

Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a bent axis type hydraulic rotating machine, for example, used as a hydraulic pump or a hydraulic motor in a construction machine or the other general machine.

BACKGROUND ART

10 **[0002]** In general, a fixed displacement type or variable displacement type bent axis type hydraulic rotating machine is known as a hydraulic rotating machine used as a hydraulic pump or a hydraulic motor in the filed of construction machines or general machines.

15 **[0003]** The bent axis type hydraulic rotating machine according to this type of conventional art is constituted by including a casing, a rotational shaft rotatably provided in the casing, a cylinder block which is rotatably provided in the casing to rotate together with the rotational shaft and in which a plurality of cylinder holes are formed in such a manner as to be spaced in the circumferential direction and axially extend, and a plurality of pistons each of which has one end in an axial direction supported on the rotational shaft and the other end slidably inserted into each of the cylinder holes of the cylinder block for reciprocating in the respective cylinder holes with rotation of the cylinder block.

20 **[0004]** On the other hand, the bent axis type hydraulic rotating machine is provided with a center hole formed along a rotational shaft center of the cylinder block, a center shaft fitted into the center hole of the cylinder block to center the cylinder block, a valve plate which is provided between the casing and the cylinder block to be positioned in the other side in the axial direction and in which supply and discharge ports (low-pressure port and high-pressure port) communicated with each of the cylinder holes are formed, and a spring provided between the center shaft and the cylinder block to urge the cylinder block toward the valve plate.

25 **[0005]** Meanwhile, a drive disc is provided integrally with the rotational shaft positioned in the casing at a base end-side end portion thereof, and a protrusion-side end portion of each piston protruding from the cylinder block and a protrusion-side end portion of the center shaft are pivotably coupled to the drive disc (Patent Document 1).

30 **[0006]** In a case where this type of bent axis hydraulic rotating machine is used, for example, as a hydraulic motor, when pressurized oil is sequentially supplied into respective cylinder holes through a high-pressure port from an outside, the protrusion-side end portions of the respective pistons are sequentially pushed toward the drive disc. In consequence, a rotational force around the rotational shaft in the drive disc is generated and the rotational force is taken out as motor output.

PRIOR ART DOCUMENT

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PATENT DOCUMENT

[0007]

40 Patent Document 1: Japanese Patent Laid-Open No. 2008-101581 A

SUMMARY OF THE INVENTION

45 **[0008]** Incidentally, in the aforementioned conventional art, a base material of the cylinder block is formed with a cast metal, a steel material or the like and, for example, a nitriding layer formed by executing nitride-based heat treatment is provided on a surface side of the base material. The nitriding layer is constituted by, for example, a diffusion layer and a compound layer.

50 **[0009]** However, wear tracks are generated on a contact location between the cylinder block and the piston due to contact of an inlet peripheral edge (opening peripheral edge) of each cylinder hole with the piston while the piston reciprocates. When such wear is developed, there are some cases where the compound layer is separated from the nitriding layer composed of the diffusion layer and the compound layer as described above. As a result, there occurs a problem that galling, burn-in or the like is possibly generated at the contact location between the cylinder block and the piston.

55 **[0010]** In view of the above-discussed problems with the conventional art, it is an object of the present invention to provide a bent axis type hydraulic rotating machine which can suppress wear at a contact location between each cylinder hole of a cylinder block and a piston to prevent generation of galling, burn-in or the like at the contact location.

[0011] (1) In order to overcome the aforementioned problem, the present invention is applied to a bent axis type hydraulic rotating machine comprising: a tubular casing; a rotational shaft rotatably provided in the casing; a cylinder

block which is provided in the casing to rotate together with the rotational shaft and provided with a plurality of cylinder holes to be spaced in the circumferential direction and axially extend; and a plurality of tapered pistons each of which has one end in an axial direction pivotably supported on the rotational shaft and the other end reciprocally inserted into each of the cylinder holes of the cylinder block.

[0012] Further, a characteristic feature of the construction adopted in the present invention lies in that a nitriding layer formed by executing nitride-based treatment together with the cylinder hole is formed in the cylinder block, and a chemical conversion film composed of a manganese phosphate film is formed on a surface side of the nitriding layer.

[0013] With this arrangement, the chemical conversion film composed of the manganese phosphate film is formed on the peripheral wall (surface) side of the cylinder hole as to cover the nitriding layer. The chemical conversion film promptly fits in the configuration of the tapered piston sliding and displacing in the cylinder hole. Therefore, a surface pressure on the contact location between the cylinder hole and the piston can be reduced to achieve a reduction in wear thereof. On the other hand, when the chemical conversion film of the manganese phosphate is formed as having a film thickness equal to or more than the wear amount, it can be prevented for the wear to reach the vicinity of a boundary surface between the compound layer and the diffusion layer in the nitriding layer to prevent the nitriding layer formed in the cylinder block from being damaged due to wear. Further, since the chemical conversion film can be formed in a state where the surface area increases by forming the nitriding layer and executing the chemical treatment by manganese phosphate on the surface thereof, the chemical conversion film is easier to adhere thereto.

[0014] Further, when the chemical conversion film of the manganese phosphate promptly fits in the configuration of the piston sliding and displacing in the cylinder hole, occurrence of a bias in a contact region between the opening peripheral edge of the cylinder hole and the tapered piston can be suppressed. This can suppress spreading of the contact region between the opening peripheral edge of the cylinder hole and the tapered piston, and can suppress an increase in heat value caused by enlargement of the contact region. Therefore, risks such as galling, burn-in or the like between the opening peripheral edge of the cylinder hole and the tapered piston can be reduced, enhancing reliability as the bent axis type hydraulic rotating machine.

[0015] (2) According to the present invention, the nitriding layer formed in the cylinder block is constituted by a diffusion layer formed on a surface side of a base material and a compound layer formed on a surface side of the diffusion layer, and the chemical conversion film composed of the manganese phosphate film is formed on a surface side of the compound layer. Therefore, the chemical conversion film of the manganese phosphate promptly fits in the configuration of the tapered piston sliding and displacing in the cylinder hole, and a reduction in wear of the contact section between the cylinder hole and the piston can be achieved.

[0016] (3) According to the present invention, the nitriding layer formed in the cylinder block is constituted by a diffusion layer formed on a surface side of a base material and a compound layer formed on a surface side of the diffusion layer, and the chemical conversion film composed of the manganese phosphate film is formed in the cylinder hole of the cylinder block in a state of removing the compound layer in the nitriding layer by abrasive means.

[0017] With this arrangement, when the compound layer positioned on the surface side in the nitriding layer is removed by abrasive means, in a case where the cylinder block rotates repeatedly in the forward direction and in the backward direction, even if an impact load is generated in the contact section between the opening peripheral edge of the cylinder hole and the tapered piston, separation of the compound layer following generation of the impact load can be eliminated to reduce generation of galling, burn-in and the like. In addition, the chemical conversion film of the manganese phosphate can be stably ensured and left in the opening peripheral edge of the cylinder hole. Further, the chemical conversion film equal to or more than the wear amount of the opening peripheral edge is formed after removing the compound layer by the abrasive means, and thereby damages of the nitriding layer formed in the cylinder block due to the wear can be suppressed. Therefore, the deteriorating of the roughness of the sliding surface at the opening peripheral edge of the cylinder hole can be suppressed to keep sliding characteristics of the tapered piston to be proper.

[0018] (4) According to the present invention, the tapered piston is provided with a nitriding layer formed by executing nitride-based treatment thereon and an oxidized film formed on a surface side of the nitriding layer.

[0019] With this arrangement, since the oxidized film in addition to the nitriding layer is formed on the surface side of the tapered piston, the tapered piston subjected to surface treatment having more appropriate resistance to galling by the oxidized film can be manufactured, and the wear to the cylinder block at the opening peripheral edge of each cylinder hole can be effectively reduced. Therefore, damages of the nitriding layer formed in the cylinder block due to the wear can be suppressed. Further even under a condition that the surface pressure in the contact section between the opening peripheral edge of the cylinder hole and the tapered piston becomes excessive, or the oil film out or the like is generated therein, generation of the galling, the burn-in or the like can be prevented by forming a layer of the oxidized film on the outermost surface side of the surface of the tapered piston.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Fig. 1 is a longitudinal sectional view showing a bent axis type hydraulic motor according to a first embodiment of the present invention.

Fig. 2 is an enlarged sectional view showing a cylinder block in Fig. 1 as a single unit.

Fig. 3 is a partial cutaway front view shown by enlarging a tapered piston in Fig. 1 as a single unit.

Fig. 4 is a sectional view shown by enlarging a state where a plurality of pistons are inserted into respective cylinder holes of the cylinder block in the direction of arrows IV - IV in Fig. 1.

Fig. 5 is a partial enlarged view of the cylinder block shown by enlarging a wear configuration of an opening peripheral edge formed in the cylinder hole in Fig. 4.

