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(11)

EP 1 342 919 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

10.09.2003 Bulletin 2003/37

(51) Int Cl.7: **F04B 27/08**

(21) Application number: **03004888.8**

(22) Date of filing: **06.03.2003**

(84) Designated Contracting States:

**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IT LI LU MC NL PT SE SI SK TR**

Designated Extension States:

AL LT LV MK RO

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(30) Priority: **07.03.2002 JP 2002061513**

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Patent- und Rechtsanwälte

Arabellastrasse 4

81925 München (DE)

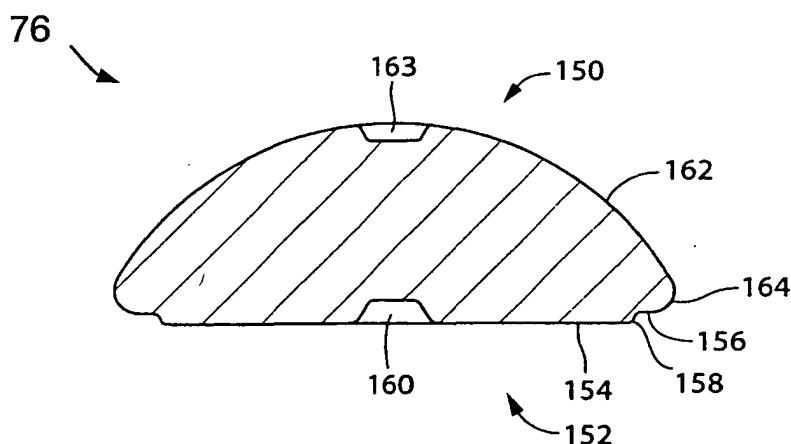
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(54) **Shoe for use in swash plate type compressor and method of forming the same**

(57) A shoe in a swash plate type compressor has a spherical engaging surface that engages with a piston, and a plane engaging surface that is substantially a plane and engages with a swash plate. The plane engaging surface includes a substantially planar sliding surface, a substantially radially extending peripheral surface and a connecting surface. The sliding surface is formed near a center of the plane engaging surface

and slides over the swash plate. The peripheral surface is formed near a periphery of the plane engaging surface, is formed at a distance from the sliding surface away from the surface of the swash plate so as to form an inwardly-directed step in the plane engaging surface, and is connected to the spherical engaging surface at its outer periphery. The connecting surface connects the sliding surface to the peripheral surface.

FIG. 2



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a shoe for use in a swash plate type compressor and a method of forming the shoe.

[0002] A swash plate type compressor compresses gas by converting rotation of a swash plate to reciprocation of a piston. A pair of shoes, or sliding members, is interposed between the swash plate, which rotates at a high speed, and the piston, which reciprocates at a high speed, to ensure smooth operations of the swash plate and the piston. Since the swash plate rotates at a high speed, sliding performance between the swash plate and the piston is required to be relatively high. The shoe is generally hemispherical crown-shaped. Namely, the shoe includes a substantially plane engaging surface engaging with the swash plate, and a substantially hemispherical engaging surface engaging with the piston. In the hemispherical crown shoe, sliding performance between a plane sliding surface and a sliding surface of the swash plate is desired to be relatively high. Lubricant oil is thus generally required to be involved in between the sliding surfaces. On the other hand, existing foreign substances are required not to be involved in between the sliding surfaces so that the foreign substances do not flaw the sliding surfaces.

[0003] In order to fulfill the above two contradicting requirements, as shown in Japanese Unexamined Patent Publication No. 2002-332959, a shoe, in which a side surface connects a hemispherical engaging surface to a plane engaging surface, is disclosed. For example, the side surface is formed such that the side surface is inclined with respect to the surface of the swash plate at an angle of 45° . The shoe has relatively high sliding performance.

[0004] The above mentioned shoe is preferably formed by forging similarly to a common shoe. In forging the above mentioned shoe, a pair of dies that includes a first die for forming the hemispherical engaging surface and a second die for forming the plane engaging surface and the side surface is utilized. A blank piece is set in the middle of the pair of dies, and the pair of dies is closed so as to form the shoe. The blank piece plastically flows to an outer periphery of a cavity of the pair of dies in the cavity and reaches a surface corresponding to a side surface of the pair of dies. Then, the blank piece plastically flows along the surface, and finally the shoe is formed by strongly pressing the blank piece against the entire surface of the pair of dies.

[0005] Dimensional accuracy in a shoe is required to be relatively high. Especially, the dimensional accuracy in the height of the shoe, or the dimensional accuracy in a distance between the plane engaging surface and the hemispherical engaging surface, is required to be relatively high since tolerance for clearance is small due to a mechanism of a swash plate type compressor. On

the other hand, variation in quantities of blank pieces may be permitted to some extent.

[0006] Although the periphery of the cavity in the pair of dies molds a surface that connects the side surface to the hemispherical engaging surface, the periphery of the cavity functions as a space for absorbing the above variation in the quantities of the blank pieces. However, as mentioned above, since the side surface is inclined with respect to the surface of the swash plate at a relatively large angle, a part of a surface of the pair of dies for molding the side surface causes resistance to plastic flow of the blank piece. As a result, for example, when the quantity of the blank piece is larger than a predetermined normal quantity, rate of increase in reactive force from the blank piece to the pair of dies and in amount of spring back becomes large. Namely, when a shoe is manufactured through forging, in which relatively large resistance to the plastic flow of the blank piece is generated, the shoe is not accurately forged due to the variation in the quantities of the blank pieces.

SUMMARY OF THE INVENTION

[0007] The present invention provides a shoe that has relatively high sliding performance and dimensional accuracy.

[0008] According to one preferred embodiment, a shoe for use in a swash plate type compressor, interposed between a swash plate and a piston, has a spherical engaging surface and a plane engaging surface. The spherical engaging surface engages with the piston. The plane engaging surface being substantially a plane engages with the swash plate. The plane engaging surface includes a substantially planar sliding surface, a substantially radially extending peripheral surface and a connecting surface. The sliding surface is formed near a center of the plane engaging surface and slides over a surface of the swash plate. The peripheral surface is formed near a periphery of the plane engaging surface. The peripheral surface is formed at a distance from the sliding surface away from the surface of the swash plate so as to form an inwardly-directed step in the plane engaging surface. The peripheral surface is connected to the spherical engaging surface at its outer periphery. The connecting surface connects the sliding surface to the peripheral surface.

[0009] According to one method embodiment, the present invention also provides a method of forming a shoe that is interposed between a swash plate and a piston in a swash plate type compressor. The shoe includes a spherical engaging surface and a plane engaging surface. The plane engaging surface is substantially a plane and has a substantially planar sliding surface, a substantially radially extending peripheral surface and a connecting surface. The sliding surface is formed near a center of the plane engaging surface and has a predetermined outer diameter. The peripheral surface is formed near a periphery of the plane engaging surface

and is formed at a distance from the sliding surface so as to form an inwardly-directed step in the engaging surface. The connecting surface connects the sliding surface to the peripheral surface. The method embodiment includes the steps of preparing a blank piece having a predetermined outer diameter that is smaller than that of the sliding surface, preparing a pair of dies including a first die for molding the spherical engaging surface and a second die for molding the plane engaging surface, setting the blank piece in the pair of the dies and closing the pair of the dies for forging the shoe.

BRIEF DISCRIPTION OF THE DRAWINGS

[0010] The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. 1 is a longitudinal cross-sectional view of a swash plate type compressor provided with a pair of shoes in an embodiment according to the present invention;

FIG. 2 is an enlarged cross-sectional view of one of the pair of shoes in FIG. 1;

FIG. 3 is a partially enlarged cross-sectional view of one of the pair of shoes in FIG. 2 sliding over the swash plate according to the embodiment;

FIG 4 is a partially enlarged cross-sectional view of one of pair of shoes in another embodiment according to the present invention;

FIG. 5 is a perspective view of a blank piece from which the shoe is forged;

FIG. 6 is a schematic view of a preparing process for preparing a blank piece;

FIG. 7 is a schematic view of a forging process for forging a shoe;

FIG. 8 shows plastic flow of a part of the blank piece corresponding to the periphery of the shoe upon forging the shoe;

FIG 9 is a cross-sectional view of a comparative shoe;

FIG 10 is a schematic view of a forging process for forging a comparative shoe;

FIG. 11 shows plastic flow of a part of a blank of the

comparative shoe corresponding to the periphery of the comparative shoe upon forging the comparative shoe;

FIG. 12 is a graph of the change of the reactive force with respect to the molding time upon forging the shoe in the embodiment and the comparative shoe; and

FIG 13 is a graph of the change of the maximal reactive force with respect to the change of the quantity of the blank piece upon forging the shoe in the embodiment and the comparative shoe.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0011] An embodiment of the present invention will now be described by referring to FIGs. 1 to 13. A pair of shoes in a swash plate type compressor for use in an air conditioner of a vehicle will be described, for example. The front side and the rear side respectively correspond to the left side and the right side in FIG. 1.

[0012] As shown in FIG. 1, a reference numeral 10 denotes a cylinder block, and a plurality of cylinder bores 12 is formed in the cylinder block 10 on an identical circumference relative to the central axis of the cylinder block 10. The cylinder bores 12 extend in the direction of the central axis of the cylinder block 10. A single-headed piston 14 is accommodated in each of the cylinder bores 12 so as to reciprocate. A front housing 16 is fixed to the front end surface of the cylinder block 10, and a rear housing 18 is fixed to the rear end of the cylinder block 10 through a valve plate assembly 20. The front housing 16, the rear housing 18 and the cylinder block 10 constitute a housing of the swash plate type compressor. A suction chamber 22 and a discharge chamber 24 are defined between the rear housing 18 and the valve plate assembly 20 and are connected to an external refrigerant circuit, which is not shown, through an inlet 26 and an outlet 28, respectively. A suction port 32, a suction valve 34, a discharge port 36 and a discharge valve 38 are formed in the valve plate assembly 20.

[0013] A drive shaft 50 is supported by the housing so as to rotate with respect to the central axis of the cylinder block 10. The drive shaft 50 is rotatably supported by the front housing 16 and the cylinder block 10 through bearings. A support hole 56 is formed in the center of the cylinder block 10 along the central axis of the cylinder block 10 and supports the rear end of the drive shaft 50 through one of the bearings. The front end of the drive shaft 50 is connected to a vehicle engine, as a driving source, which is not shown, through a clutch mechanism such as an electromagnetic clutch. Therefore, when the drive shaft 50 is connected to the vehicle engine by the clutch mechanism upon an operation of the vehicle engine, the drive shaft 50 rotates around its axis.

[0014] A swash plate 60 is operatively connected to the drive shaft 50 so as to move along and to tilt with respect to the axis of the drive shaft 50. A through hole 61 is formed in the swash plate 60 along the central axis of the swash plate 60, and the drive shaft 50 is interposed through the through hole 61. The through hole 61 gradually increases in diameter toward both opening ends of the through hole 61, and the cross section of the opening ends are oblong holes. A lug plate 62 is secured to the drive shaft 50 and is supported by the front housing 16 through a thrust bearing 64. A hinge mechanism 66 allows the swash plate 60 to integrally rotate with the drive shaft 50 and to tilt with respect to the axis of the drive shaft 50. The hinge mechanism 66 includes a pair of support arms 67 fixed to the lug plate 62, a pair of guide pins 69 slidably fitted into a pair of guide holes 68 of the support arms 67, the through hole 61 of the swash plate 60, and the outer circumferential surface of the drive shaft 50.

