate 8 is fitted to the drive shaft 1 behind a rotor 7 fixed to the drive shaft 1. The piston 6 is comprised of a cylindrical main body 6a and a L-shaped shoe receiving portion 6b formed at one end of the main portion 6a.

[0004] In the swash-plate type compressor of the variable-capacity and single-headed piston type, the swash plate 8 is supported on the drive shaft 1 to be inclinable with respecto to the drive shaft. Inclination angle of the swash plate 8 is controlled by balance of gas pressure acting on both end surfaces of the pistons 6 due to pressure change in the crank chamber 4. To a flat engage (slidable-contact) surface 8a formed on an outer periphery of the both end surfaces of the swash-plate 8, shoes 9 are abutted. Each of the shoes 9 engages with a semi-spherical surface 6c formed on the shoe receiving portion 6b. Through such connection by the shoes 9 between the pistons 6 and the swash plate 8, rotation movement of the swash plate 8 is converted to linear movement of the pistons 6 to compress refrigerant gas.

[0005] In view of demand for lightening when the swash-plate type compressor is used in the vehicle air conditioner, in addition to the cylinder block, the pistons have been made of an aluminum alloy by a forging method or a casting method. Since the engage surfaces between the pistons and the shoes are put under severe sliding condition, good wear-proof character as a mechanical characteristic is demanded for the pistons. In view of this, the casted article have been subjected to a solution treatment and an artificial ageing treatment thereafter to increase the wear-proof character. Here, "solution treatment" means a quench treatment of a blank material after heated up to temperature in a range of solid solution for a constant time period. On the other hand, "artificial ageing treatment" means a natural cooling of the blank material after heated up to 200 °C and held in this condition for a predetermined time period.

[0006] By the above solution treatment, the mechanical characteristic of the casted article, especially the wear-proof character in the manufacturing of the piston for swash-plate type compressor, can be increased. That is, an eutectic Si phase (Si crystal in eutectic composition) in a Al-Si alloy mainly used as the aluminium alloy has changed to a needle shape after casted to deteriorate the mechanical characteristic of the Al-Si alloy. Whereas, the needle-shape eutectic Si phase changes to spherical shape by the solution treatment to improve the mechanical characteristic of the Al-Si alloy, especially the wear-proof character.

[0007] However, the solution treatment heating and holding the blank material in a high temperature just below a melt starting temperature of 500 °C or therearound, suffers from increase of a manufacturing cost of an equipment and an electrical power, and blister generated in the casted article.

Summary of the Invention

[0008] In view of the above disadvantage in the prior art, the present invention intends to provide a manufacturing method of a piston for a swash-plate type compressor and the piston manufactured by this manufacturing method, which is excellent in the wear-proof character, in which blister is not generated, and which manufactures the piston by low cost, without the solution treatment after the die casting.

[0009] For achieving the above object, a manufacturing method of a piston for a swash-plate type compressor, comprises a molten metal treating step including at least adding treatment for adding Na and/or Sr by 20 to 1000 ppm to a Al-Si alloy molten metal including Si of 7 to 18 wt%, and a die casting step for die casting the Al-Si alloy molten metal.

[0010] The manufacturing method of the piston for the swash-plate type compressor of the present invention adopts a die-casting method especially a pressure die-casting method, as the casting method. This is because the pressure die-casting method is suitable for a mass production and can manufacture the casted article having a smooth casted surface, thereby having high utilizing valve. In the manufacturing method of the piston for the swash-plate type compressor of the present invention, the molten metal treating step adding at least one of Na and Sr to a molten metal is performed before the die casting.

[0011] The molten metal treating step is used in a sand mold casting method etc. to fine the eutectic Si phase. The eutectic Si phase, not subjected to the fining treatment, has the needle shape in the composition after having been casted. However, it can be fined in the composition after the casting by the eutectic Si phase fining treatment. Fining of the eutectic Si phase can increase the mechanical characteristic of the casted article, especially an extending character and resisting value against shock.

[0012] However, in the die casting method quenching a filled molten metal, the eutectic Si phase in the composition after the casting is fined due to the rapid cooling speed. For this reason, the fining treatment of the eutectic Si phase has not been performed in the die casting method.