Fig. 6 is a partial enlarged view of a cylinder block shown by enlarging a wear configuration of an opening peripheral edge formed in a cylinder hole as a comparative example.

Fig. 7 is a flow chart showing each step of surface treatment to the cylinder block.

Fig. 8 is a flow chart showing each step of surface treatment to the tapered piston.

Fig. 9 is an enlarged sectional view showing a surface treatment layer including a chemical conversion film formed on a peripheral wall surface of the cylinder hole, and the like in an arrow IX section in Fig. 2.

Fig. 10 is an enlarged sectional view showing the peripheral wall surface of the cylinder hole and the like in a state before forming the surface treatment layer, in a position similar to Fig. 9.

Fig. 11 is an enlarged sectional view showing a state of forming a nitriding layer on the peripheral wall surface of the cylinder hole in a position similar to Fig. 9.

Fig. 12 is an enlarged sectional view showing a surface treatment layer including an oxidized film formed on an outer peripheral surface side of the tapered piston, and the like in an arrow XII section in Fig. 3.

Fig. 13 is an enlarged sectional view showing an outer peripheral wall surface of the tapered piston and the like in a state before forming the surface treatment layer in a position similar to Fig. 12.

Fig. 14 is an enlarged sectional view showing a state of forming a nitriding layer on the outer peripheral surface side of the tapered piston in a position similar to Fig. 12.

Fig. 15 is a characteristics line diagram showing a change in surface roughness in an opening peripheral edge of the cylinder hole in relation to a test time.

Fig. 16 is a characteristics line diagram showing a wear amount in the opening peripheral edge of the cylinder hole in relation to a test time.

Fig. 17 is a flow chart showing a surface treatment process of the cylinder block according to a second embodiment.

Fig. 18 is an enlarged sectional view showing a state of forming the nitriding layer on the peripheral wall surface of the cylinder hole in a position similar to Fig. 9.

Fig. 19 is an enlarged sectional view showing a state of removing the compound layer from the nitriding layer in Fig. 18.

Fig. 20 is an enlarged sectional view showing a state of forming a chemical conversion film on the nitriding layer from which the compound layer is removed in a position similar to Fig. 18.

MODE FOR CARRYING OUT THE INVENTION

[0021] Hereinafter, a bent axis type hydraulic rotating machine according to an embodiment of the present invention will be in detail explained with reference to the following drawings, by taking a case of being applied to a hydraulic motor of a fixed displacement type bent axis type as an example.

[0022] Fig. 1 to Fig. 16 show a bent axis type hydraulic rotating machine according to a first embodiment in the present invention.

[0023] In the figure, denoted at 1 is a casing of a hydraulic motor representative of bent axis type hydraulic rotating machines. The casing 1 is constituted by a tubular casing body 2, an intermediate section of which is bent in the longitudinal direction, and a head casing 3 to be described later.

[0024] The casing body 2 is constituted by one side tubular portion 2A positioned in one side in an axial direction and the other side tubular portion 2B positioned in the other side in the axial direction, wherein an intermediate section between the one side tubular portion 2A and the other side tubular portion 2B is bent. The one side tubular portion 2A of the casing body 2 is provided with a shaft through hole 2C formed in one end portion in the axial direction.

[0025] Denoted at 3 is a head casing fixed to an end face (head side end face) in a side of the other side tubular portion 2B in the casing body 2, and the head casing 3 is provided with a pair of supply and discharge passages (any of them is not shown) formed therein. A high-pressure side supply and discharge passage among the supply and discharge passages supplies pressurized oil discharged from a hydraulic pump (not shown) through a supply and discharge port 13B of a valve plate 13 to be described later to respective cylinder holes 8. A low-pressure side supply and discharge passage discharges return oil from a side of a supply and discharge port 13C of the valve plate 13 to be described later to a side of a tank (not shown).

[0026] Denoted at 4 is a rotational shaft provided in the one side tubular portion 2A of the casing body 2, and the rotational shaft 4 is constituted as an output shaft of the hydraulic motor. The rotational shaft 4 is rotatably supported

through a bearing in the one side tubular portion 2A of the casing body 2. The rotational shaft 4 has one end side protruding through the shaft through hole 2C outside of the casing body 2.

[0027] On the other hand, the rotational shaft 4 has the other end side extending in the one side tubular portion 2A of the casing body 2 toward the other side tubular portion 2B and the end portion provided integrally with a drive disc 5 rotating together with the rotational shaft 4. The drive disc 5 is arranged in a position in the vicinity of the boundary section between the one side tubular portion 2A and the other side tubular portion 2B of the casing body 2. The drive disc 5 is respectively provided with a central-side concave spherical portion 5A positioned in the central-side of the other side end face and a plurality of concave spherical portions 5B for rotational transmission positioned outside of the concave spherical portion 5A in a radial direction to be spaced in the circumferential direction from each other. Here, the central-side concave spherical portion 5A is slidably coupled to a spherical portion 9A of a center shaft 9 to be described later. The plurality of the concave spherical portions 5B are pivotably coupled to spherical portions 10B of respective tapered pistons 10 to be described later.

[0028] Denoted at 6 is a cylinder block rotatably provided in the casing 1, and the cylinder block 6 is coupled through the center shaft 9 and the respective tapered pistons 10 to be described later to the drive disc 5 to rotate together with the rotational shaft 4. The cylinder block 6 is formed in a thick, cylindrical shape, and has a central portion in which a center hole 7 is formed along a rotational center axis O - O for slidably inserting the center shaft 9 to be described later therein. In addition, the cylinder block 6 is provided with a plurality of cylinder holes 8 (regularly the odd number such as five, seven or nine) formed therein, which are spaced from each other by a constant interval in the circumferential direction around the center hole 7 and extend in an axial direction.

[0029] The cylinder block 6 is constituted by executing nitriding treatment and chemical conversion film treatment of manganese phosphate, which will be described later, as surface treatment to a base material 16, which will be described later, formed by using an iron-based material such as cast iron or cast steel. The cylinder block 6 has an end face in a side of the head casing 3 constituted as a sliding surface 6A in a concave curved shape in sliding contact with the valve plate 13 to be described later.

[0030] A plurality of cylinder ports 8A (one cylinder port only is shown) are formed between the sliding surface 6A of the cylinder block 6 and the respective cylinder holes 8, which are communicated/blocked in a side of the sliding surface 6A by the valve plate 13. As shown in Fig. 2, each of the cylinder holes 8 has an opening peripheral edge 8B, and the opening peripheral edge 8B is also constituted as an inlet portion peripheral edge for inserting the tapered piston 10 to be described later into the cylinder hole 8.

[0031] Denoted at 9 is the center shaft provided to be inserted into the center hole 7 for centering the cylinder block 6. As shown in Fig. 1, the center shaft 9 has one end side formed as the spherical portion 9A and the other end side formed as a spring accommodating hole 9B with a bottom. The spherical portion 9A of the center shaft 9 is slidably fitted into the concave spherical portion 5A formed in the center side of the drive disc 5. On the other hand, a spring 14 to be described later is disposed in the spring accommodating hole 9B of the center shaft 9.

[0032] Denoted at 10 are the plurality of the tapered pistons reciprocally inserted into the respective cylinder holes 8 of the cylinder block 6. As shown in Fig. 3, the tapered piston 10 is constituted by a tapered shaft portion 10A formed to be enlarged in diameter in a tapered shape from one end side to the other end side, a spherical portion 10B formed integrally with one (small diameter portion) end side of the tapered shaft portion 10A, a piston portion 10C formed in the other (large diameter portion) end side of the tapered shaft portion 10A, and an oil hole 10D axially extending in the tapered piston 10 from an end face of a side of the piston portion 10C to a side of the spherical portion 10B.

[0033] The tapered piston 10 has the side of the piston portion 10C slidably inserted into the cylinder hole 8. The piston portion 10C has an outer peripheral side provided with two sealing members 11 and 12 composed of piston rings attached thereto for ensuring sealing properties between the cylinder hole 8 and the piston 10. The spherical portion 10B of the tapered piston 10 is pivotably (slidably) coupled in the concave spherical portion 5B of the drive disc 5, and a part of the oil liquid supplied into the cylinder hole 8 is resupplied on the sliding surface therebetween as lubricating oil from the oil hole 10D side.

[0034] Denoted at 13 is the valve plate provided between the head casing 3 of the casing 1 and the cylinder block 6, and the valve plate 13 has one side face, which opposes the cylinder block 6, formed as a switching surface 13A in a convex curved shape and the other side face formed as a flat surface to be fixed to the head casing 3. In the cylinder block 6, the sliding surface 6A slides and rotates to the switching surface 13A of the valve plate 13, and thereby supply and discharge of pressurized oil to and from each cylinder hole 8 is performed as follows.