[0015] The piston 14 includes an engaging portion 70 and a head 72. The engaging portion 70 overpasses the periphery of the swash plate 60. The head 72 is integral with the engaging portion 70 and is fitted into the cylinder bore 12. The head 72 in the present embodiment is a hollow head to be light in weight. The head 72, the cylinder bore 12 and the valve plate assembly 20 cooperatively define a compression chamber. The engaging portion 70 engages with the periphery of the swash plate 60 through a pair of shoes 76, which is substantially hemispherical. The shoes 76 will be described later.

[0016] Rotation of the swash plate 60 is converted into reciprocation of the piston 14 through the pair of shoes 76. As the piston 14 moves from a top dead center toward a bottom dead center, refrigerant gas in the suction chamber 22 is sucked into the compression chamber in the cylinder bore 12 through the suction port 32 and the suction valve 34. As the piston moves from the dead center toward the top center, the refrigerant gas in the compression chamber in the cylinder bore 12 is compressed and discharged into the discharge chamber 24 through the discharge port 36 and the discharge valve 38. Compression reactive force is applied to the piston 14 in a direction of the axis of the drive shaft 50 in accordance with compressing the refrigerant gas. The front housing 16 receives the compression reactive force through the piston 14, the swash plate 60, the lug plate 62 and the thrust bearing 64.

[0017] A supply passage 80 is formed in the cylinder block 10 so as to extend through the cylinder block 10. The supply passage 80 interconnects the discharge chamber 24 and a crank chamber 86 that is defined between the front housing 16 and the cylinder block 10. A control valve 90 is disposed on the supply passage 80. The value of an electric current supplied to a solenoid 92 of the control valve 90 is controlled by a controller mainly constituted of a computer, which is not shown, based on information such as cooling load.

[0018] A bleed passage 100 is formed inside the drive

shaft 50. The bleed passage 100 opens its one end to the support hole 56, and opens its other end to the crank chamber 86. The support hole 56 interconnects to the suction chamber 22 through a bleed port 104.

[0019] The swash plate type compressor in the present embodiment is a variable displacement type. The pressure in the crank chamber 86 is controlled by utilizing pressure differential between the discharge chamber 24 as a relatively high pressure region and the suction chamber 22 as a relatively low pressure region. Thereby, pressure differential between the pressure in the compression chambers in the cylinder bores 12 applied to the pistons 14 and the pressure in the crank chamber 86 is adjusted, and strokes of the pistons 14 are varied by varying the inclination angle of the swash plate 60, thus adjusting the displacement of the compressor. Additionally, the crank chamber 86 disconnects from the discharge chamber 24 and interconnects with the discharge chamber 24 by opening and closing the control valve 90. Thereby, the pressure in the crank chamber 86 is controlled.

[0020] The cylinder block 10 and the pistons 14 are preferably made of aluminum alloy. The outer circumferential surfaces of the pistons 14 are preferably coated with fluororesin. With the pistons 14 coated with fluororesin, seizure is inhibited by avoiding directly contacting with a metal of the same kind, and clearances between the cylinder block 12 and the pistons 14 are reduced. The material of the cylinder block 10, the pistons 14 and the coating layers are not limited as described above, but may be changed into other materials.

[0021] The engaging portions 70 of the pistons 14 are substantially U-shaped. The engaging portions 70 each provide a pair of arms 120, 122 and a connecting portion 124. The pair of arms 120, 122 extends in parallel with each other in a direction perpendicular to the central axis of the head 72. The connecting portion 124 interconnects the bases of the arms 120, 122. Spherical concave surfaces 128 are formed on the facing surfaces of the arms 120, 122 for supporting the shoes 76 and sliding over the shoes 76, respectively. The spherical concave surfaces 128 cooperatively form a part of an identical hypothetical spherical sliding surface.

[0022] A base member of the swash plate 60, which slides over the shoes 76, is made of ductile iron. Aluminum layers are formed on the sliding surfaces 132, 134 of the base member of the swash plate 60 by metal spraying, and lubricant layers are further formed on the aluminum layers. The lubricant layers are made of synthetic resin dispersedly containing molybdenum disulfide and graphite as a solid lubricant. The aluminum layers sufficiently reduce friction generated between the sliding surfaces, and ensure relatively high sliding performance between the shoes 76 and the swash plate 60. Even if the lubricant layers abrade or peel off due to some causes, the aluminum layers maintain a smooth slide. The structure of the swash plate 60, such as material of the base member of the swash plate 60, the ma-

terial and the thickness of the lubricant layer, with or without the lubricant layer, the thickness of the aluminum spraying layers, and with or without the aluminum spraying layer, can be varied.

[0023] As shown in FIG 2, the shoe 76 includes a spherical engaging surface 150 and a plane engaging surface 152. The spherical engaging surface 150 is substantially a part of a sphere surface in shape and engages with the piston 14. The plane engaging surface 152 is substantially a plane in shape and engages with the swash plate 60. The plane engaging surface 152 includes a plane sliding surface 154, a peripheral surface 156 and an annular connecting surface 158. The plane sliding surface 154 is formed near the center of the plane engaging surface 152 and slides over the sliding surfaces 132 or 134 of the swash plate 60. The peripheral surface 156 is formed adjacent to the periphery of the plane engaging surface 152. The peripheral surface 156 extends in a substantially radial direction, such that the peripheral surface 156 is oriented in a range from substantially parallel to the plane sliding surface 154 to slightly inclined with respect to the plane sliding surface 154. The peripheral surface 156 and the plane sliding surface 154 form an inwardly-directed step therebetween. Namely, the peripheral surface 156 is formed at a distance from an extended plane surface of the plane sliding surface 154 away from the sliding surface 132 or 134 facing the plane sliding surface 154. The peripheral surface 156 is connected to the spherical engaging surface 150. The connecting surface 158 connects the plane sliding surface 154 to the peripheral surface 156. In FIG. 2, the step between the peripheral surface 156 and the plane sliding surface 154 is exaggeratingly shown for easy understanding. Preferably, the plane sliding surface 154 forms a convex surface, the radius of the curvature of which is very large. In the present embodiment, where a first hypothetical plane includes the periphery of the plane engaging surface 152, and where a second hypothetical plane that is parallel with the first hypothetical plane contacts the plane engaging surface 152, a distance between the first and second hypothetical planes is 5 μ m along a straight line perpendicular to the first and second hypothetical planes. A first shoe recess 160 is formed at the center of the plane engaging surface 152 so as to store lubricant oil therein. Thereby, high sliding performance is ensured. Consequently, the plane engaging surface 152 is annular in shape. Meanwhile, the spherical engaging surface 150 includes a spherical sliding surface 162 and a peripheral rounded surface 164. The spherical sliding surface 162 is substantially a part of a sphere surface and slides over the spherical concave surface 128 of the piston 14. A second shoe recess 163 is formed at the center of the spherical sliding surface 162 so as to be pressed by a dowel pin upon forging. The peripheral rounded surface 164 connects the spherical sliding surface 162 to the peripheral surface 156 of the plane engaging surface 152. The shoe 76 is generally called a hemispherical

crown shoe. Practically, a spherical engaging surface and a plane engaging surface of the hemispherical crown shoe are respectively modified from a strict spherical engaging surface and a strict plane engaging surface so as to improve sliding performance. For example, a plane sliding surface forms a convex surface such that the center of the plane sliding surface protrudes by 5 to 10 μ m from the periphery of the plane sliding surface. The hemispherical crown shoe in the present embodiment includes the modified plane engaging surface. Although the shoe in the present embodiment can be used in variable and fixed displacement type compressors, generally, a shoe for use in a variable displacement type compressor is smaller than a hemisphere, and a shoe for use in a fixed displacement type compressor is larger than a hemisphere. In the variable displacement type compressor, both spherical engaging surfaces of the pair of shoes on each side of the swash plate needs to cooperatively form a part of identical hypothetical spherical surface. Each of the shoes is substantially a part of sphere and is smaller in thickness by substantially a half of the thickness of the swash plate than a hemisphere. On the other hand, in the fixed displacement type compressor, no such limitations as that of the variable displacement type compressor is required. Therefore, thickness of each of the shoes is more than a hemisphere in order to inhibit the area of the sliding surface of the shoe from reducing even if the plane engaging surface abrades.

[0024] Referring to FIGs. 1 and 2, the pair of shoes 76 is slidably held by the spherical concave surface 128 of the piston engaging portion 70. The plane sliding surfaces 154 of the pair of shoes 76 are in contact with the sliding surfaces 132 and 134, which are both surfaces of the periphery of the swash plate 60, and the swash plate 60 is interposed between the pair of shoes 76. In other words, the plane sliding surfaces 154 of the pair of shoes 76 slide over the swash plate 60, and the spherical sliding surfaces 162 of the pair of shoes 76 slide over the piston 14. The spherical sliding surfaces 162 of the pair of shoes 76 cooperatively form a part of an identical hypothetical spherical sliding surface. Namely, the shoe 76 is substantially a part of a sphere, the thickness of which is substantially smaller than a hemisphere by a half of the thickness of the swash plate 60.

[0025] The shoe 76 includes a base member and a metal plating layer that coats the surface of the base member of the shoe 76. The base member is made of Al-Si series alloy such as A4032, the base of which is aluminum and contains silicone such that the composition ratio is closer to that of eutectic. The metal plating layer is formed by electroless plating with nickel. The hardness and the strength of the metal plating layer is relatively high. Thereby, the shoe is inhibited from abrading and being flawed. The average thickness of the electroless nickel plating layer is 50 μ m and is omitted in FIG. 2. The structure of the shoe 76, such as the material of the base member of the shoe 76, and the

material and the thickness of the metal plating layer, are not limited to that in the present embodiment. The shoe, the base member of which is made of aluminum series alloy, is relatively right in weight. Therefore, the shoe is appropriate for use in a swash plate type compressor installed in an air conditioner of a vehicle. A kind of aluminum series alloy is not limited. Aluminum series alloy, which is generally used in various fields, or which is well known, may be applied. For example, Al-Si having eutectic composition of approximately A4032 (JIS H 4000) may be applied. Al-Si series alloy has relatively small coefficient of thermal expansion and relatively high abrasion resistance. Therefore, the shoe, the base member of which is made of Al-Si series alloy, slides smoothly. Also, for example, Al-Cu-Mg series alloy such as A2017 and A2024 (JIS H 4000) may be applied. Since the strength of the Al-Cu-Mg series alloy is relatively high, the shoe, the base member of which is made of Al-Cu-Mg series alloy, performs relatively high strength and high durability. It is preferable that the surface of the base member made of aluminum series alloy is coated with metal plating layer. The metal plating layer is preferably electroless nickel plating layer such as Ni-P and Ni-B. Electroless nickel plating layer is uniform. When solidified, electroless nickel plating layer has a hardness of more than Hv500 (Vickers hardness). Thereby, electroless nickel plating layer performs relatively high abrasion and high anti-corrosion. Furthermore, the shoe made of aluminum series alloy is usually forged from a cylindrical blank piece. Quantities of the cylindrical blank pieces vary in a wide range. However, since the shoe in the present invention is accurately forged as mentioned later, the shoe made of aluminum series alloy is advantageous to the present invention. The base member of the shoe in the present invention may also be made of iron series alloy. Iron series alloy is relatively low cost and relatively high in strength and hardness. Therefore, the shoe, the base member of which is made of iron series alloy, is relatively low cost, and provides relatively high abrasion resistance and high durability. A kind of iron series alloy is not limited. High carbon chromium bearing steel SUJ2 (JIS G 4805) is preferably employed. The shoe made of high carbon chromium bearing steel is manufactured by thermal refining such as quenching or tempering, and nitriding. A relatively large load is required upon forging the shoe made of high carbon chromium bearing steel compared to the shoe made of aluminum series alloy. In the shoe in the present invention, since the blank piece plastically flows easily upon forging even when the quantities of the blank pieces vary in a wide range, cost of a die is reduced. Therefore, the shoe made of high carbon chromium bearing steel is advantageous to the present invention. Furthermore, metallic material such as magnesium, and resin may be employed as material of the base member of the shoe.