[0013] The molten metal treating step in the manufacturing method of the piston of the present invention is performed, not to fine the eutectic Si phase but to sphere it. Sphering of the eutectic Si phase by the molten metal treating step by adding at least one of Na and Sr to the molten metal has been found out by inventors of the present invention through repeated experiments. It can be confirmed on a composition photograph to be explained later. However, a mechanism in which the eutectic Si phase is sphered has not been clarified at present, unfortunately.

[0014] According to the manufacturing method of the piston for the swash-plate type compressor of the present invention, the eutectic Si phase in the Al-Si alloy can be sphered by addition of Na and/or Sr. As will be fully explained in the embodiment, in the aluminum alloy composition in which the eutectic Si phase is sphered, the composition is hardly broken because of no stress concentrated portions being existed. Thus, the piston for the swash-plate type compressor which is excellent in the wear-proof character and in which the blister is not generated, can be manufactured by the low cost.

[0015] The present invention can have various embodying modes or variations within scope of the claims to be described below.

[0016] In the following, variations of the manufacturing method of the piston, that is, a base metal (an original alloy to be molten) selected to manufacture the piston and the manufacturing steps of the piston will be explained.

[0017] A Al-Si alloy including Si by 7 to 18 wt%, in addition to Cu, Mg, Zn and Fe, is used for the base metal to manufacture the piston. Si is included in the aluminum alloy for the die casting since it can perform improvement of the casting characters such as improvement of fluidity of the molten metal, decrease of heat expansion, decrease of hot crack, and decrease of shrinkage in the casting. Concretely, AD1, AD3, Ad10, AD10Z and AD12 etc. defined in JIS (Japanese Industrial Standard) H2118, or equivalents thereof can be used. From aspect of workability and tenacity, the Al-Si alloy including Si of 7 to 12 wt% is especially preferable.

[0018] By usage of the above base metal, the manufacturing method of the present invention can manufacture the piston for the swash-plate type compressor by a melting step for melting the base metal, a molten metal treating step for adding Na etc. to the molten base metal, and a die casting step. Further, an artificial-age treating step and a post treating step can be selectively performed.

Next, each of the steps will be explained sequentially.

[0019] The melting step melts the base metal by a suitable melting method generally used in the melting of the aluminum alloy. For example, the aluminum alloy can be melted in a crucible furnace or an inducing furnace in a melting temperature of 670 to 710 °C.

[0020] The molten metal treating step includes, in addition to a degassing treatment and a dreg-removing treatment, the adding treatment for addition of Na etc., that is, the sphering treatment to sphere the eutectic Si phase. Here, the degassing treatment is performed to reduce hydrogen gas amount in the molten metal which may cause porosity of the casted article. As the degassing treatment, an inert gas such argon and nitrogen generally used can be blown into the molten metal. On the other hand, the dreg-removing treatment is performed to remove an intervening materials such as oxide etc. which may deteriorate casting character and reduce mechanical characteristics of the casted article. As the dreg-removing treatment, a float separating method performed by blowing in inert gas and a flux treatment generally used can be adopted.

[0021] The sphering treatment of the eutectic Si phase, which is the most remarkable feature of the present invention, is performed by adding at least one of Na and Sr to the molten metal. When large sphering effect of the eutectic Si phase is desired, Na is preferably selected. On the other hand, when long hold treating time period due to small wear of Sr by oxidation, and safe and simple handling are desired, Sr is preferably selected. Na or Sr can be added to the molten metal independently, or both of them can be added simultaneously.

[0022] The adding method of Na is not limited, but that generally used in the sand mold casting method can be used. For example, in the first method, the flux including a metal Na, or NaF or NaCl is pressed into the molten metal by phosphorizer etc. and is agitated. In the second method, a tablet type flux floated on surface of the molten metal can be used. When the long hold treating effect due to small change of Na by oxidation wear is desired, the second method is preferably adopted.

[0023] The adding method of Sr is not limited, but that generally used in the sand mold casting method can be used. For example, a Al-Sr mother alloy can be put into the molten metal.