[0035] That is, as shown in Fig. 4, the valve plate 13 is provided with a pair of supply and discharge ports 13B and 13C formed therein, each having an eyebrow shape and extending in the circumferential direction. The supply and discharge ports 13B and 13C are communicated with the pair of the supply and discharge passages formed in the head casing 3. The supply and discharge ports 13B and 13C are intermittently communicated with the cylinder ports 8A of the respective cylinder holes 8 with rotation of the cylinder block 6.

[0036] In this case, for example, one supply and discharge port 13B as a high-pressure side is connected to the high-pressure side supply and discharge passage among the pair of the supply and discharge passages and supplies

pressurized oil discharged from the hydraulic pump (not shown) into each of the cylinder holes 8. On the other hand, the other supply and discharge port 13C as a low-pressure side is connected to the low-pressure side supply and discharge passage among the pair of the supply and discharge passages, and discharges return oil discharged from each of the cylinder holes 8 to a side of the tank (not shown).

[0037] Denoted at 14 is the spring provided between the center shaft 9 and the cylinder block 6, and the spring 14 is arranged in the spring accommodating hole 9B of the center shaft 9, and all the time urges the cylinder block 6 toward the switching surface 13A of the valve plate 13. Therefore, the cylinder block 6 rotates relative to the valve plate 13 in the forward direction or in the backward direction in a state where the sliding surface 6A is in close contact with the switching surface 13A of the valve plate 13.

[0038] Next, respective surface treatment layers applied to the cylinder block 6 and the tapered piston 10 will be described.

[0039] Designated at 15 is the surface treatment layer formed in the cylinder block 6. The surface treatment layer 15 is formed to cover the surface side of the cylinder block 6 including the center hole 7 and the plurality of cylinder holes 8 wholly. As shown in Fig. 9, the surface treatment layer 15 is constituted by a nitriding treatment layer 17 formed by executing nitride-based heat treatment as described later to a base material 16 of the cylinder block 6 formed using an iron-based material such as cast iron or cast steel, and a chemical conversion film 18 to be described later.

[0040] Here, as shown in Fig. 9 and Fig. 11, the nitriding layer 17 comprises a diffusion layer 17A formed on the surface side of the base material 16 and a compound layer 17B formed to cover the surface side of the diffusion layer 17A. The compound layer 17B of them is formed as a harder layer than the diffusion layer 17A, and a thickness of the compound layer 17B is the order of 10 to 20 μ m.

[0041] Denoted at 18 is the chemical conversion film formed to cover the compound layer 17B of the nitriding layer 17. The chemical conversion film 18 forms a manganese phosphate film on the surface side of the compound layer 17B by treatment means such as dipping, for example. The chemical conversion film 18 of the manganese phosphate is excellent in initial fitting properties to a sliding material such as the tapered piston 10, and a film thickness thereof is set as a thickness of 10 to 20 μ m or more, for example. Further, the chemical conversion film 18 of manganese phosphate promptly fits in the surface configuration of the tapered piston 10 sliding and displacing in the cylinder hole 8, and reduces the surface pressure in the contact section between the cylinder hole 8 and the tapered piston 10 to reduce the wear therebetween.

[0042] Next, designated at 20 is a surface treatment layer formed in the tapered piston 10. The surface treatment layer 20 is formed to cover the surface side of each of the tapered shaft portion 10A, the spherical portion 10B and the piston portion 10C of the tapered piston 10 wholly. As shown in Fig. 12, the surface treatment layer 20 comprises a nitriding layer 21 formed by executing nitride-based heat treatment to be described later to a base material 10' of the tapered piston 10 and an oxidized film 22 to be described later. Here, the nitriding layer 21 of the tapered piston 10 also comprises a diffusion layer 21A and a compound layer 21B as similar to the nitriding layer 17 of the cylinder block 6.

[0043] Denoted at 22 is the oxidized film formed to cover the compound layer 21B of the nitriding layer 21. The oxidized film 22 forms a surface layer of oxidized iron (Fe_3O_4) by attaching superheated steam of, for example, 500°C or more to the surface side of the compound layer 21B. The oxidized film 22 forms a dense and stable layer at the outermost surface side of the tapered piston 10 to enhance anti-oxidation properties, anti-corrosion properties, anti-wear properties, and the like of the tapered piston 10.

[0044] The bent axis type hydraulic motor according to the first embodiment has the construction as described above, and hereinafter, an operation thereof will be explained.

[0045] At the time of driving the rotational shaft 4 in the hydraulic motor, the pressurized oil discharged from the hydraulic pump (not shown) is sequentially supplied through the high-pressure side supply and discharge passage formed in the head casing 3 and the supply and the discharge port 13B in the valve plate 13 to the respective cylinder holes 8, and the hydraulic force at this time sequentially expands each of the tapered pistons 10 from each of the cylinder holes 8 toward the side of the drive disc 5. On the other hand, the return oil from each of the cylinder holes 8 is discharged from the low-pressure side supply and discharge port 13C and the supply and discharge passage to the side of the tank following the displacement of each of the tapered pistons 10 into the cylinder hole 8 in the contracting direction.

[0046] At this time, in each of the cylinder holes 8 to which the pressurized oil is sequentially supplied, the spherical portion 10B as a protrusion-side end portion of the tapered piston 10 inserted therein is sequentially pressed down to the side of the concave spherical portion 5B of the drive disc 5. Thereby, a rotational force around the rotational shaft 4 is generated in the drive disc 5, and the rotational force is taken out as motor output from the front side of the rotational shaft 4.

[0047] At rotation of the hydraulic motor, each of the tapered pistons 10 makes contact with the inner peripheral wall and the opening peripheral edge 8B of the cylinder hole 8, and therefore the rotational force is transmitted to the cylinder block 6 to cause the cylinder block 6 and the drive disc 5 to rotate in synchronization with each other. In this case, there exists a region where one piston 10 out of the respective tapered pistons 10 makes contact with the inner peripheral wall and the opening peripheral edge 8B of one cylinder hole 8. This region includes a constant section (contact region

A of a low-pressure side shown in Fig. 4) at the time the cylinder hole 8 into which the tapered piston 10 is inserted is communicated with the low-pressure side supply and discharge port 13C and a constant section (contact region B of a high-pressure side) at the time the cylinder hole 8 is communicated with the high-pressure side supply and discharge port 13B.

[0048] Namely, each of the tapered pistons 10 provided to be inserted into the respective cylinder holes 8 of the cylinder block 6 makes contact with the inner peripheral wall and the opening peripheral edge 8B of the cylinder hole 8 in the low-pressure side contact region A and the high-pressure side contact region B shown in Fig. 4 while the cylinder block 6 rotates one revolution. As a result, transmission of the rotational force from the tapered piston 10 to the cylinder block 6 is made to cause the cylinder block 6 and the drive disc 5 to rotate in synchronization with each other.

[0049] Here, a comparative example according to the conventional arts will be explained with reference to Fig. 6. In this comparative example, a nitriding layer alone is formed in each of cylinder holes 8' of a cylinder block 6'. Therefore, wear tracks 23' are formed in an opening peripheral edge 8B' of each of the cylinder holes 8' in the cylinder block 6'. When this wear develops, in a case of the comparative example where the chemical conversion film is not formed, there are some cases where among the nitriding layer comprising a diffusion layer and a compound layer formed in the cylinder hole 8', the compound layer on the surface side is separated, and galling or burn-in or the like is possibly generated in the side of the opening peripheral edge 8B' of the cylinder hole 8'.

[0050] On the other hand, in the conventional arts, there are some cases where the compound layer is in advance removed from the nitriding layer, for example, by honing processing or the like to form a honing surface excellent in anti-galling properties and anti-burn-in properties. Even in this case, however, when the wear track 23' reaches a depth of 10 μ m or something, in some cases the honing surface is eliminated due to wear. When the wear further develops in this state, the surface roughness of the opening peripheral edge 8B' is deteriorated, so that sliding characteristics of the tapered piston are deteriorated to cause the galling, the burn-in or the like to be easily generated.

[0051] Further, in the conventional arts, there are some cases where a bias of a contact region between the opening peripheral edge 8B' of the cylinder hole 8' and the tapered piston is generated caused by variations in configuration of the cylinder hole 8' and the tapered piston. When this bias is generated, a heat value due to the sliding contact therebetween increases, and therefore the galling, the burn-in or the like are more likely to be occurred.

[0052] Therefore, in the first embodiment, the surface treatment of the cylinder block 6 is executed according to the procedure shown in Fig. 7. In this case, as shown in Fig. 10, the base material 16 of the cylinder block 6 formed by using an iron-based material is prepared. Next, nitride-based heat treatment is executed to the base material 16 of the cylinder block 6. Therefore, as shown in Fig. 11, the nitriding layer 17 comprising the diffusion layer 17A and the compound layer 17B is formed (step 1 in Fig. 7).