[0026] As shown in FIG. 3, the connecting surface 158 is located in the step between the plane sliding surface

154 and the peripheral surface 156. The connecting surface 158 includes a chamfered surface 180, a first rounded corner 182 and a second rounded corner 184. The chamfered surface 180 is a side surface of a circular truncated cone. The diameter of the chamfered surface 180 near the peripheral surface 156 is larger than that of the chamfered surface 180 near the plane sliding surface 154. The first rounded corner 182 connects the chamfered surface 180 to the plane sliding surface 154. The second rounded corner 184 connects the chamfered surface 180 to the peripheral surface 156. Each boundary is indicated by a circle in FIG. 3 for the sake of convenience. A distance D of the step between the plane sliding surface 154 and the peripheral surface 156 is a predetermined distance. The distance D of the step corresponds to a distance between an extended plane sliding surface 186, which is substantially perpendicular to the central axis of the shoe 76 and contacts the plane sliding surface 154, and a periphery of the peripheral surface 156 connecting to the second rounded corner 184. When the plane sliding surface 154 is a plane in shape and parallel to the peripheral surface 156, the distance D is a distance between the plane sliding surface 154 and the peripheral surface 156. In the present embodiment, the distance D is 0.2mm. A chamfered surface angle α between the chamfered surface 180 and the extended plane sliding surface 186, the radius r of curvature of the first rounded corner 182 and the radius r' of the second rounded corner 184 are respectively determined. In the shoe 76 in the present embodiment, the chamfered angle is preferably 45° , and the radii r and r' of curvature are preferably 0.2mm.

[0027] In FIG. 3, the shoe 76 is in contact with the swash plate 60 such that a central axis of the shoe 76 is perpendicular to the sliding surface 132 of swash plate 60. The plane sliding surface 154 of the shoe 76 is slightly convex in shape as mentioned above. Therefore, a small clearance 190 that gradually increases in a direction of the periphery of the shoe 76 is maintained between the plane sliding surface 154 and the sliding surface 132. The clearance 190 is exaggeratingly shown in FIG. 3 for easy understanding. A layer of lubricant oil is formed in between the sliding surfaces. Thereby, sliding performance improves. The extended plane sliding surface 186 as a standard for the distance D and chamfered surface angle α is a plane that is perpendicular to the central axis of the shoe 76 and contacts the plane sliding surface 154 as mentioned above. In FIG. 3, since the plane sliding surface 154 of the shoe 76 is slightly convex in shape, the extended plane sliding surface 186 corresponds to the sliding surface 132 of the swash plate 60. The distance D corresponds to a distance between the sliding surface 132 of the swash plate 60 and the peripheral surface 156, and the chamfered surface angle α corresponds to an angle between the chamfered surface 180 and the sliding surface 132 of the swash plate 60.

[0028] When the shoe 76 slides over the swash plate

60, that is, the shoe 76 relatively moves toward a direction indicated by an arrow in FIG. 3, lubricant oil on the surface of the swash plate 60, which is omitted in the drawings, is led from a space 192 between the connecting surface 158 of the shoe 76 and the sliding surface 132 of the swash plate 60 into the clearance 190. The cross section of the space 192 is wedge-shaped. When foreign substances 194 are involved in the space 192, since the chamfered surface angle α and the radius r of curvature of the first corner 182 are appropriately designed, relatively large foreign substances 194, which may affect sliding performance, is retarded from being involved in the clearance 190. Namely, when the connecting surface 158 is appropriately formed at the periphery of the plane sliding surface 154 as shown in FIG. 3, the foreign substances 194 can be excluded while the lubricant oil is included between the sliding surfaces. Therefore, when the shoe includes the connecting surface 158, the shape of which is appropriate, high sliding performance is ensured. As mentioned above, unless lubricant oil is included between the sliding surfaces and harmful foreign substances are not included between the sliding surfaces, relatively high sliding performance between the sliding surfaces cannot be obtained. Including the lubricant oil and excluding the foreign substances will be described by referring to a swash plate type compressor constituting an air conditioner. The lubricant oil is included in the refrigerant gas, and the lubricant oil forms oil film such that relatively high sliding performance between the sliding surfaces is maintained. Therefore, when the lubricant oil is not included between the sliding surfaces, sliding performance deteriorates. Also, there may be various foreign substances in the swash plate type compressor, such as, for example, tailing generated due to friction in various places, remaining microscopic burrs from manufacturing, and dusts introduced from a refrigerant conduit connected to the compressor. These foreign substances should be sufficiently managed. However, it is hard to completely remove these foreign substances. Therefore, these foreign substances exist in between the sliding surfaces, and then remain. When the foreign substances remain between the sliding surfaces, the sliding surfaces are flawed, and sliding performance between the sliding surfaces deteriorates. To sufficiently include the lubricant oil and to sufficiently exclude the foreign substances, the geometry of the shoe 76, which slides over the swash plate 60, is important. In the shoe in the present invention, these requirements can be satisfied by adjusting the shape of the connecting surface 158 adjacent to the periphery of the plane sliding surface 154. The structure in the present embodiment is one of the examples. Characteristics for excluding foreign substances and characteristics for including lubricant oil are regulated by adjusting the shapes of the chamfered surface 180 and the first rounded corner 182. Therefore, a shoe having relatively high sliding performance is obtained. Meanwhile, since the chamfered surface is formed in the

step, which is relatively small, the length of the chamfered surface 180, which is a distance of the chamfered surface 180 in the height of the shoe, is relatively short. For example, when the step is relatively small and the first and second rounded corners 182 and 184 are relatively large, the length of the chamfered surface 180 is extremely short. In an ultimate case, the length of the chamfered surface 180 is zero. In this case, a boundary between the first rounded corner 182 and the second rounded corner 184 can be regarded as the chamfered surface 180. In the present embodiment, the chamfered surface 180 includes the above configurations.

[0029] In FIG. 3, a representative foreign substance 194 is substantially a sphere in shape, the diameter of which is about 100 μ m. Since the foreign substance 194, which is relatively large, contacts the chamfered surface 180, characteristics for excluding foreign substance is determined based on the chamfered angle α . When the foreign substances are relatively small, the foreign substances contact the first rounded corner 182, not the chamfered surface 180. Therefore, characteristics for excluding foreign substances are determined based on the radius r of curvature of the first rounded corner 182. More particularly, when the foreign substances contact the first rounded corner 182, characteristics for excluding foreign substances is determined based on a tangent plane angle between the extended plane sliding surface 186 and a tangent plane to the first sliding rounded corner 182 at a point of contact, where the foreign substances contact the first rounded corner 182. When the tangent plane angle is relatively large, the foreign substance is easily excluded. When the tangent plane angle is relatively small, the foreign substances are easily included between the sliding surfaces. When the diameter of the foreign substance is unchanged, as the radius r of curvature of the first rounded corner 182 is small, characteristics for excluding foreign substances become excellent. On the other hand, as the radius r of curvature of the first rounded corner 182 is large, the lubricant oil is easily included between the sliding surfaces. When the radius r of curvature of the first rounded corner 182 is extremely small and the first rounded corner 182 contacts the sliding surface 132 of the swash plate 60, the first rounded corner 182 may peel off the lubricant layer containing a solid lubricant because of the relatively low strength and hardness of the lubricant layer. Also, when the radius r of curvature of the first rounded corner 182 is extremely small, the rounded corner 182 excludes not only the foreign substances but also the lubricant oil. Furthermore, the surfaces of the shoes 76 are usually smoothed by barrel polishing, and the shoes 76 abut against each other upon barrel polishing. Therefore, when the radius r of curvature of the first rounded corner 182 is extremely small, the shoes 76 may be flawed from the first rounded corner 182. Accordingly, the chamfered surface angle α and the radius r of curvature of the first rounded corner 182 can be appropriately determined in accordance with

the purpose of the shoe 76 in view of characteristics for excluding foreign substances and characteristics for including lubricant oil. When the chamfered surface angle α is an appropriate angle, which is relatively small, the lubricant oil is sufficiently included between the sliding surfaces. However, when the chamfered surface angle α is too small, characteristics for excluding foreign substances deteriorates. In other words, the foreign substances are easily caught in between the chamfered surface 180 and the sliding surface 132 of the swash plate 60, when the shoe 76 moves in this state, the foreign substances are included between the plane sliding surface 154 of the shoe 76 and the sliding surface 132 of the swash plate 60. On the other hand, when the chamfered surface angle α is increased to an angle of 90° , the chamfered surface 180 pushes the foreign substances aside. Namely, as the chamfered surface angle α is large, characteristics for excluding foreign substances improves. Even when the chamfered surface angle α is relatively large, the chamfered surface 180 substantially does not restrict the plastic flow of the blank piece upon forging due to the relatively small distance D. Therefore, the chamfered surface 180 hardly becomes one of causes that reduce the dimensional accuracy in the shoe 76. To obtain relatively high characteristics for excluding foreign substances, it is preferable that the chamfered surface angle α is 35° or above. The chamfered surface angle α is more preferably 40° or above. On the other hand, it is preferable that the chamfered surface angle α is 90° or below. In view of characteristics for involving lubricant oil and for restricting the plastic flow of the blank piece upon forging, the smooth plastic flow requires the smaller chamfered surface angle α , the chamfered surface angle α is preferably 75° or below, more preferably 60° or below, and much more preferably 50° or below. When the length of the chamfered surface 180 is substantially zero, the chamfered surface angle α is defined as an angle between the first and second rounded corner. That is, where the cross-section of the shoe is taken along a hypothetical plane including a central axis of the shoe and perpendicular to the plane sliding surface 154, the chamfered surface angle α is defined as an angle between the extended plane sliding surface 186 and a hypothetical tangent line of both the first and second rounded corners 182 and 184. In view of characteristics for involving the lubricant oil in between the sliding surfaces, for inhibiting the shoe from being flaved upon barrel polishing, and for avoiding the metal plating layer from abrading, the radius r of curvature of the first rounded corner 182 is preferably 0.05mm or above. The radius r of curvature of the first rounded corner 182 is more preferably 0.1 mm or above, and is much more preferably 0.15mm or above. When the radius r of curvature of the first rounded corner 182 is relatively large, relatively small foreign substances contact the first rounded corner 182, not the chamfered surface 180. In such a state, characteristics for excluding foreign substances

depends on an angle between a tangent plane at a point of contact with foreign substance and the extended plane sliding surface, that is, a tangent plane angle. When the shoe contacts foreign substances at its chamfered surface, characteristics for excluding foreign substances improves as the tangent plane angle increases. In addition, when a foreign substance of the same diameter contacts the first rounded corner 182, the tangent plane angle increases as the radius r of curvature of the first rounded corner 182 decreases. Namely, as the radius r of curvature of the first rounded corner 182 reduces, characteristics for excluding foreign substances improves. Accordingly, when focusing on characteristics for excluding foreign substances, the radius r of curvature of the first rounded corner 182 is 0.5mm or below, is preferably 0.4mm or below, and is more preferably 0.3mm or below. Furthermore, Japanese Unexamined Patent No. 2002-332959 can be referred to about a relationship between the diameter of the foreign substance and the radius r of curvature for a help of understanding.