[0024] As regard the added amount, at least one of Na and Sr is added to the molten metal to be contained by 20 to 1000 ppm (here, ppm means wt. ppm) in the molten metal treating step. When both of Na and Sr are added to the molten metal, sum of both of the added amount of Na and the added amount of Sr should be selected in range of 20 to 1000 ppm. If the added amount is smaller than 20 ppm, due to small sphered rate of the eutectic Si phase, sufficient treating effect can not be obtained. To the contrary, when the added amount is larger than 1000 ppm, not only fluidity of the molten metal during the casting deteriorates but lifetime of the furnace is shortened due to corrosion. For manufacturing the piston excellent in the wear-proof character, at least one of Na and Sr is preferably added to be contained by 30 to 150 ppm before the die casting step.

[0025] In any cases Na and/or Sr being added, the added Na and/or Sr wear by oxidation, so that the treating effect by them decreases as lapse of time. For this reason, Na and/or Sr are preferably supplemented into the molten metal to be contained by 20 to 1000 ppm in the molten metal treating step and before the die casting step. Excessive addition of Na may deteriorate the eutectic composition, so the max. amount of Na should be selected below 150 ppm. Sphering of the eutectic Si phase is preferably performed so that particle of the eutectic Si phase has an average particle diameter of 1.5 to 3.0 μ m.

[0026] The pressure die-casting step pours the molten metal into a mold in high speed under high pressure, and coagulates the poured-in molten metal rapidly to manufacture the casted article. For the pressure die-casting, a casting apparatus and casting conditions generally used can be adopted. For example, as the casting apparatus, a cold chamber pressure die-casting machine can be used for example, and the casting conditions such as casting pressure of 20 to 100 MPa, gate speed of 40 to 80 m/s and filling time period of 5 to 100 sec. can be adopted.

[0027] The artificial-age treating step selectively performed heats the casted article in relatively low temperature of 200 °C or the therearound ,and hold it in this condition for the constant time period, and then naturally cools it. This artificial-age treating step is performed to further increase strength and dimensional stability of the casted article. For the artificial-age treating step, process generally used can be adopted. For example, the casted article heated in 90 to 210 °C and held for few hours, can be naturally cooled. For this reason, for manufacturing the piston excellent in strength, the manufacturing method of the present invention preferably includes the artificial age treating step, in addition to the above mentioned molten metal treating step and the pressure die-casting step. According to JIS, the casted article such as the piston of this embodying mode having been subjected to the artificial-age treating step after the casting is represented by "T5" in the refining mark (JIS H 0001). The casted article subjected to the solution treatment before the artificial-age treating step is represented by "T6" in the refining mark (JIS H 0001).

[0028] When the casted article has not been subjected to the artificial-age treating step, it is aged naturally. In the natural ageing, an alloy component precipitates in the normal temperature. Thus, the heating equipment for heating the casted article and electric power can be saved, so that the manufacturing cost can be reduced. For this reason, when manufacturing the piston cheaper is desired, the manufacturing method of the present invention can omit the artificial-age treating step.

[0029] The post treating step performs a machining of predetermined parts of the casted article and a surface treatment such as plating. For the post treating step, process generally used can be adopted. As the surface treatment, a fluorocarbon resin film can be formed on an engage surface of the piston with the bore, and Sn can be plated on a receiving seat surface for shoe of the piston.

[0030] The piston manufactured by the above manufacturing method has a cylindrical main body and a shoe receiving portion. It maintains composition of the aluminum alloy including Si of 7 to 18 wt% as the base metal. In addition to Si, Cu, Mg, Zn and Fe etc. can be included. Also, the piston, having been manufactured through the molten metal treating step, includes added Na and/or Sr of 20 to 1000 ppm. In the micro composition, the eutectic Si phase is sphered to be explained later. That is, the eutectic Si phase is removed edges thereof to have round shape, which results in increase of mechanical characteristics, especially wear-proof character.

[0031] Inventors think increase of the wear-proof character is related to shape of the eutectic Si phase in the alloy composition. That is, the eutectic Si phase having the needle shape in the alloy composition of the piston, if stress is applied to the piston, is formed stress concentrated portion at both ends thereof and is opened at a central portion. This is same as state where crack is generated in the alloy composition. With further stress being applied, the opening extends to break the composition. Especially, if the needle-shape eutectic Si phase exists in the surface of the piston, the opening extends by small stress, so that the composition breaks remarkably by friction on the surface. In this way, the wear-proof character of the piston deteriorates.