[0053] Next, in the chemical conversion film treatment at step 2, for example, the base material 16 of the cylinder block 6 is dipped over a predetermined time in a bath (not shown) in which manganese phosphate is heated and melted. The chemical conversion film 18 of manganese phosphate is formed on the surface side of the compound layer 17B by the dipping treatment. As shown in Fig. 9, the compound layer 17B of the nitriding layer 17 is covered with the chemical conversion film 18 from an outside to be coated over the entire surface.

[0054] On the other hand, in the first embodiment, the surface treatment is also executed to the tapered piston 10 according to the procedure shown in Fig. 8. In this case, as shown in Fig. 13, the base material 10' of the tapered piston 10 formed by using an iron-based material or the like is prepared. Next, nitride-based heat treatment is executed to the base material 10' of the tapered piston 10. Therefore, as shown in Fig. 14, the nitriding layer 21 comprising the diffusion layer 21A and the compound layer 21B is formed (step 11 in Fig. 8).

[0055] Next, in the oxidized film treatment at step 12, for example, superheated steam of 500°C or more is attached to the surface side of the compound layer 21B. Thereby, the oxidized film 22 made up of a surface layer of oxidized iron (Fe₃O₄) is formed. As shown in Fig. 12, the compound layer 21B of the nitriding layer 21 is covered with the oxidized film 22 from an outside to be coated over the entire surface.

[0056] Thus, according to the first embodiment, the chemical conversion film 18 made up of the manganese phosphate film is formed on the surface side of the cylinder block 6, particularly on the peripheral wall (surface) side of the cylinder hole 8 to cover the nitriding layer 17. Therefore, the chemical conversion film 18 of manganese phosphate positioned in the outermost side in the surface treatment layer 15 promptly fits in the outer configuration of the tapered piston 10 sliding and displacing in the cylinder hole 8, making it possible to achieve the initial fitting effect.

[0057] As a result, the surface pressure in the contact section between the cylinder hole 8 and the tapered piston 10 can be reduced to achieve a reduction in wear. On the other hand, by forming the chemical conversion film 18 of manganese phosphate to have the film thickness equal to or more than the wear amount, it can prevent the wear from reaching the vicinity of the boundary surface between the compound layer 17B and the diffusion layer 17A in the nitriding layer 17. Namely, at this time, the chemical conversion film 18 of manganese phosphate alone is worn and the wear does not develop more than that. Therefore, damages of the nitriding layer 17 formed in the cylinder block 6 due to wear can be suppressed.

[0058] Therefore, as shown in Fig. 5, even in a case where the wear tracks 23 are formed on the opening peripheral

edge 8B in each of the cylinder holes 8 of the cylinder block 6, it can be prevented that the wear tracks 23 are as deep as to reach the vicinity of the boundary surface between the compound layer 17B and the diffusion layer 17A in the nitriding layer 17. As a result, formation of the chemical conversion film 18 of manganese phosphate can suppress damages of the nitriding layer 17 formed in the cylinder block 6 due to wear. In addition, since the chemical conversion film 18 can be formed in a state where the surface area is increased by executing manganese phosphate treatment on a surface state after the nitriding treatment, the chemical conversion film 18 more easily attaches thereto.

[0059] Here, the inventors inserted the tapered piston 10 into the cylinder hole 8 of the cylinder block 6 to repeat sliding tests and made tests of measuring a surface roughness in the opening peripheral edge 8B of the cylinder hole 8, namely, an average surface roughness (Ra). As a result, as a characteristics line 24 shown in Fig. 15, in the cylinder hole 8 of the cylinder block 6 according to the first embodiment, the average surface roughness (Ra) of the opening peripheral edge 8B is lowered with an elapse time of the sliding test, making it possible to obtain stable surface roughness.

[0060] That is, the chemical conversion film 18 of manganese phosphate positioned in the outermost side in the surface treatment layer 15 formed in the cylinder hole 8 of the cylinder block 6 fits in the outer configuration of the tapered piston 10 sliding and displacing in the cylinder hole 8. Therefore, the average surface roughness (Ra) of the opening peripheral edge 8B is lowered as the sliding test continues. After the chemical conversion film 18 of manganese phosphate fits in the outer configuration of the tapered piston 10, the surface roughness of the opening peripheral edge 8B becomes a proper degree, and it can be confirmed that the surface roughness becomes stable in this state.

[0061] On the other hand, for example, in a case of a comparative example shown in Fig. 6, the comparative example does not include a chemical conversion film of manganese phosphate or the like. Therefore, as a characteristics line 25 in Fig. 15, the surface roughness of the opening peripheral edge 8B' of the cylinder hole 8', namely, the average surface roughness (Ra) is deteriorated with an elapse time and the wear gradually develops.

[0062] Next, the wear amount in the opening peripheral edge 8B of the cylinder hole 8 was measured for examination. As a result, as a characteristics line 26 in Fig. 16, it can be confirmed that the wear amount of the opening peripheral edge 8B can be suppressed to an amount smaller than a depth dimension h. Namely, the chemical conversion film 18 of manganese phosphate is formed to have a film thickness equivalent to a dimension h. In consequence, an adverse influence of the wear on the nitriding layer 17 formed in the cylinder block 6 can be suppressed, and the nitriding layer 17 can be protected by the chemical conversion film 18 of manganese phosphate.

[0063] Meanwhile, in a case of the comparative example shown in Fig. 6, the comparative example does not include the chemical conversion film of manganese phosphate or the like. Therefore, as a characteristics line 27 in Fig. 16, it is confirmed that in the opening peripheral edge 8B' of the cylinder hole 8', the wear amount increases with an elapse time and the wear develops largely over the depth dimension h.

[0064] On the other hand, in the first embodiment, the oxidized film 22 in addition to the nitriding layer 21 is formed on the surface side of the tapered piston 10. Therefore, the tapered piston 10, in which the surface treatment more excellent in anti-galling properties is executed by the oxidized film 22, can be manufactured. In addition, the wear of the cylinder block 6, that is, the wear of the opening peripheral edge 8B of each of the cylinder holes 8 can be effectively reduced.

[0065] In this manner, the tapered piston 10, to which the surface treatment of the oxidized film 22 was executed, was inserted into the cylinder hole 8 of the cylinder block 6 for making sliding tests. In this case, as a characteristics line 28 shown in Fig. 16, the wear on the opening peripheral edge 8B can be reduced. Namely, it was confirmed that, the wear in the tapered piston 10, to which the surface treatment of the oxidized film 22 was executed, could be further reduced in comparison with a case of the tapered piston to which the surface treatment of the oxidized film 22 was not executed (characteristics line 26).

[0066] Therefore, it is possible to suppress damages of the nitriding layer 17 formed in the cylinder block 6 due to wear to reduce generation of galling, burn-in or the like. In addition, a layer of the oxidized film 22 is formed on the outermost surface side of the surface of the tapered piston 10. Thereby, even under a condition that the surface pressure in the contact section between the opening peripheral edge 8B of the cylinder hole 8 and the tapered piston 10 becomes excessive, or the oil film out or the like is generated, generation of the galling, burn-in or the like can be prevented.

[0067] According to the first embodiment, the wear in the contact section between each of the cylinder holes 8 in the cylinder block 6 and the tapered piston 10 can be suppressed. Further, the chemical conversion film 18 of manganese phosphate is adapted for the outer configuration of the tapered piston 10 sliding and displacing in the cylinder hole 8 for prompt fitting. Accordingly, generation of the bias in the contact region between the opening peripheral edge 8B of the cylinder hole 8 and the tapered piston 10 can be suppressed.

[0068] Therefore, the spreading of the contact region between the opening peripheral edge 8B of the cylinder hole 8 and the tapered piston 10 can be suppressed and an increase of a heat value due to enlargement of the contact region can be suppressed to enhance reliability of the bent axis type hydraulic motor (hydraulic rotating machine).

[0069] Fig. 17 to Fig. 20 show a bent axis type hydraulic rotating machine according to a second embodiment in the present invention.

[0070] The second embodiment is characterized in the structure that the compound layer positioned on the surface

side in the nitriding layer is removed by abrasive means and in this state, the chemical conversion film is formed on the surface side. It should be noted that in the present embodiment, components identical to those in the first embodiment are referred to as identical codes and an explanation thereof is omitted.

[0071] In the second embodiment, the surface treatment of the cylinder block 6 is executed according to the procedure shown in Fig. 17. In this case, as shown in Fig. 20, a surface treatment layer 31 formed on the surface side of the cylinder block 6 comprises the nitriding layer 17 and a chemical conversion film 32 to be described later as similar to the first embodiment. Namely, as shown in Fig. 18, nitride-based heat treatment is executed to the base material 16 of the cylinder block 6. Therefore, the nitriding layer 17 comprising the diffusion layer 17A and the compound layer 17B is formed as similar to the first embodiment (step 31 in Fig. 17).