[0030] The distance D of the step between the peripheral surface 156 and the plane sliding surface 154 affects characteristics of the shoe 76. In the present embodiment, since the distance D of the step between the peripheral surface 156 and the plane sliding surface 154 is preferably about 0.2mm, the foreign substance, the diameter of which is smaller than $200\mu\text{m}$, is not caught in between the sliding surface 132 of the swash plate 60 and the peripheral surface 156. The distance D can be set in accordance with largeness of expected foreign substances, the shape of the connecting surface 158 and easiness of plastic flow of a blank piece upon forging as will be mentioned later. When the distance D is too small, it is hard to include the lubricant oil between the sliding surface 132 of the swash plate 60 and the plane sliding surface 154 of the shoe 76. When considering the above description, it is preferable that the distance D is 0.02mm or above. As the distance D is small, it is easy to include relatively small foreign substances in between the peripheral surface 156 and the sliding surface 132 of the swash plate 60. When the distance D is much smaller, the shape of the connecting surface 158 is limited, and the connecting surface 158 may not be appropriately formed such that the lubricant oil is sufficiently included between the sliding surface 132 of the swash plate 60 and the plane sliding surface 154 of the shoe 76 and the foreign substances are sufficiently excluded. When considering the above descriptions, it is preferable that the distance D is 0.05mm or above. When focusing on excluding larger foreign substances, the distance D is preferably 0.1 mm or above, and is more preferably 0.15mm or above. On the other hand, when the distance D is relatively large, the resistance to the plastic flow of the blank piece upon forging becomes large. When considering the above description, it is preferable that the distance D is 0.5mm or below. When focusing on that the resistance is reduced more, the dis-

tance is preferably 0.3mm or below, and is more preferably 0.25mm or below. Furthermore, in the above mentioned embodiment, the peripheral surface 156 is substantially parallel to the plane sliding surface 154. When considering that the resistance to the plastic flow of the blank piece upon forging is reduced, the structure is preferable. However, as shown in FIG. 4, the peripheral surface 156 can be inclined with respect to the plane sliding surface 154. In this case, it is desired that the peripheral surface 156 is formed such that an angle β between the peripheral surface 156 and the extended plane sliding surface 186 is less than 10° . In the above range of the angle β , the resistance to the plastic flow of the blank piece does not increase upon forging as will be mentioned in detail later. In addition, the width of the peripheral surface 156, that is, a distance between the outer and the inner edges of the peripheral surface 156, can be determined by considering variation in quantities of blank pieces and the easiness of plastic flow of the blank upon forging. As the area of the plane sliding surface 154 is large, sliding becomes stable. It is desired that the width of the peripheral surface 156 is determined such that the sufficient area of the plane sliding surface 154 is ensured. Since the peripheral rounded surface 164, which is an outer periphery of the shoe 76, is a part for absorbing variation in quantities of blank pieces, the shape of the peripheral rounded surface 164 is different in each shoe.

[0031] One of the manufacturing processes of the shoe 76 in the present embodiment will be described. The shoe is manufactured by the steps of a preparing process for preparing a blank piece, a forging process, a thermal refining process, a grinding and polishing process, a plating process and a finishing process. A method of forming a shoe according to an embodiment of the present invention includes the preparing process and the forging process.

[0032] The blank is the aluminum series alloy as mentioned above. A blank piece 200 formed from the blank is cylindrical as shown in FIG. 5. Particularly, the cylindrical blank 200 has an outer diameter that is smaller than that of the plane sliding surface 154 of the shoe 76, and a height that is larger than that of the shoe 76. A first recess 202 corresponding to the first shoe recess 160 on the plane engaging surface 152 of the shoe 76 is formed on one end surface and a second recess 203 corresponding to the second shoe recess 163 on the plane engaging surface 152 of the shoe 76 is formed on the other end surface. The blank piece 200 is made by forming the first and second recesses 202 and 203 in a cylindrical blank base. The blank base is preferably made by the steps of molding a billet made of aluminum series alloy with predetermined composition, forming a cylindrical rod with a predetermined diameter by extruding and drawing the billet, annealing the cylindrical rod, cutting the cylindrical rod into pieces with a predetermined length by a sawing machine or a shear, and smoothing a surface of the cut blank by barrel polishing.

[0033] As shown in FIG. 6, the first and second recesses 202 and 203 are formed by upset forging. A pair of dies 206 for forming a recess includes a drag 212 supported by a base 210 through a spring damper 208, and a cope 213 opposite to the drag 212. The drag 212 has a setting recess 214 where a blank base 204 is set. The setting recess 214 is formed such that the inner diameter of the setting recess 214 is slightly larger than the outer diameter of the blank base 204 and the depth of the setting recess 214 is smaller than the height of the blank piece 200. The drag 212 has a circular through hole 215 that connects the center of the bottom of the setting recess 214. A cylindrical pin 216 is formed on the base 210. One end of the cylindrical pin 216 is fixed to the base 210, and the other end of the cylindrical pin 216 is interposed in the circular through hole 215. The cope 213 has a contacting recess 218 such that the bottom of the contacting recess 218 contacts one end of the blank base 204 when the pair of dies 206 is closed. The inner diameter of the contacting recess 218 is slightly larger than the outer diameter of the blank base 204. A protrusion 219 is formed on the center of the bottom of the contacting recess 218. In a state when the blank base 204 is set in the setting recess 214 of the drag 212, when the cope 213 is operated downward, the cope 213 and the drag 212 are closed, and then the drag 212 is lowered with respect to the base 210. Therefore, the one end of the cylindrical pin 216 protrudes into the setting recess 214 from the circular through hole 215, and the one end of the cylindrical pin 216 and the protrusion 219 of the cope 213 are pressed against each of the end surfaces of the blank base 204. Accordingly, the first and second recesses 202 and 203 are formed on each of the surfaces of the blank base 204, and the blank piece 200 is completed.

[0034] The preparing process finishes as mentioned above. The preparing process is not limited to the above mentioned embodiment. For example, when a shoe is formed from a spherical blank piece, the spherical blank piece is made in the preparing process. In this case, the preparing process includes the steps of cutting a cylindrical blank into pieces, pressing, flushing, grinding and polishing. When a shoe is formed from a blank piece that does not have a recess, a recess does not need to be formed in the blank piece in the preparing process. When a predetermined blank piece is purchased, the preparing process is not necessarily performed. A shoe may be formed from the purchased predetermined blank piece.

[0035] The blank piece 200 is applied to the forging process. A forging process is schematically shown in FIG. 7. A forging apparatus with a pair of dies 224 including a cope 220 and a drag 222 is used for cold forging. In a state when the cope 220 and the drag 222 are closed, a cavity, which has substantially the same shape as the shoe 76, is formed. The cavity has substantially the same shape as the base member of the shoe 76. The cavity is smaller than the shoe 76 substantially by

a portion corresponding to the thickness of the electroless nickel plating layer formed on the surface of the base member of the shoe 76. The drag 222 has a protrusion 226, the shape of which is substantially the same shape as the first recess 202. The blank piece 200 is positioned on the drag 222 by fitting the protrusion 226 into the first recess 202. The cope 220 has a movable dowel pin 227. The top end of the dowel pin 227 is fitted into the second recess 203 formed in the blank piece 200. In this manner, since the first and second recesses 202 and 203 are previously formed before a forging process, the blank piece 200 is positioned appropriately in the pair of dies 224 by means of the first and second recesses 202 and 203, the protrusion 226 and the dowel pin 227. Thereby, the blank piece 200 plastically flows isotropically. The shapes and the dimensions of the forged base members of the shoes 76 vary in a narrow range, and the shoes 76 ensure high quality. After putting the blank piece 200 on the drag 222, the base member of the shoe 76 is forged by operating the cope 220 downward and fitting the cope 220 onto the drag 222.

[0036] More particularly, a molding surface of the cope 220 as a first die molds the spherical engaging surface 150 of the shoe 76. A molding surface of the drag 222 as a second die molds the plane engaging surface 152 of the shoe 76. In a state when the cope 220 and the drag 222 are closed, a space between a part of the surface of the drag 222 that molds the plane sliding surface 154 and the surface of the cope 220 determines the dimension of the height of the base member of the shoe 76. The cope 220 and the drag 222 are closed so that the periphery of the cope 220 contacts the periphery of the drag 222. Therefore, the pair of the dies 224 contributes to improve dimensional accuracy in the height of the base member of the shoe 76. However, since the contact between the pair of dies 224 has an influence on a durability of the dies, it is desired to determine whether the cope 220 contacts the drag 222 or not, and which parts of the cope 220 and the drag 222 contact each other by considering the influence.

[0037] The cavity of the pair of dies 224 is formed such that a surplus space 228 that is not filled with the blank piece in the periphery of the cavity is left. The surplus space 228 absorbs the variation in the quantities of the blank pieces 200. In other words, the surface of the drag 222 that molds the peripheral surface 156 extends toward the periphery of drag 222, and the surface of the cope 220 that molds the spherical sliding surface 162 extends. The surplus space 228 is defined by the extended surfaces of the drag 222 and the cope 220. On the contrary, the quantity of the blank piece 200 is determined such that the surplus space 228 is left unfilled. The peripheries of the base materials of the shoes 76, which are formed in the surplus space 228, are slightly different from each other due to the variation in the quantities of the blank pieces 200. However, in a state when the shoe 76 is put in a swash plate type compressor,

since the peripheral rounded surface 164 corresponding to the surface of the periphery of the base material of the shoe 76 does not slide over a piston and a swash plate, the above mentioned variation does not affect performance of the swash plate type compressor.