[0032] However, when the eutectic Si phase is rounded, no stress concentrated portion is formed even if stress is applied to the piston. As a result, the aluminum alloy composition is hardly broken, so that wear-proof character of the piston increases. Here, the sphered eutectic Si phase preferably has an average particle diameter of 1.5 to 3.0 μ m.

Brief Explanation of the Drawings

[0033] Fig. 1 is a longitudinal-section view of a single-headed and capacity-variable type swash-plate compressor;
[0034] Fig. 2 is a front view of a single-headed type piston used in the above swash-plate type compressor;
[0035] Fig. 3(a) is a photograph showing an alloy composition of the piston manufactured with sphering of the eutectic Si phase, while Fig. 3(b) is a photograph showing an alloy composition of the piston manufactured without sphering treatment of the eutectic Si phase;
[0036] Fig. 4 is an explanatory view showing measuring position of worn amount of the piston; and
[0037] Fig. 5 is a graph showing measured result of worn amount of the piston.

Preferred Embodiment of the Present Invention

[0038] Hereinafter, an embodiment of the present invention will be explained with reference to attached drawings. Needless to say, this embodiment is a mere illustration. The present invention is not limited to this embodiment, but can includes various modification made by the skilled person in this technical field.
[0039] Pistons are manufactured by the manufacturing method of present invention and that of the different manufacturing method. They are tested for examining wear-proof character. Detail of the piston, wear-proof test, evaluation based on tested results, and observed result of the alloy composition will be explained.

<Piston of Embodiment >

[0040] A piston of an embodiment has been manufactured according to the present invention in the following manner. Al-Si alloy including Si of 12 wt% which corresponds to AD12 defined in JIS H 211 8 is used as the base metal. Chemical components of the Al-Si alloy is shown in a following Table 1.

<Table 1>

Si	Cu	Mg, Zn, Fe	Mn, Ni	Al
12.0	3.0 to 5.0	each below 1.0	each below 0.5	Rest

[0041] The Al-Si alloy is melted in the crucible furnace at the melting temperature of 680 to 700 °C for the melting time period of 2 hours. Next, the degassing treatment, dreg-removing treatment and adding (sphering) treatment of the eutectic Si phase are performed, as the molten metal treating step. That is, the flux treatment contributing to both of the degassing treatment and the dreg-removing treatment is performed. As the sphering treatment of the eutectic Si phase, only Na is added in 1 hour to the tablet (which is marketed as "Prima Pack", by JAPAN METAL AND CHEMICAL") floated on the molten metal. Adding amount of Na is controlled to be contained by 100 ppm in the molten metal before the casting. A cold chamber pressure die-casting apparatus is used for the pressure die-casting under casting pressure of 200 to 250 MPa. The artificial-age treating step is performed to heat the casted article having been casted up to 200 °C, and to naturally cool it after holdings for 1 hour.
[0042] Finally, as the post treating step, as shown in Fig. 2, the piston 6 is machined at the predetermined portions and is subjected to the surface treatment such as the plating etc.. This piston is comprised of the cylindrical main portion 6a and the shoe receiving portion 6b, and corresponds to the piston subjected to the treatment represented by "T5" in the refining mark (JIS H 0001) defined in JIS.

<Piston of Comparative Sample 1>

[0043] The manufacturing method of a piston of a comparative sample 1 differs from that of the piston of above embodiment, only in a molten metal treating step being performed without the sphering treatment of the eutectic Si phase. That is, the piston is manufactured by subjecting a molten base metal same as that of the embodiment to a molten metal treating step including only the degassing treatment and the dreg-removing treatment, pressure die-casting step, artificial-age treating step and post treating step. Conditions of the metal step, pressure die-casting step, artificial-age treating step and post treating step are same as that of the above embodiment. Also, the piston of the comparative sample 1 is same as that of the above embodiment and corresponds to the piston having been subjected to the treatment represented by "T5 " in the refining mark (JIS H 0001) defined in JIS.

<Observed Result of Alloy Composition>

[0044] The alloy compositions of the piston manufactured by the embodiment and that by the comparative sample

1 are observed. Observed compositions of them are respectively shown in Fig. 3(a) and Fig. 3(b) by magnification of 400. As apparent from these photographies, different from the eutectic Si phase of the comparative sample 1 being thin and having the needle-shape, the eutectic Si phase of the embodiment is removed the edges thereof to have the round shape. Thus, sphering of the eutectic Si phase by the molten metal treating step adding Na of the embodiment can be confirmed through the composition observation.