[0072] In the second embodiment, however, the removing treatment at step 32 is added to be executed. Thereby, the compound layer 17B positioned on the surface side in the nitriding layer 17 is removed by abrasive means such as honing processing. In consequence, the diffusion layer 17A of the nitriding layer 17 is exposed to an outside on the surface side of the base material 16 as shown in Fig. 19.

[0073] Next, in the chemical conversion film treatment at step 33 in this state, for example, the base material 16 of the cylinder block 6 is dipped over a predetermined time in a bath (not shown) in which manganese phosphate is heated and melted. The chemical conversion film 32 of manganese phosphate is formed on the surface side of the diffusion layer 17A by the dipping treatment as shown in Fig. 20, and the diffusion layer 17A of the nitriding layer 17 is covered with the chemical conversion film 32 from an outside to be coated over the entire surface.

[0074] Thus, also in the second embodiment as constructed in this manner, when the surface treatment layer 31 comprising the nitriding layer 17 and the chemical conversion film 32 of manganese phosphate is formed on the surface side of the cylinder block 6, the operational effect similar to that of the first embodiment mentioned before can be obtained. Particularly in the second embodiment, the following effect can be achieved by removing the compound layer 17B positioned on the surface side of the nitriding layer 17 by abrasive means.

[0075] Namely, in a case of the hydraulic motor, the rotational direction of the rotational shaft 4 is frequently changed. In a case where the cylinder block 6 thus rotates repeatedly in the forward direction and in the backward direction, even if an impact load is generated in the contact section between the opening peripheral edge 8B of the cylinder hole 8 and the tapered piston 10, separation of the compound layer 17B due to this impact load does not occur. Therefore, generation of galling, burn-in or the like in the contact section therebetween can be prevented, and in addition, the chemical conversion film 32 of manganese phosphate can be stably ensured and left in the opening peripheral edge 8B of the cylinder hole 8.

[0076] Further, after the compound layer 17B is removed by abrasive means, the chemical conversion film 32 equal to or more than the wear amount of the opening peripheral edge 8B is formed. Thereby, damages of the diffusion layer 17A in the nitriding layer 17 formed in the cylinder block 6 due to wear can be suppressed. Therefore, the deteriorating of the roughness of the sliding surface on the opening peripheral edge 8B of the cylinder hole 8 can be suppressed to keep sliding characteristics of the tapered piston 10 to be appropriate.

[0077] In each of the above embodiments, an explanation is made by taking a case where the fixed displacement type hydraulic motor of the bent axis type is used as the bent axis type hydraulic rotating machine as an example. However, the present invention is not limited to the same, and it may be applied to, for example, a variable displacement type hydraulic motor of a bent axis type. Further, the present invention may be applied to a fixed displacement type or a variable displacement type hydraulic pump of a bent axis type. In this case, a low-pressure side port among a pair of supply and discharge ports is used as a suction port, and a high-pressure side port is used as a supply port.

[0078] Further, in the first embodiment, an explanation is made by taking a case where the surface treatment layer 20 formed in the tapered piston 10 comprises the nitriding layer 21 and the oxidized film 22 as an example. However, the present invention is not limited to the same, and for example, the surface treatment layer of the tapered piston 10 may comprise the nitriding layer alone. On the other hand, the tapered piston may be subjected to heat treatment other than nitride-based treatment for increasing a hardness of the surface.

DESCRIPTION OF REFERENCE NUMERALS

[0079]

1:	Casing
2:	Casing body
2A:	One side tubular portion
2B:	Other side tubular portion
3:	Head casing
4:	Rotational shaft
5:	Drive disc

(continued)

6:	Cylinder block
7:	Center hole
8:	Cylinder hole
8B:	Opening peripheral edge
9:	Center shaft
10:	Tapered piston
13:	Valve plate
13B, 13C:	Supply and discharge port
15, 20, 31:	Surface treatment layer
17, 21:	Nitriding layer
17A, 21A:	Diffusion layer
17B, 21B:	Compound layer
18, 32:	Chemical conversion film (Manganese phosphate film)
22:	Oxidized film

Claims

1. A bent axis type hydraulic rotating machine comprising:

a tubular casing (1);
a rotational shaft (4) rotatably provided in said casing (1);
a cylinder block (6) which is provided in said casing (1) to rotate together with said rotational shaft (4) and provided with a plurality of cylinder holes (8) to be spaced in the circumferential direction and axially extend; and
a plurality of tapered pistons (10) each of which has one end in an axial direction pivotably supported on said rotational shaft (4) and the other end reciprocally inserted into each of said cylinder hole (8) of said cylinder block (6), **characterized in that:**

a nitriding layer (17) formed by executing nitride-based treatment together with said cylinder hole (8) is formed in said cylinder block (6), and
a chemical conversion film (18, 32) composed of a manganese phosphate film is formed on a surface side of said nitriding layer (17).

2. A bent axis type hydraulic rotating machine according to claim 1, wherein said nitriding layer (17) formed in said cylinder block (6) is constituted by a diffusion layer (17A) formed on a surface side of a base material and a compound layer (17B) formed on a surface side of said diffusion layer (17A), and
said chemical conversion film (18) composed of said manganese phosphate film is formed on a surface side of said compound layer (17B).

3. A bent axis type hydraulic rotating machine according to claim 1, wherein said nitriding layer (17) formed in said cylinder block (6) is constituted by a diffusion layer (17A) formed on a surface side of a base material and a compound layer (17B) formed on a surface side of said diffusion layer (17A), and
said chemical conversion film (32) composed of said manganese phosphate film is formed in said cylinder hole (8) of said cylinder block (6) in a state of removing said compound layer (17B) in said nitriding layer (17) by abrasive means.

4. A bent axis type hydraulic rotating machine according to claim 1, wherein said tapered piston (10) is provided with a nitriding layer (21) formed by executing nitride-based treatment thereon and an oxidized film (22) formed on a surface side of said nitriding layer (21).