[0038] After the blank piece 200 is set in the pair of dies 224, once the pair of dies 224 begins to close, the blank piece 200 is pressed by the pair of dies 224 in a vertical direction. Thereby, the blank piece 200 deforms such that the blank piece 200 spreads toward the outer periphery of the cavity. Namely, the blank piece 200 plastically flows toward the outer periphery of the cavity. As the cope 220 is lowered, the side surface of the blank piece 200 moves toward the outer periphery of the cavity. When the pair of dies 224 has finished closing, the cope 220 and the drag 222 tightly press the blank piece 200, and the cavity is filled with the blank piece 200 except the above mentioned surplus space 228. At the time, the forging process has finished. Besides, in a case that the forged shoe 76 is taken from the pair of dies 224, the dowel pin 227 is pushed down as the cope 220 is operated upward. Thereby, the forged shoe 76 is separated from the cope 220 and is easily taken from the pair of dies 224.

[0039] Plastic flow of a part of the blank piece 200 corresponding to the periphery of the shoe 76 is shown in FIG. 8. In the forging process for the shoe 76 in the present embodiment, the blank piece 200 spreads toward the outer periphery of the cavity. A step part 230 of the surface of the drag 222 for forming the connecting surface 158 can cause resistance to the plastic flow of the blank piece 200. However, since the distance D of the step between the peripheral surface 156 and the plane sliding surface 154 is relatively short, the blank piece 200 plastically flows over the step part 230. Therefore, the resistance to the plastic flow of the blank piece 200 is relatively small. As a result, relatively large load is not required upon forging, and the amount of spring back is relatively small after forging. Besides, when the blank piece 200, the quantity of which is larger than a predetermined normal quantity, is forged with the pair of dies 224, increase in the resistance to the plastic flow of the blank piece 200 is relatively small. Accordingly, the variation in the dimensions of the forged shoes 76 by the variation in the quantities of the blank pieces 200 becomes relatively small due to the shape of the shoe 76.

[0040] For comparison, a comparative shoe that has a side surface connecting a spherical engaging surface to a plane engaging surface, and forging the comparative shoe will be described. A cross-sectional view of a comparative shoe 250 is shown in FIG. 9. The comparative shoe 250 includes a spherical engaging surface 252 for engaging with a piston, a plane engaging surface 254 for engaging with a swash plate and a peripheral surface 256 on its outer surface. The peripheral surface 256 connects the spherical engaging surface 252 to the plane engaging surface 254. The peripheral surface 256

includes a chamfered surface 260 and a rounded surface 264. The chamfered surface 260 is inclined with respect to a plane sliding surface 258 of the plane engaging surface 254 at an angle of 45° . The rounded surface 264 connects the chamfered surface 260 to a spherical sliding surface 262 of the spherical engaging surface 252. Similarly to the shoe 76 in the present embodiment, the chamfered surface 260 is adjacent to the plane sliding surface 258 through a small rounded corner, and the rounded surface 264 corresponds to a part for absorbing variation in quantities of blank pieces upon forging. Furthermore, the plane engaging surface 254 and the spherical engaging surface 252 respectively include a first shoe recess 266 and a second shoe recess 268.

[0041] A forging process for forging the comparative shoe 250 is schematically shown in FIG. 10. With respect to a pair of dies, the same reference numerals denote the same identical elements as those in FIG. 7. Upon forging the comparative shoe 250, the same pair of dies 224 is utilized, and the same forging process is performed as the shoe 76 of the present embodiment. What is different with respect to the pair of dies 224 is that a drag 222 includes a surface that can mold the chamfered surface 260 of the peripheral surface 256. Similarly, the cavity in the pair of dies 224 is formed such that a surplus space 228 that is not filled with the blank piece 200 in the periphery of the cavity is left for absorbing the variation in the quantities of the blank pieces 200.

[0042] Plastic flow of a part of the blank corresponding to the periphery of the shoe 250 is shown in FIG. 11. Upon forging the comparative shoe 250, the blank piece 200 similarly spreads toward the outer periphery of the cavity. What is different from forging the shoe 76 in the present embodiment is that the drag 222 includes a molding surface 270, toward which the side surface of the blank piece 200 moves. After the side surface of the blank piece 200 contacts the molding surface 270 at a point of A in FIG. 11, the molding surface 270 causes relatively large resistance to the plastic flow of the blank piece 200. More particularly, a force for pressing the blank piece 200 toward a corner part B in FIG. 11, and a force for moving the blank piece 200 toward the surplus space 228 along the molding surface 270 while pressing the blank piece 200 against the molding surface 270, that is, a force indicated by an arrow a and a force indicated by an arrow b, are required. Therefore, a relatively large load has to be applied to the blank piece 200. When the blank piece 200, the quantity of which is larger than a predetermined normal quantity, is forged with the pair of dies 224, a much larger load is required for forging. Since the blank piece 200 receives a much larger load, the amount of spring back becomes large after forging. As a result, in the comparative shoe 250, the resistance to the plastic flow of the blank 200 is generated due to the shape of the comparative shoe 250, and the comparative shoe 250 may vary in shape when the quantities of the blank pieces 200 vary. Since

a relatively large load is applied upon forging, the pair of dies 224 receives a relatively large load. When a shoe is forged from a blank piece made of material having relatively high strength such as high carbon chromium bearing steel, the strength of the pair of dies 224 has to be enhanced. Thereby, cost for manufacturing a shoe increases

[0043] With respect to reactive force that the pair of dies 224 receives upon forging, the case of forging the shoe 76 in the present embodiment is compared with that of forging the comparative shoe 250. When the reactive force is large, the load upon forging has to be relatively large, and the blank piece 200 receives a relatively large load. The comparison is analyzed by CAE (computer-aided experiment). For the analysis, blank pieces are aluminum alloy, and a normal quantity of the blank piece is estimated to be 3g. Cases of forging from blank pieces having the normal quantity and a quantity of 3.04g, which is heavier than the normal quantity by 0.04g, are evaluated. In FIG. 12, the change of the reactive force with respect to the molding time upon forging the shoe in the embodiment and the comparative shoe is shown. In FIG. 13, the change of the maximal reactive force with respect to the change of the quantities of the blank pieces upon forging the shoe of embodiment and the comparative shoe is shown.

[0044] According to FIG. 12, reactive forces gradually increase after the forging starts in both shoes. As the blanks approach a part corresponding to the periphery of the shoe, gradients of the reactive forces become large. Each reactive force becomes its maximum just before the forging has finished. In the case of forging from the blank piece having the normal quantity, when the shoe in the present embodiment is compared with the comparative shoe, the reactive force for the comparative shoe is larger than that for the shoe in the present embodiment as mentioned above. The maximum reactive force for the shoe in the present embodiment is about 9t while the maximum reactive force for the comparative shoe is about 15t. In the case of forging from the blank piece having the quantity of 3.04g, the reactive force increase upon forging both the shoe in the present embodiment and the comparative shoe. The maximum reactive force for the shoe in the present embodiment is about 12t and increases by 3t. The degree of the increase is relatively small. On the other hand, the maximum reactive force for the comparative shoe is about 26t and increases by 11t. The degree of the increase is relatively large. FIG. 13 indicates that the degree of the increase for the shoe in the present embodiment is smaller than that for the comparative shoe when the quantity of the blank increases. As a result, the required load upon forging is smaller in the shoe in the present embodiment than in the comparative shoe. Even when the quantities of the blank pieces vary, since the difference between the reactive forces that the blank pieces receive is relatively small, the shoe in the present embodiment is accurately forged. Roughly speaking, the

shoe in the present embodiment includes a periphery surface that is offset with respect to the middle part of a plane engaging surface, so as to form a step on its part corresponding to a periphery of a plane engaging surface in a common shoe. It is desired that the periphery of the plane engaging surface includes lubricant oil between a plane sliding surface and a sliding surface of a swash plate and inhibits relatively large foreign substances from being allowed between the sliding surfaces. Therefore, the above mentioned connecting surface, which is located in the step corresponding to the periphery of the plane engaging surface, is important. Although the shape of the connecting surface is not limited, the connecting surface can include lubricant oil and exclude foreign substances due to its above mentioned structure. In a shoe shown in Japan Unexamined Patent Publication No. 2002-332959, a side surface formed as a chamfered surface can include lubricant oil and exclude foreign substances. However, relatively large resistance can be generated upon forging due to the side surface. On the other hand, since the shoe in the present embodiment does not have such a side surface that can be cause of relatively large resistance upon forging, the shoe in the present embodiment is accurately forged. Therefore, relatively high sliding performance is ensured and dimensional accuracy is obtained. When a shoe is forged with relatively low dimensional accuracy, for example, it takes relatively long time to adjust the dimension of the shoe by grinding after forging, and cost for manufacturing a shoe increases. In this point, the shoe in the present embodiment is manufactured at a relatively low cost.

[0045] Dimensional accuracy will be described in detail. In the forging process, the blank piece is set in the pair of dies, and the blank piece plastically flows toward the periphery of the cavity. As mentioned above, when resistance to the plastic flow of the blank piece is relatively large upon forging, the load is required to be relatively large upon forging. Therefore, the reactive force becomes relatively large from the blank piece to the pair of dies. When a relatively large force is applied to the blank piece and the pair of dies, elastic deformation is generated in the blank piece and the pair of dies. For example, when relatively large elastic deformation is generated in the pair of dies, the shape of the cavity changes. When relatively large elastic deformation is generated in the blank piece, the amount of spring back becomes relatively large after forging. It is assumed that variation in quantities of blank pieces is permitted to some extent and resistance to the plastic flow of the blank piece is generated upon forging. In this case, even though a space for absorbing variation in quantities of blank pieces is unfilled, variation in dimension becomes relatively large due to the variation in the quantities of the blank pieces. In the shoe in the present embodiment, since the blank piece plastically flows over the above mentioned step upon forging, a relatively large resistance is not generated. Therefore, the shoe can be

forged with a relatively small load. As a result, dimensional accuracy in the height of the shoe is obtained. In short, the periphery of the shoe between the peripheral surface and the spherical engaging surface can function as a part for effectively absorbing variation in quantities of blank pieces. In conclusion, sliding performance is compatible with relatively high dimensional accuracy in the shoe in the present embodiment due to the shape of the shoe. Incidentally, when dimensional accuracy in the height of a shoe is relatively low, for example, a distance between a plane engaging surface and a spherical engaging surface is too large, foreign substances are easily allowed between the sliding surfaces. On the other hand, when a distance between a plane engaging surface and a spherical engaging surface is too small, friction between the sliding surfaces becomes relatively large. Therefore, sliding performance deteriorates in both cases.

[0046] As mentioned above, the blank piece plastically flows easily upon forging due to the shape of the shoe in the present invention. Therefore, the present invention is effective to a shoe manufactured through forging. The cylindrical blank piece is utilized in the above mentioned forging process. Although the cylindrical blank piece is made by cutting a cylindrical rod at a relatively low cost, quantities of the cylindrical blanks vary. Especially, when the cylindrical blank piece is made by means of a shear, although the cost is cheaper, quantities of the cylindrical blank pieces vary in a wide range. However, since the shoe in the present invention is accurately forged even though quantities of the blank pieces vary, the present invention is effective to a shoe forged from the cylindrical blank piece. When the relatively cheap cylindrical blank piece is utilized, a relatively cheap shoe can be obtained. Also, a spherical blank piece can be utilized. In this case, similarly to manufacturing bearing ball, the spherical blank piece is made through processes such as flushing and grinding, and quantities of the spherical blank pieces vary in a narrow range. The shape of the blank is not limited to cylinder and sphere, and blanks having various shapes can be utilized. Regardless of the shape of the blank piece, since the required load is relatively small upon forging the shoe in the present invention and the degree of the increase in the reactive force in accordance with the increase in the quantity of the blank piece is relatively small, the shoe of the present invention is accurately forged.