<Piston of comparative Sample 2>

[0045] For manufacturing a piston of comparative sample 2, the conventional manufacturing method is used. It differs from that of the embodiment in two points. The first point is sphering of the eutectic Si phase is not performed, and the second point is the solution treatment is performed after the pressure die-casting. That is, a base metal same as that of the embodiment is melted, subjected to a molten metal treating step including only the degassing treatment and the dreg-removing treatment, to the solution treatment after the pressure die-casting step, and to the artificial-age treating step and the post treating step. Among them, the casted article having been casted is heated up to 490 °C, maintained in this state for 1 hour and quenched, as the solution treatment. Another steps are same as that of the embodiment. The piston of the comparative sample 2 is same as that of the above embodiment, and corresponds to the piston having been subjected to the treatment represented by "T6" in the refining mark (JIS H 0001) defined in JIS.

<Testing Method for Wear-proof Test>

[0046] Three kinds of the pistons according to the embodiment, comparative sample 1 and comparative sample 2 each manufactured by each of the above manufacturing methods are inserted into bore 5 of the swash-plate type compressor of the single-headed and capacity variable type shown in Fig. 1, and the compressor is operated. For the operating, R134 as a refrigerant and PAG as an oil are used. The swash-plate type compressor is driven for 100 hours so that the shaft 1 and the swash plate 8 rotates by 700 rpm. Seven pistons 6 according to the embodiment 1, ten pistons 6 according to each of the comparative sample 1 and comparative 2 have been tested.

[0047] Wear-proof character of the pistons 6 is evaluated by measuring worn amount of each piston 6 at the semi-spherical seat surface 6c engaging with the shoe 9, after above operation of the swash-plate type compressor. Concretely, as shown in Fig. 4, dimension of gap L between the swash plate 8 and the shoe 9 before and after the operation is measured to calculate a varied amount ΔL.

[0048] The varied amount ΔL is assumed as worn amount of the semi-spherical seat surface 6c of the piston 6.

<Evaluation of Wear-proof Test by Tested Result>

[0049] Measured results of worn amount of the pistons are shown in Fig. 5. As can be observed in Fig. 5, the worn amounts of the pistons 6 of the embodiment, comparative sample 1 and the comparative sample 2 are respectively 5 to 19 μm, 200 to 300 μm and 5 to 20 μm. When the piston 6 of the embodiment having been sphered the eutectic Si phase is compared with the piston 6 according to the comparative sample 1 not having been sphered, the worn amount of the former piston 6 is about one-twentieth of the latter piston. Thus, the sphering treatment of eutectic Si phase greatly increasing the wear-proof character can be confirmed.

[0050] Also, when the piston 6 of the embodiment not having been subjected to the solution treatment is compared with the piston 6 of the comparative sample 2 having been subjected to it, the former piston and the latter piston has equivalent worn amount. Thus, very small (almost no) affect of the solution treatment by the worn amount can be confirmed.

[0051] The present invention intends to provide a manufacturing method of a piston for a swash-plate type compressor being excellent in the wear-proof character, no blister being generated, and capable of manufacturing the piston by low cost.

[0052] A manufacturing method of a piston for a swash-plate type compressor, comprising a molten metal treating step including at least adding treatment for adding Na and/or Sr by 20 to 1000 ppm to a Al-Si alloy molten metal including Si of 7 to 18 wt%; and a die casting step for die casting the Al-Si alloy molten metal.

Claims

1. A manufacturing method of a piston for a swash-plate type compressor, comprising:

a molten metal treating step including at least adding treatment for adding Na and/or Sr by 20 to 1000 ppm to a Al-Si alloy molten metal including Si of 7 to 18 wt %; and a die casting step for die casting the Al-Si alloy molten metal.

2. A manufacturing method of a piston according to claim 1, wherein added amount of Na and/or Sr is 30 to 150 ppm.

3. A manufacturing method of a piston according to claim 2, wherein only Na is added.

4. A manufacturing method of a piston according to claim 3, wherein added amount of Na is 100 ppm.

5. A manufacturing method of a piston according to claim 1, wherein the Al-Si alloy molten metal includes Si of 12 wt%.

6. A manufacturing method of a piston according to claim 1, wherein said molten metal treating step further includes a degassing treatment and a dreg-removing treatment performed before the adding treatment.