Fig.1

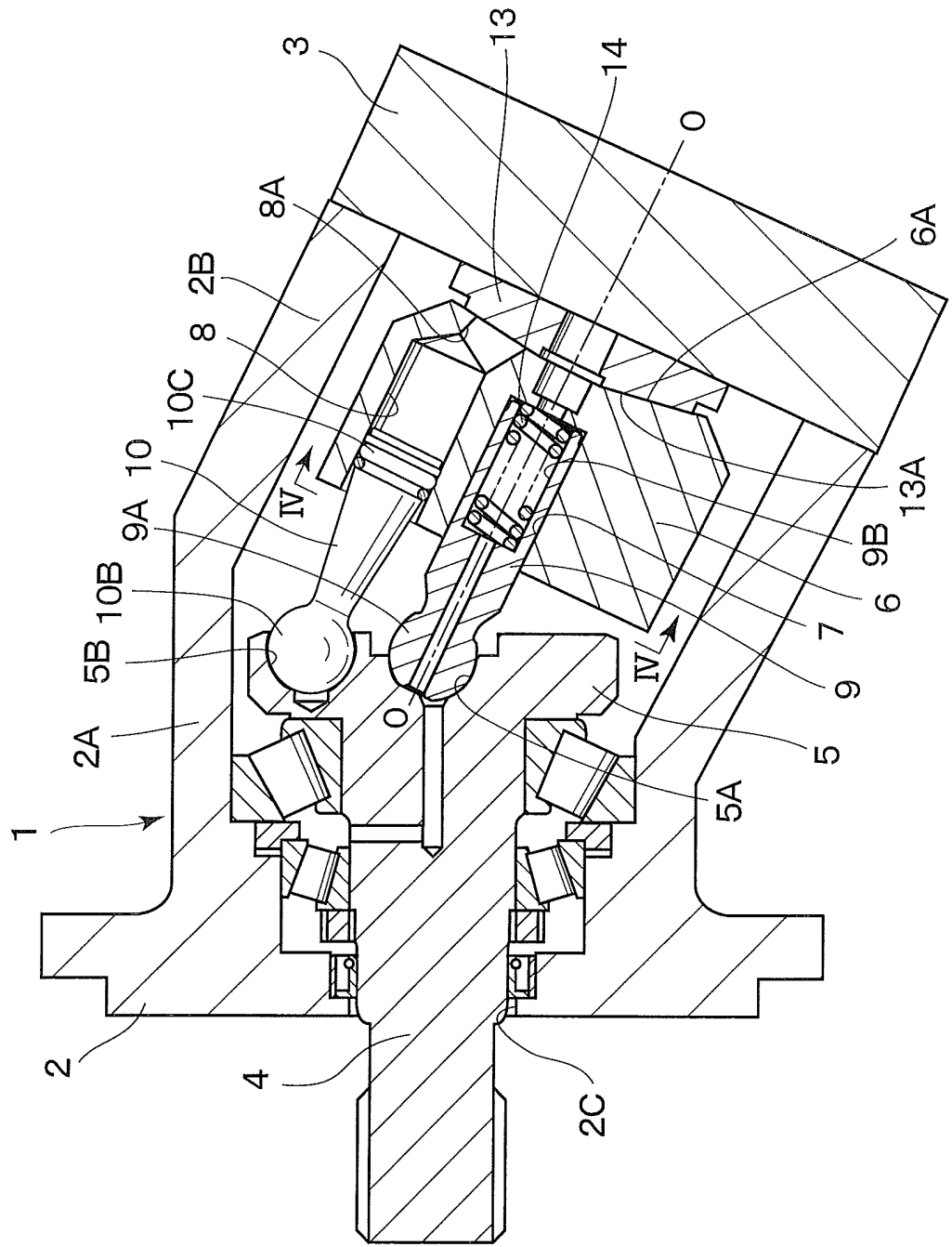


Fig. 2

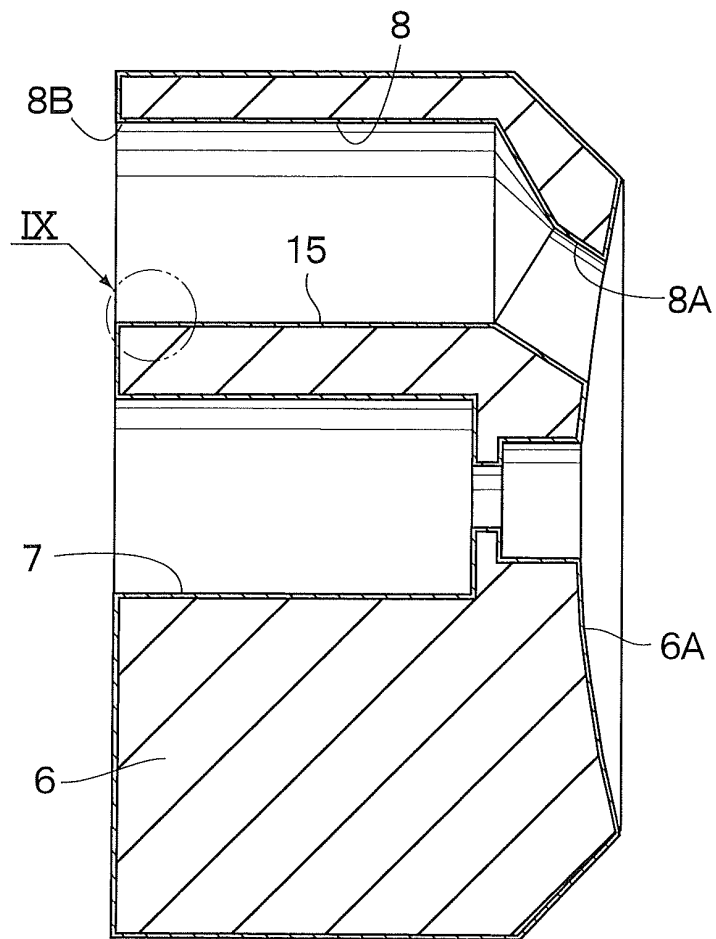


Fig. 3

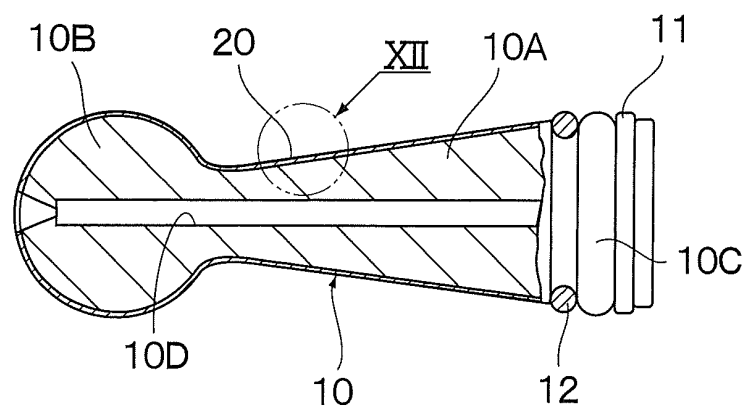


Fig.4

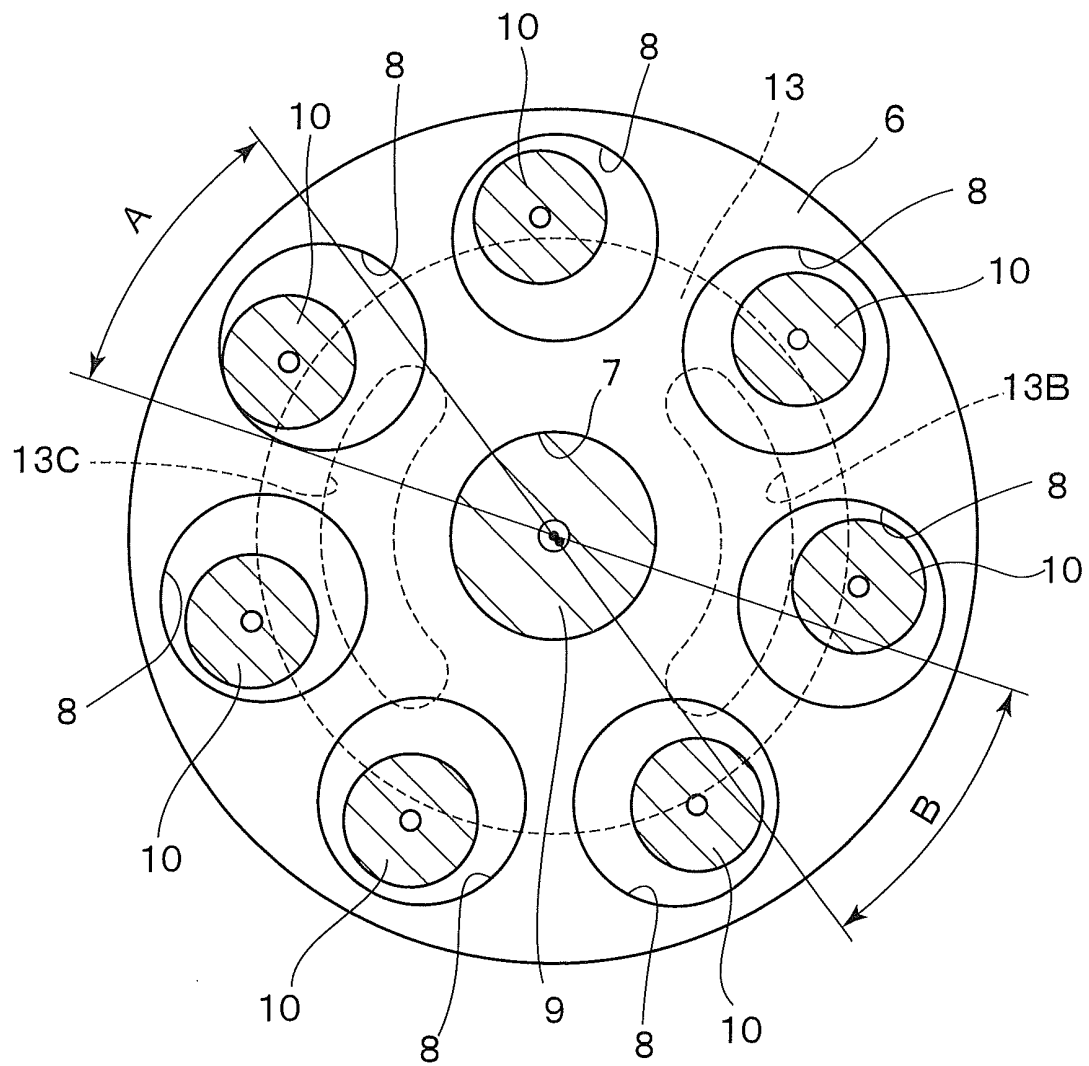


Fig.5

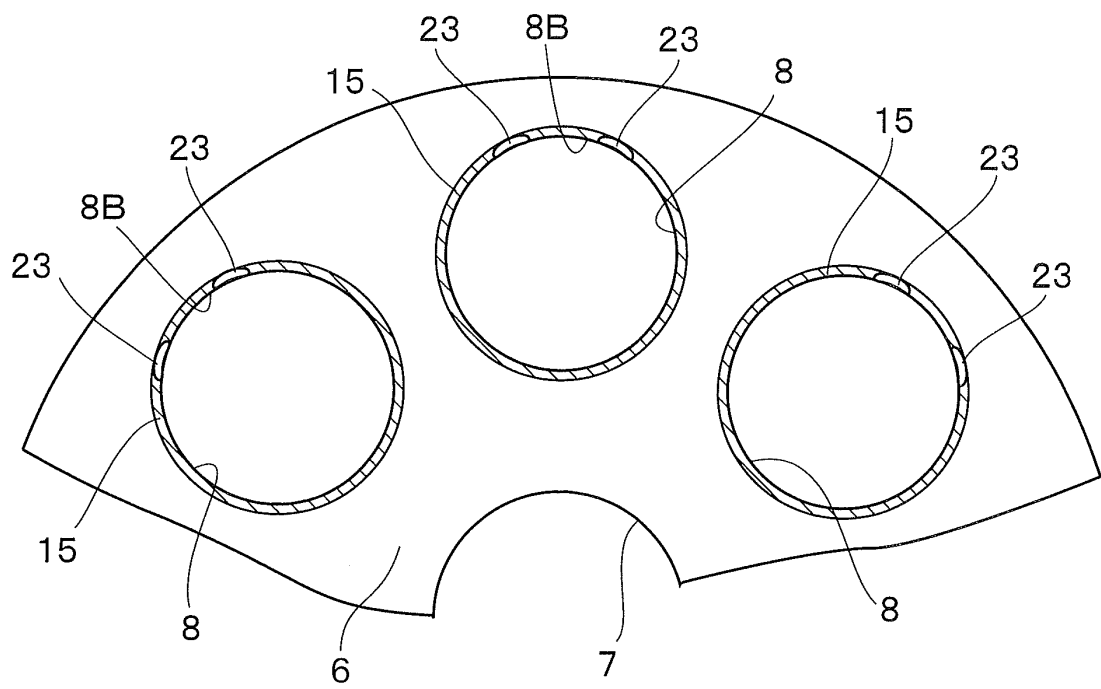


Fig.6

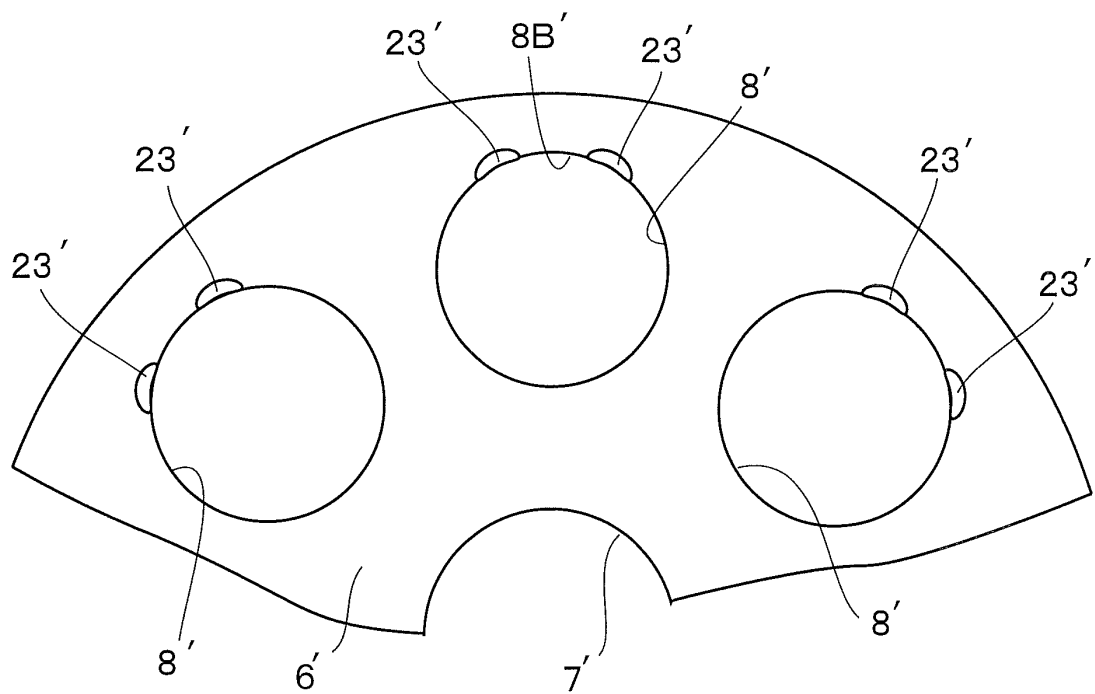