[0047] The above mentioned forging process includes one process. However, a multi-process, which includes a plurality of sub-forging processes, may be employed. For example, a precursor of the shoe 76, which does not have a part corresponding to the periphery of the shoe 76, can be forged first, and then the part corresponding to the periphery of the shoe 76 can be forged. In this case, the first forging corresponds to the forging process in the manufacturing process in the present invention, and the precursor of the shoe 76 cor-

responds to the blank piece. Also, another precursor having substantially a final shape of the shoe 76 is forged first, and then a finishing process can be conducted for adjusting dimension of the precursor. In this case, the forging corresponds to the forging process in the manufacturing process of the present invention. When a multi-forging process is conducted, annealing can be conducted after any processes.

[0048] The shoe 76 formed in the forging process is preferably treated by thermal refining including T6 treatment and T7 treatment (JIS H0001) in the thermal refining process. The shoe 76 treated by thermal refining is ground and polished for grinding its surface in the grinding and polishing process. The grinding and polishing process includes a surface grinding process and a barrel polishing process. The plane sliding surface 154 of the shoe 76 is ground in the surface grinding process. Several pieces of shoes 76 are aligned, and then ground by a surface grinding apparatus by means of free abrasive grains. The plane sliding surface 154 can form the convex surface in the surface grinding process. The entire surface of the shoe 76 is polished in the barrel polishing process. The shoe 76 together with free abrasive grains is put in a barrel polishing apparatus, and then started. Either of the surface grinding process and the barrel polishing process can be conducted first. Then, a plating process is preferably conducted. For example, the surface of the shoe 76 can be coated with electroless nickel plating layer in the plating process. Finally, the finishing process is conducted. The shoe 76 is ground by barrel polishing in the finishing process. When necessary, the shoe 76 is treated by surface grinding. The shoe 76 can be polished by buffing. The above mentioned shoe 76 is completed through the above mentioned processes. Manufacturing processes are not limited to the above mentioned processes. The shoe in the present invention may be manufactured by various kinds of processes in accordance with specifications of target shoes.

[0049] The manufacturing processes for the shoe made of aluminum alloy is described above. In a case of manufacturing processes for a shoe made of metal alloy, such as high carbon chromium bearing steel, for example, after the above mentioned forging process, a thermal refining process including quenching is conducted when necessary, and the shoe is completed through a grinding and polishing process, a nitriding process and a finishing process. The shoe may be distorted by heat in the thermal refining process. In this case, dimension of the shoe can be determined in the forging process by foreseeing the deformation. Since the shoe in the present invention is accurately forged, the above mentioned manufacturing processes can be conducted. Namely, since the shoe in the present invention is accurately forged, that facilitates adjusting dimension of the shoe after forging. Therefore, cost for manufacturing a shoe reduces.

[0050] Therefore, the present examples and embod-

iments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein but may be modified within the scope of the appended claims.

Claims

1. A shoe in a swash plate type compressor including a swash plate and a piston, the shoe being interposed between the swash plate and the piston, the shoe comprising:

a spherical engaging surface for engaging with the piston; and
a plane engaging surface being substantially a plane, the plane engaging surface engaging with the swash plate, the plane engaging surface comprising:

a substantially planar sliding surface formed near a center of the plane engaging surface, the sliding surface sliding over a surface of the swash plate;
a substantially radially extending peripheral surface formed near a periphery of the plane engaging surface, the peripheral surface being formed at a distance from the extended sliding surface away from the surface of the swash plate so as to form an inwardly-directed step in the plane engaging surface, the peripheral surface being connected to the spherical engaging surface at its outer periphery; and
a connecting surface connecting the sliding surface to the peripheral surface.

2. The shoe according to claim 1, wherein a distance between the peripheral surface and the extended sliding surface of the shoe ranges from 0.02 mm to 0.5 mm.
3. The shoe according to claim 2, wherein the distance between the peripheral surface and the extended sliding surface is 0.05 mm or above.
4. The shoe according to claim 3, wherein the distance between the peripheral surface and the extended sliding surface is 0.1 mm or above.
5. The shoe according to claim 4, wherein the distance between the peripheral surface and the extended sliding surface is 0.15 mm or above.
6. The shoe according to claim 2, wherein the distance between the peripheral surface and the extended sliding surface is 0.3 mm or below.

7. The shoe according to claim 6, wherein the distance between the peripheral surface and the extended sliding surface is 0.25 mm or below.
8. The shoe according to claim 1, wherein the peripheral surface is substantially parallel to the sliding surface. 5
9. The shoe according to claim 1, wherein the peripheral surface is inclined with respect to the sliding surface, an angle between the peripheral surface and the extended sliding surface is 10° or below. 10
10. The shoe according to claim 1, wherein the connecting surface further comprises: 15
 - a chamfered surface forming a side surface of a truncated cone; a diameter of the chamfered surface near the peripheral surface being larger than that of the chamfered surface near the sliding surface; and 20
 - a rounded corner connecting the chamfered surface to the sliding surface.
11. The shoe according to claim 10, wherein the connecting surface further comprising another rounded corner that connects the chamfered surface to the peripheral surface. 25
12. The shoe according to claim 1, wherein the spherical engaging surface further comprises a spherical sliding surface that is substantially a part of sphere surface and slides over a surface of the piston, and a peripheral rounded surface that connects the spherical sliding surface to the peripheral surface. 30 35
13. The shoe according to claim 1 further comprising a base member made of metal.
14. The shoe according to claim 13, wherein the metal is aluminum series alloy. 40
15. The shoe according to claim 14, wherein the surface of the base member is coated with metal plating layer. 45
16. The shoe according to claim 13, wherein the metal is iron series alloy.
17. The shoe according to claim 16, wherein the iron series alloy includes high carbon chromium bearing steel. 50
18. The shoe according to claim 13, wherein the metal includes magnesium. 55
19. The shoe according to claim 1 further comprising a base member made of resin.
20. A swash plate type compressor comprising:
 - a housing;
 - a drive shaft rotatably supported by the housing;
 - a swash plate operatively connected to the drive shaft;
 - a piston accommodated in the housing, the piston being operatively connected to the swash plate; and
 - a pair of shoes interposed between the swash plate and the piston, each of the shoes including:
 - a spherical engaging surface for engaging with the piston; and
 - a plane engaging surface being a substantially plane, the plane engaging surface engaging with the swash plate, the plane engaging surface comprising:
 - a substantially planar sliding surface formed near a center of the plane engaging surface, the sliding surface sliding over a surface of the swash plate;
 - a substantially radially extending peripheral surface formed near a periphery of the plane engaging surface, the peripheral surface being formed at a distance from the extended sliding surface away from the surface of the swash plate so as to form an inwardly-directed step in the plane engaging surface, the peripheral surface being connected to the spherical engaging surface at its outer periphery; and
 - a connecting surface connecting the sliding surface to the peripheral surface.
21. The swash plate type compressor according to claim 20, wherein the connecting surface further comprises:
 - a chamfered surface forming a side surface of a truncated cone, a diameter of the chamfered surface near the peripheral surface being larger than that of the chamfered surface near the sliding surface; and
 - a rounded corner connecting the chamfered surface to the sliding surface.
22. A method of forming a shoe that is interposed between a swash plate and a piston in a swash plate type compressor, the shoe including a spherical engaging surface and a plane engaging surface that is substantially a plane, the plane engaging surface

having a substantially planar sliding surface that is formed near a center of the plane engaging surface and has a predetermined outer diameter, a substantially radially extending peripheral surface that is formed near a periphery of the plane engaging surface and is formed at a distance from the extended sliding surface so as to form an inwardly-directed step in the plane engaging surface, and a connecting surface that connects the sliding surface to the peripheral surface, the method comprising the steps of:

preparing a blank piece having a predetermined outer diameter that is smaller than that of the planar sliding surface;
 preparing a pair of dies including a first die for molding the spherical engaging surface and a second die for molding the plane engaging surface;
 setting the blank piece in the pair of the dies;
 and
 closing the pair of the dies for forging the shoe.

23. The method according to claim 22, wherein the first preparing step further includes preparing the blank piece from a blank by forging.

24. The method according to claim 22, wherein the first preparing step further includes preparing the blank piece with a cylindrical shape.

25. The method according to claim 22, wherein the first preparing step further includes preparing the blank piece with a spherical shape.

26. A shoe manufactured by a method according to claim 22.

27. A shoe in a swash plate type compressor including a swash plate and a piston, the shoe being interposed between the swash plate and the piston, the shoe comprising:

a spherical engaging surface for engaging with the piston; and
 a plane engaging surface being substantially a plane, the plane engaging surface engaging with the swash plate, the plane engaging surface comprising:

a substantially planar sliding surface formed near a center of the plane engaging surface, the sliding surface sliding over a surface of the swash plate;
 a peripheral surface formed near a periphery of the plane engaging surface, the peripheral surface being formed at a distance from the extended sliding surface away

from the surface of the swash plate so as to form an inwardly-directed step in the plane engaging surface, the peripheral surface being substantially parallel with the sliding surface such that the peripheral surface is oriented at an angle, with respect to the extended sliding surface of the shoe, of from about 0 degree to about 10 degrees; and
 a connecting surface connecting the sliding surface to the peripheral surface.

28. A set of dies for molding a shoe that is interposed between a swash plate and a piston in a swash plate type compressor, the shoe including a spherical engaging surface for engaging with the piston and a plane engaging surface for engaging with the swash plate, the plane engaging surface having a substantially planar sliding surface that is formed near a center of the plane engaging surface, a substantially radially extending peripheral surface that is formed near a periphery of the plane engaging surface and is formed at a distance from the extended sliding surface so as to form an inwardly-directed step in the plane engaging surface and a connecting surface that connects the sliding surface to the peripheral surface, the set of dies comprising:

a first die having a spherical molding surface for molding the spherical engaging surface; and
 a second die having a plane molding surface for molding the plane engaging surface, the plane molding surface including:

a first molding surface formed near a center of the plane molding surface for molding the sliding surface;
 a second molding surface formed near a periphery of the plane molding surface for molding the peripheral surface; and
 a third molding surface connecting the first molding surface to the second molding surface for molding the connecting surface.