7. A manufacturing method of a piston according to claim 1, wherein an eutectic Si phase in the Al-Si alloy is sphered in said molten metal treating step to have an average particle diameter of 1. 5 to 3.0 μm.

8. A manufacturing method of a piston according to claim 1, further comprising an artificial-age treating step to increase strength of the casted article, after said die casting step.

9. A manufacturing method of a piston according to claim 1, wherein no solution treatment is performed after said die casting step.

10. A piston for a swash-plate type compressor obtainable by said manufacturing method according to one of claims 1 to 9, and has a cyilindrical main body and a shoe receiving portion formed at one axial end thereof.

FIG. 1

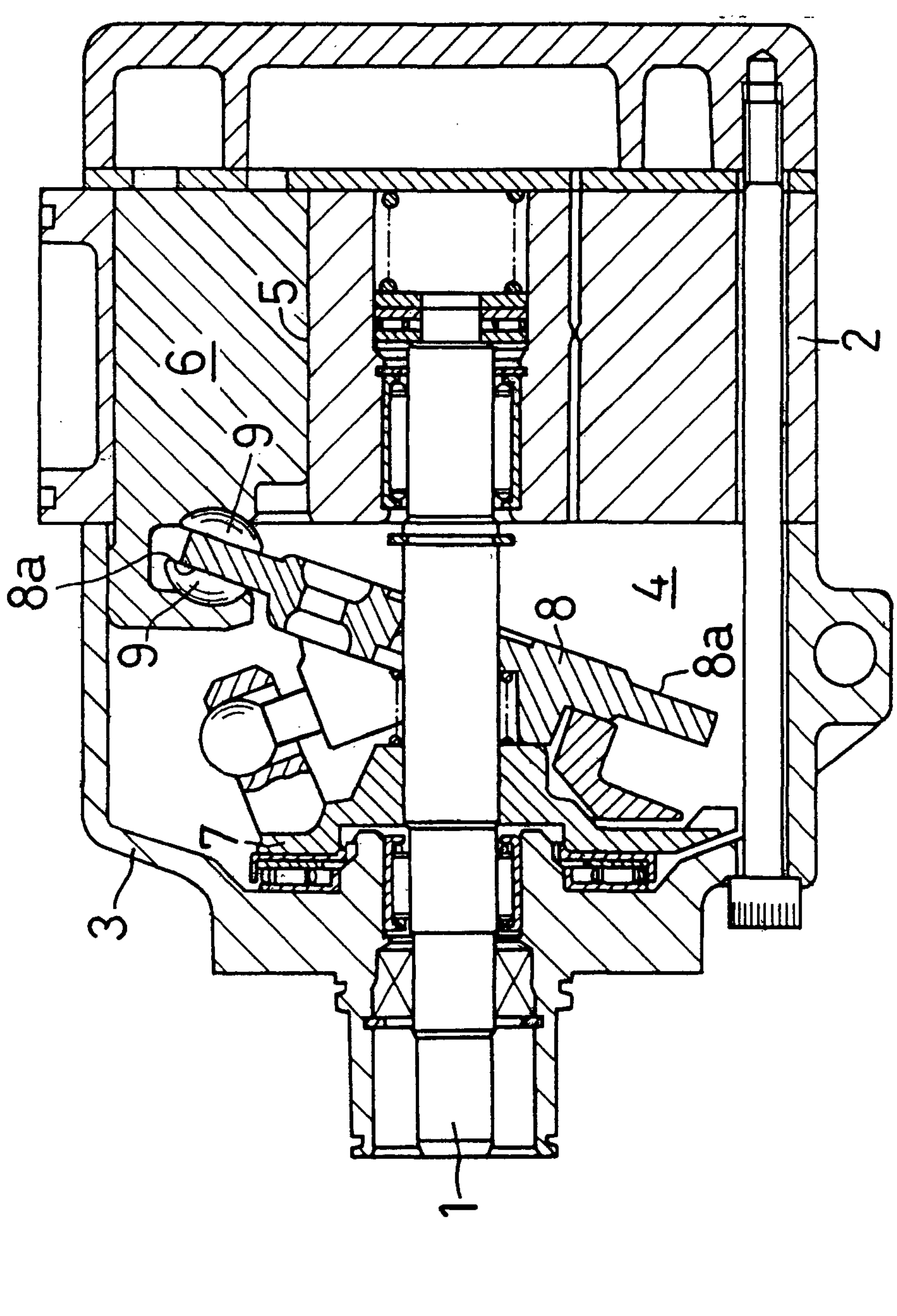
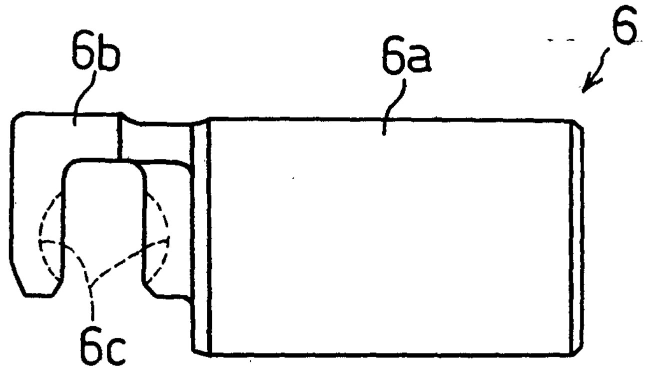