Fig.7

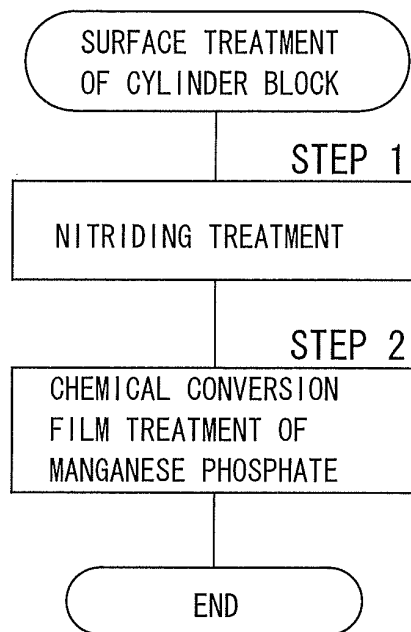


Fig.8

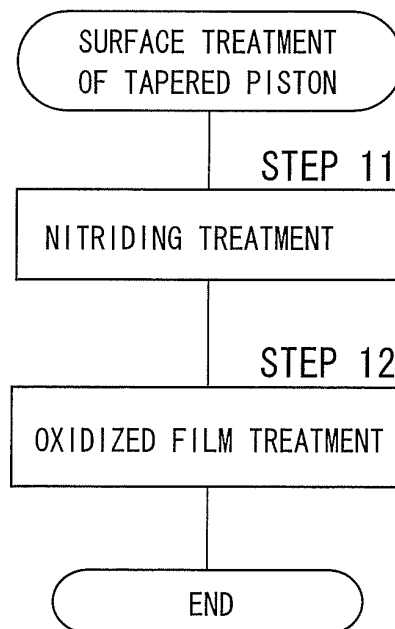


Fig. 9

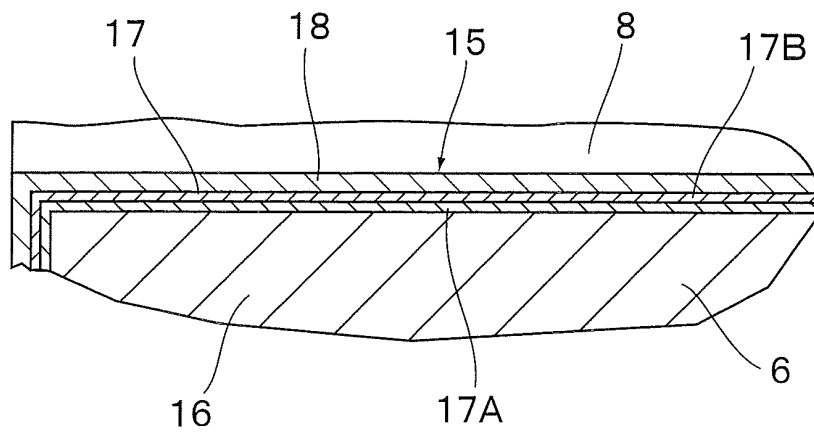


Fig. 10

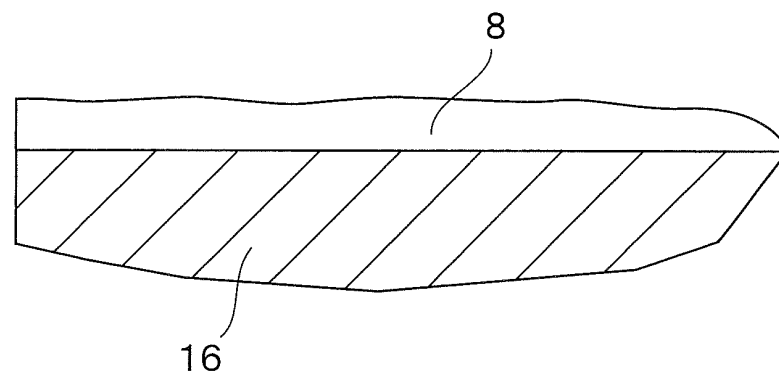


Fig. 11

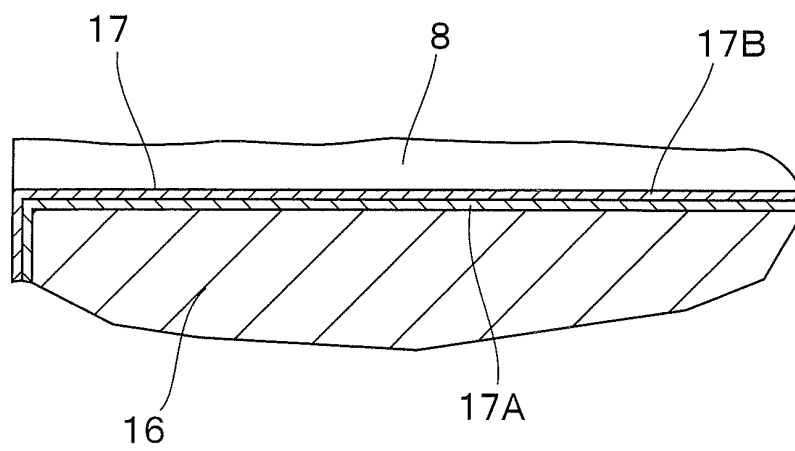


Fig.12