1. **Ge**

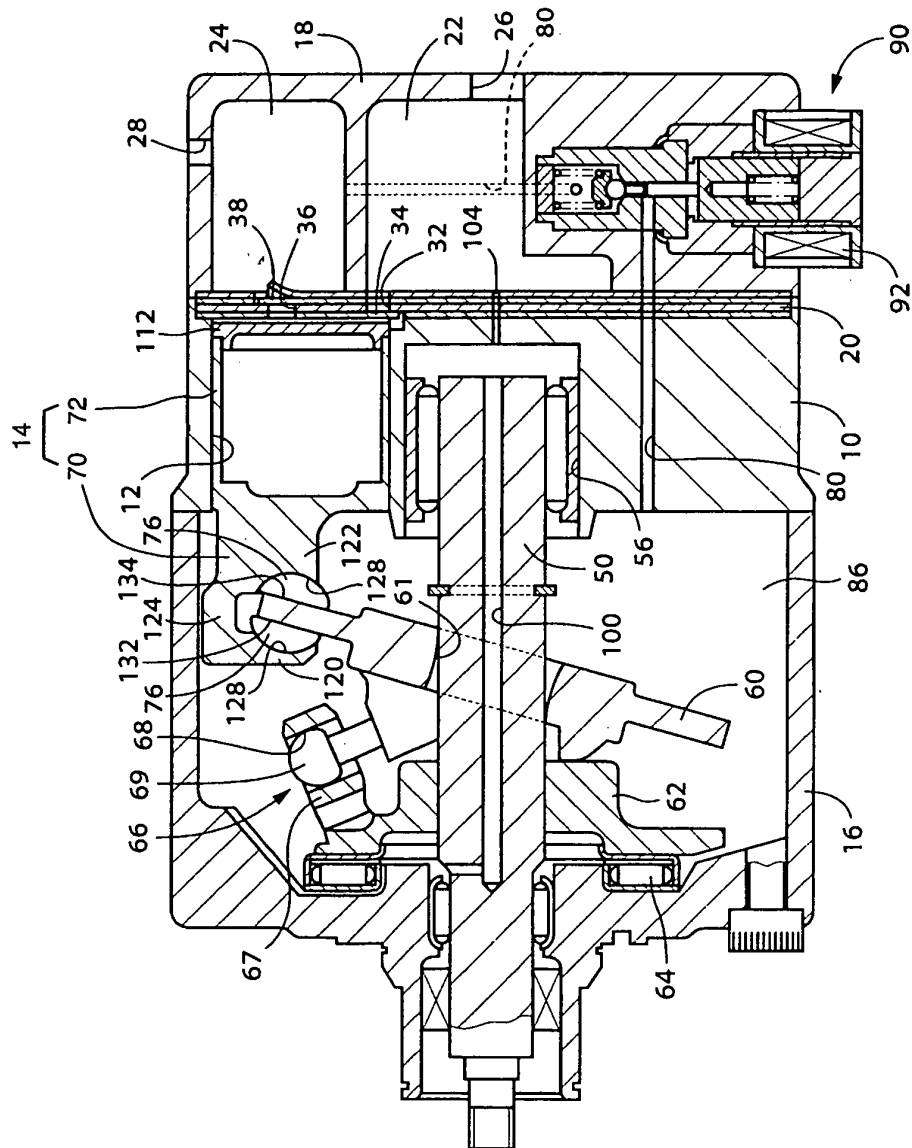


FIG. 2

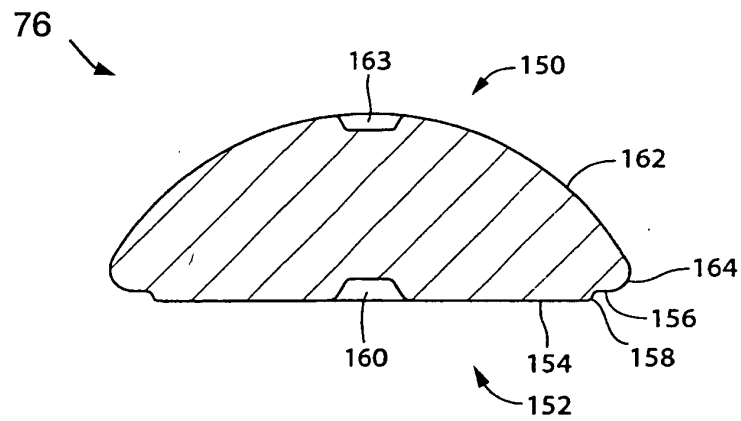


FIG. 3

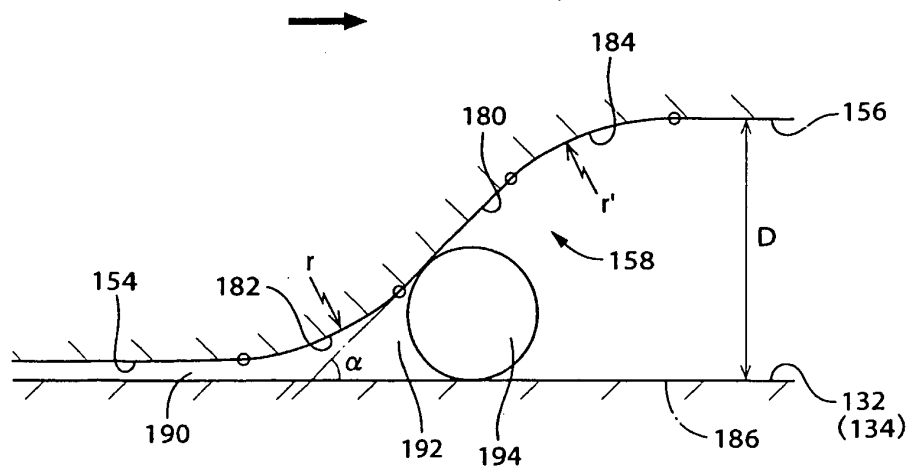


FIG. 4

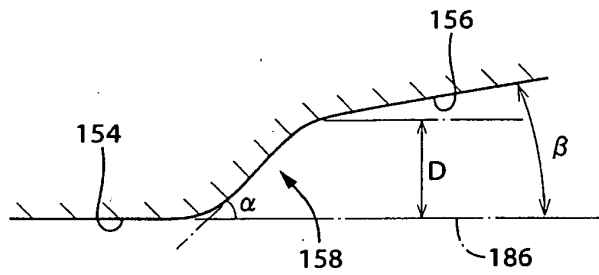


FIG. 5

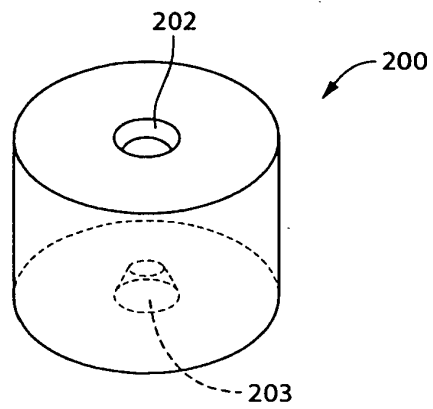


FIG. 6

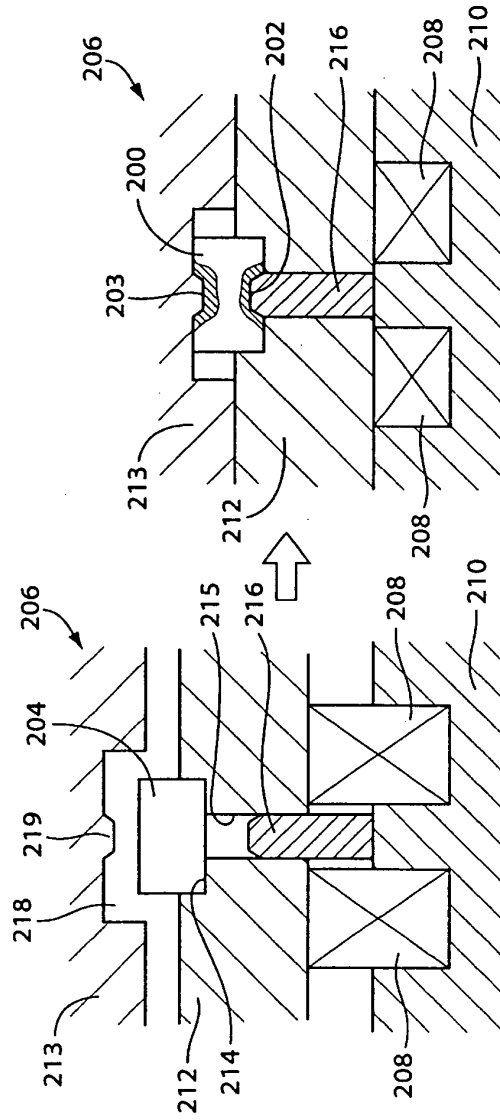


FIG. 7