FIG. 2



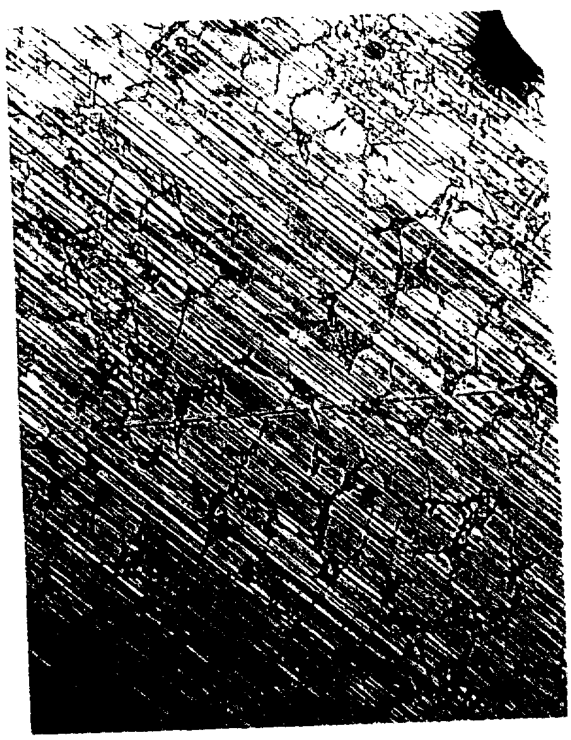


FIG. 3(a)

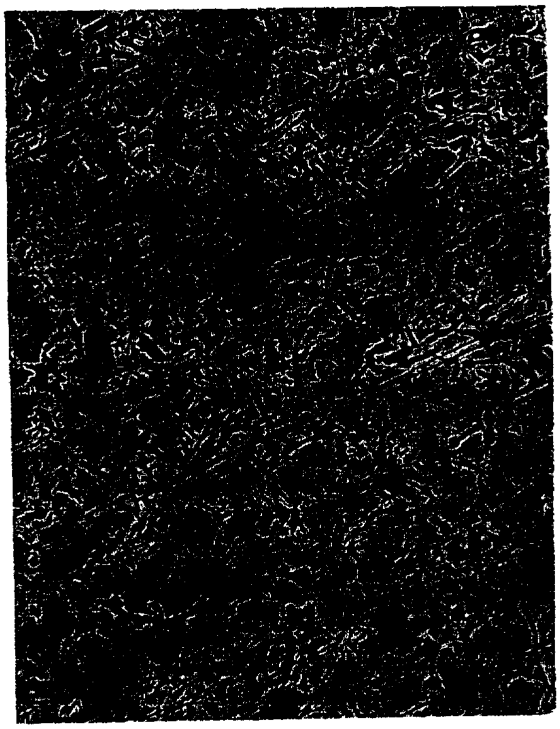


FIG. 3(b)