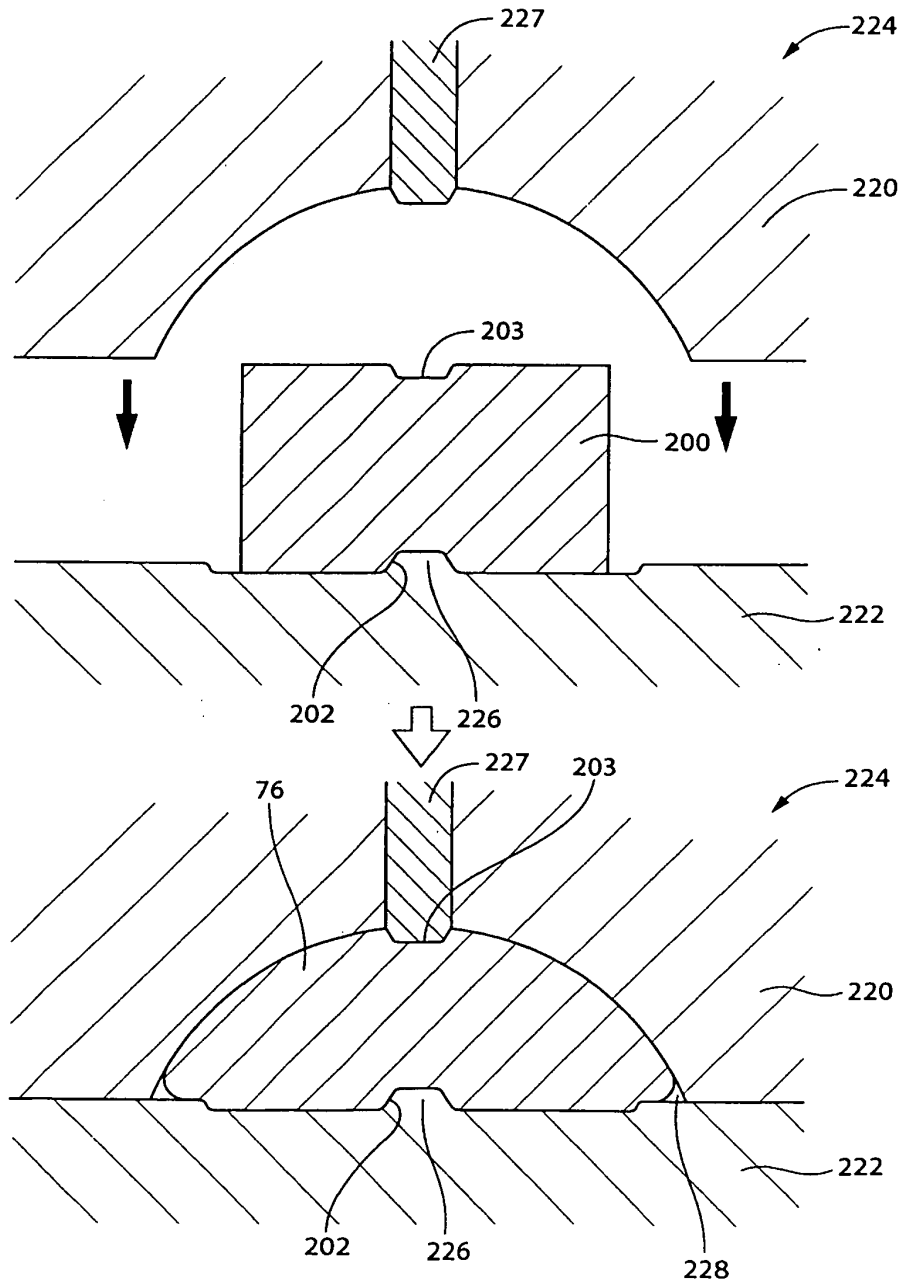


FIG. 8

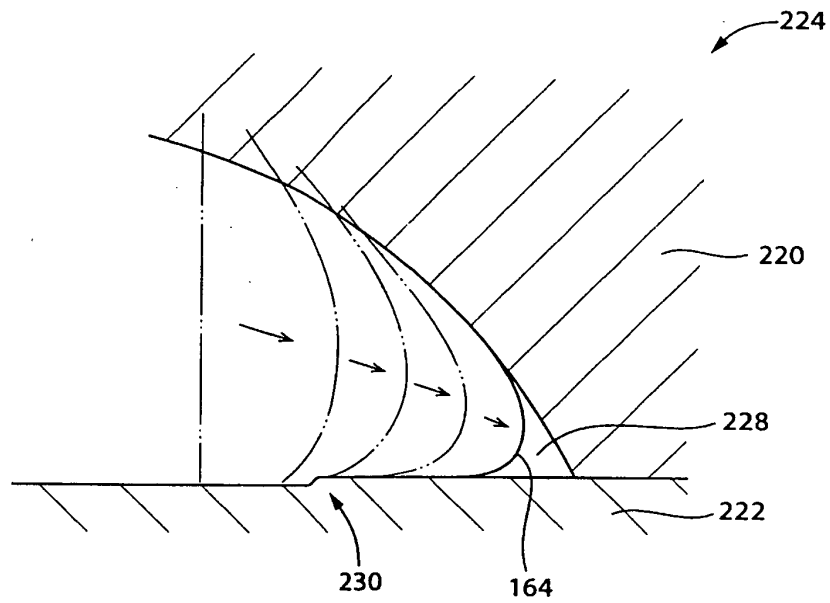


FIG. 9 (PRIOR ART)

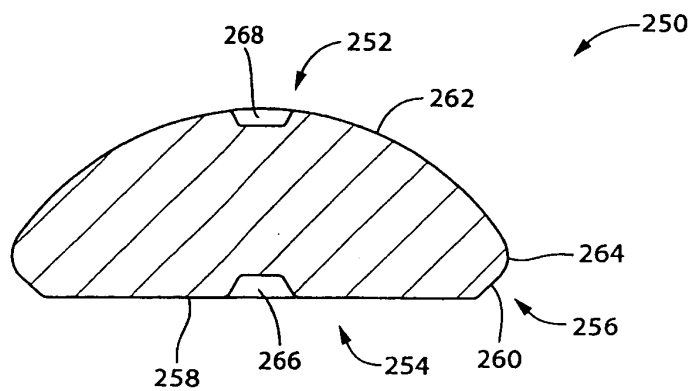


FIG. 10 (PRIOR ART)

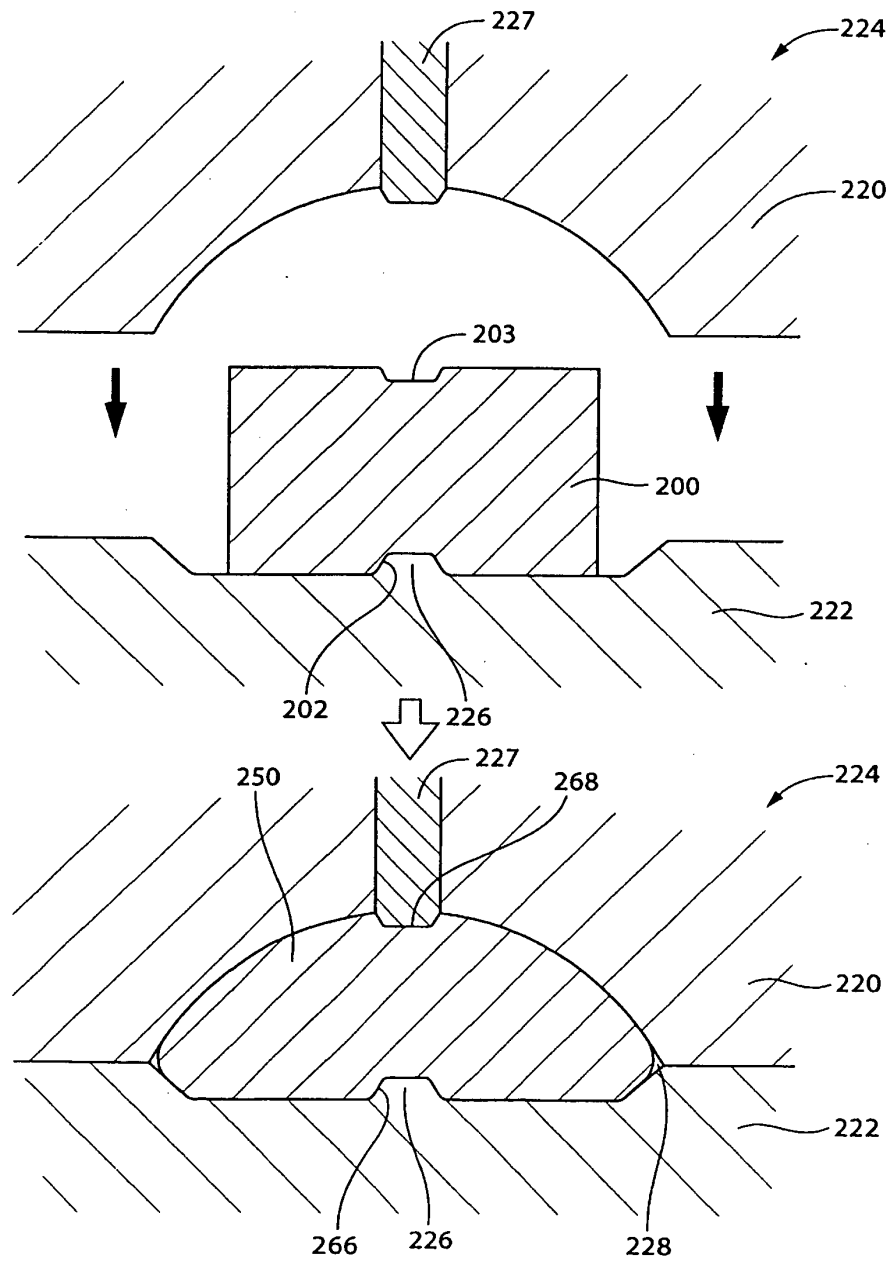


FIG. 11 (PRIOR ART)

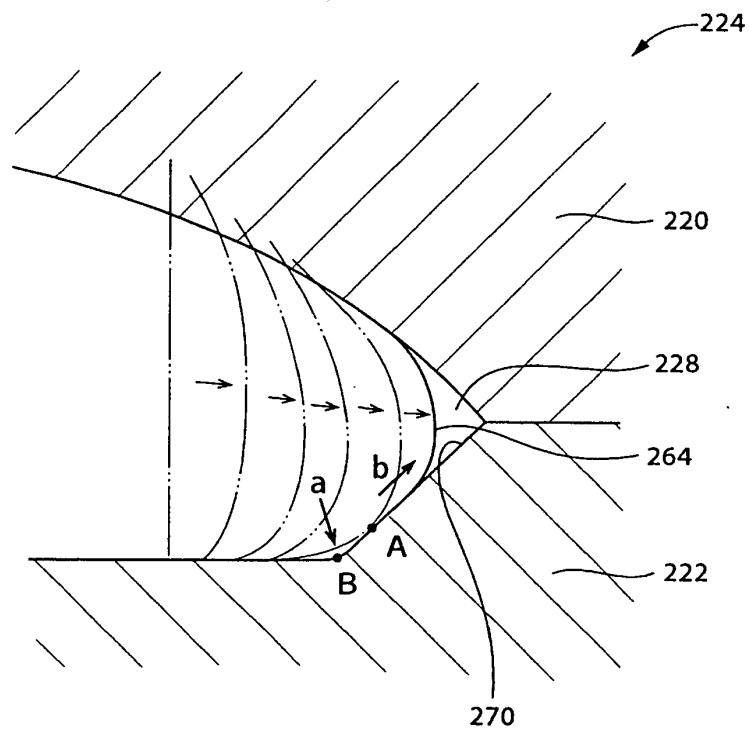


FIG. 12

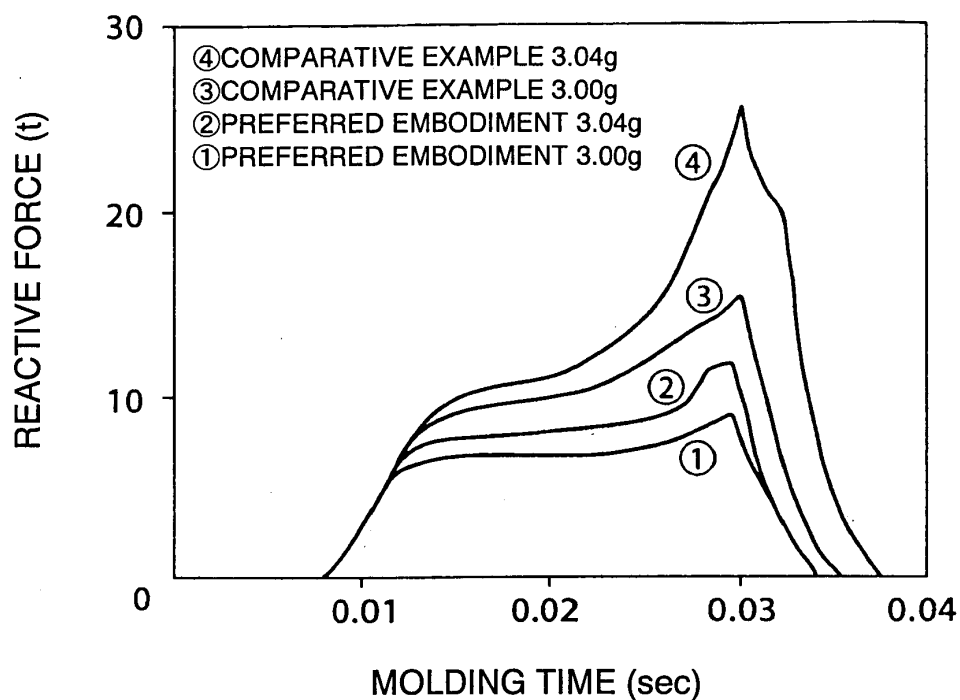


FIG. 13