FIG. 4

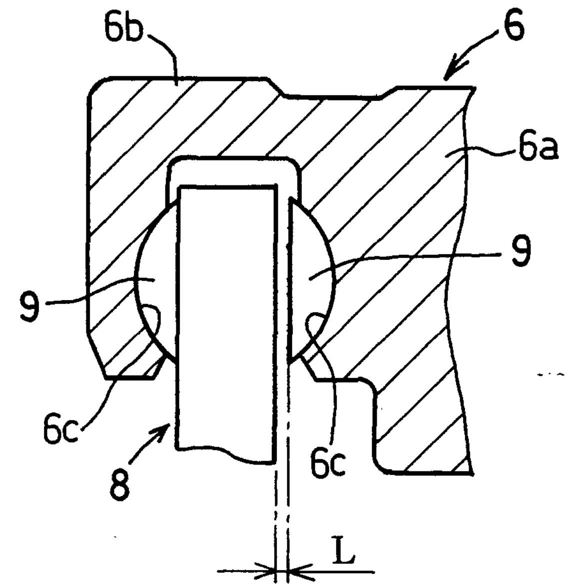
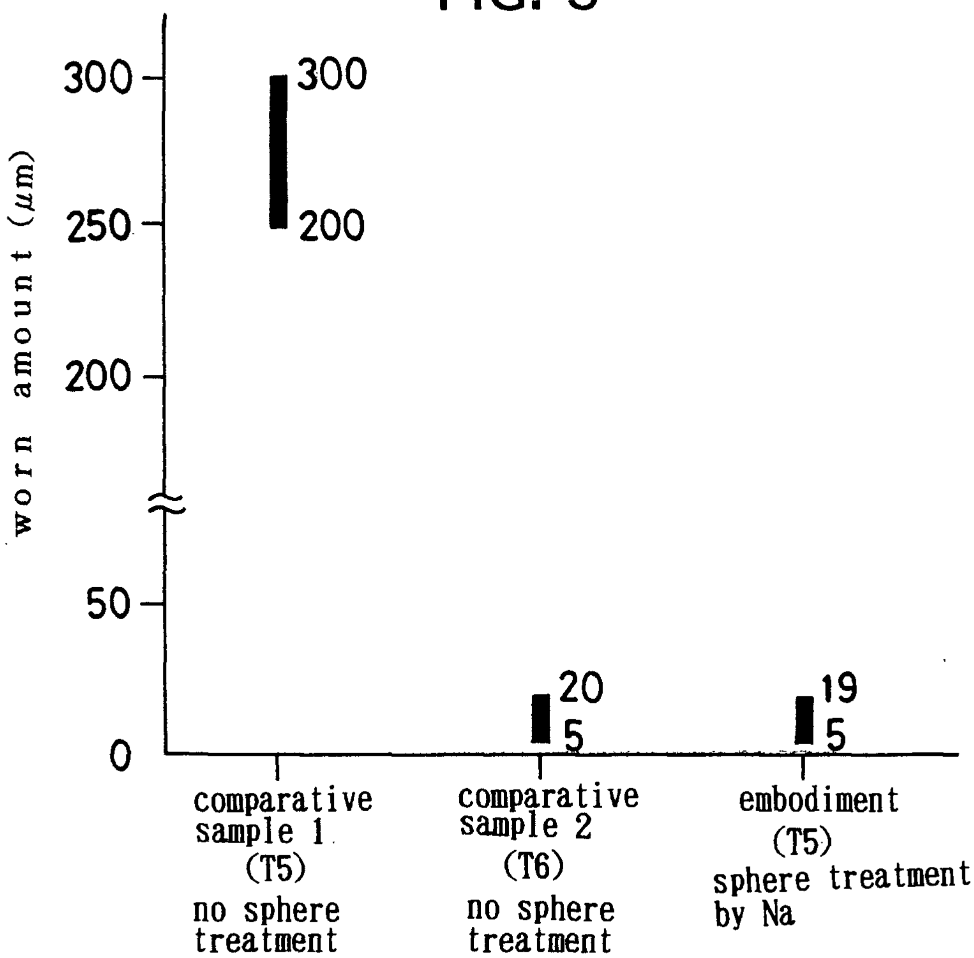

6b
6
6a
9
9
6c
8
6c
L

FIG. 5


worn amount (μm)
300
250
200
50
0
300
200
20
5
19
5
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comparative sample 2 (T6) no sphere treatment
embodiment (T5) sphere treatment by Na