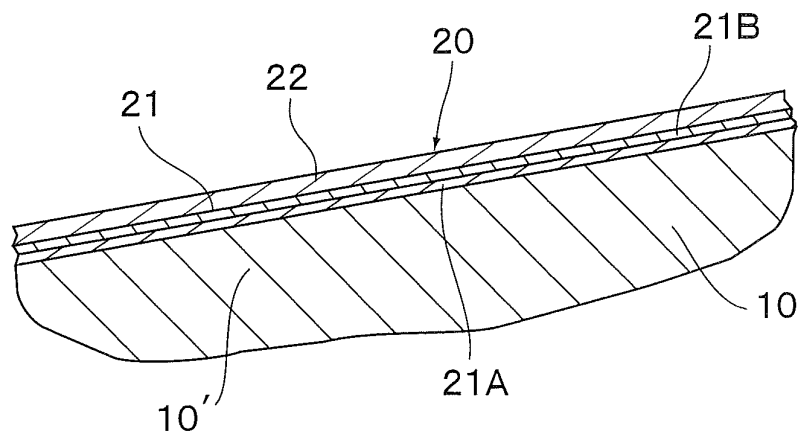


Fig.13

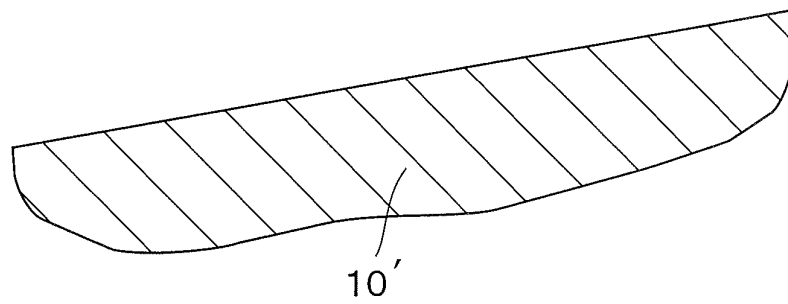


Fig.14

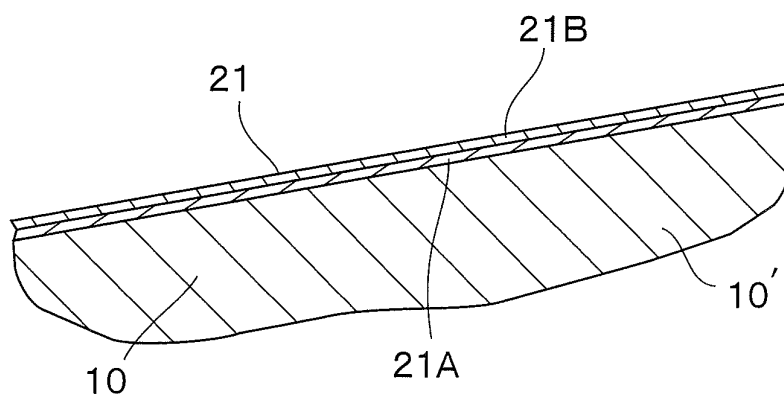


Fig.15

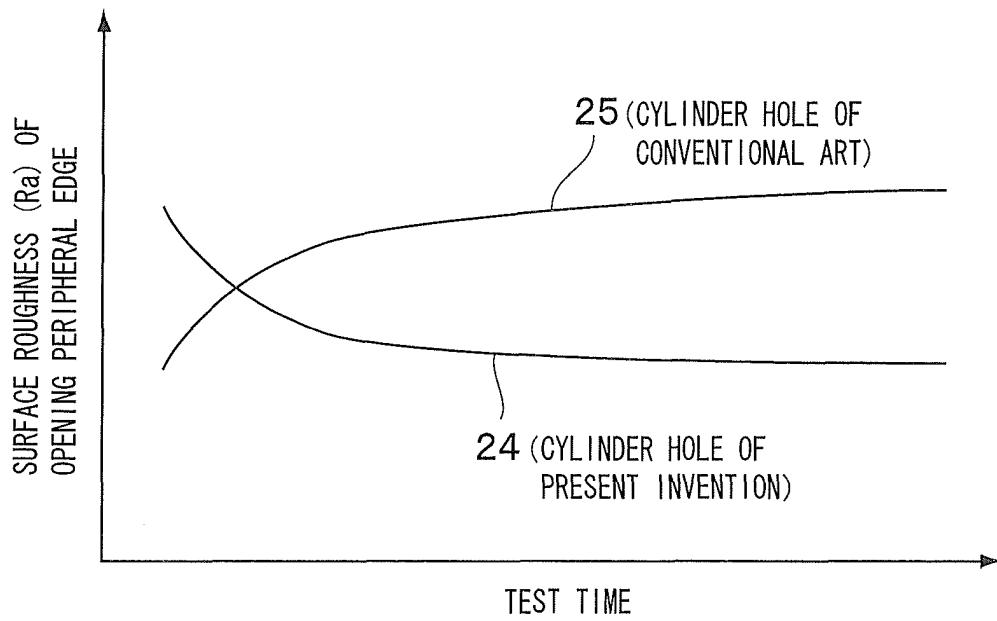


Fig.16

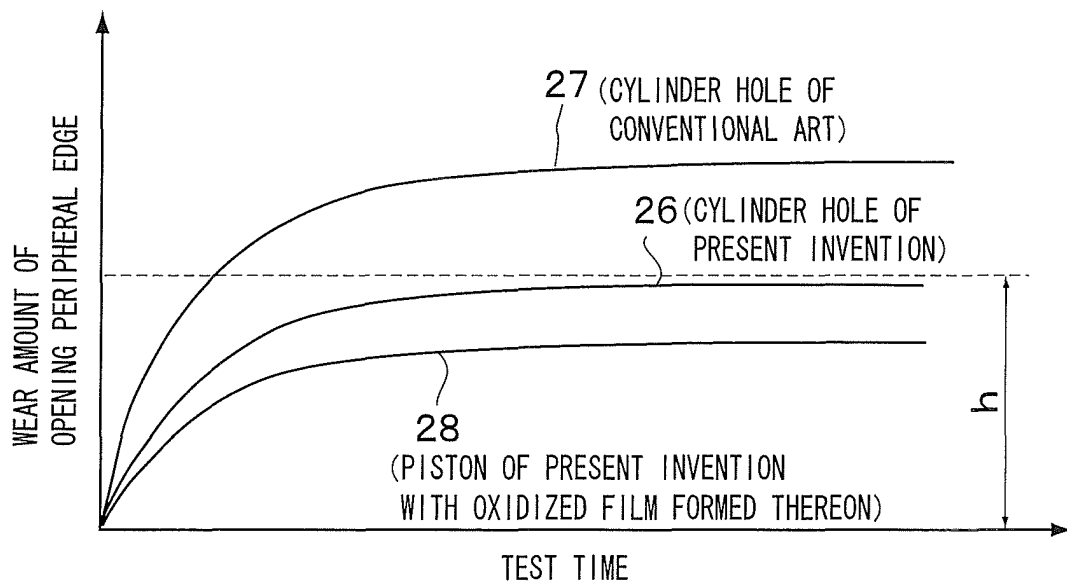


Fig. 17

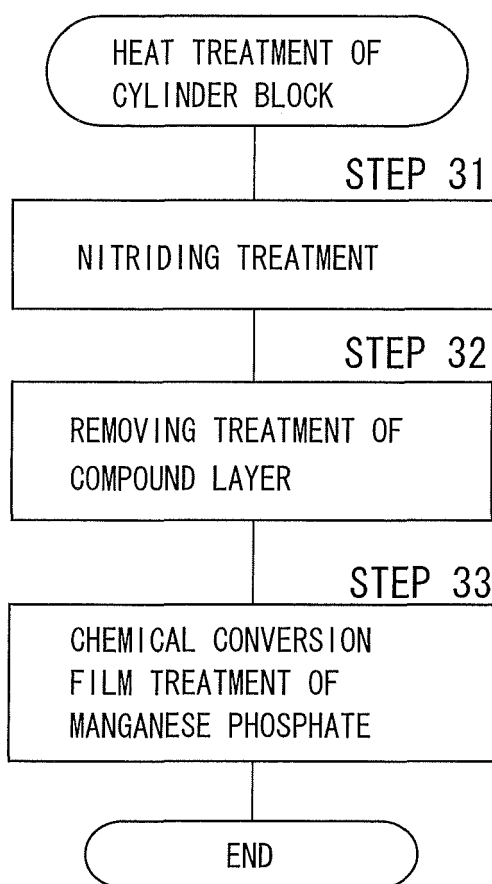


Fig.18

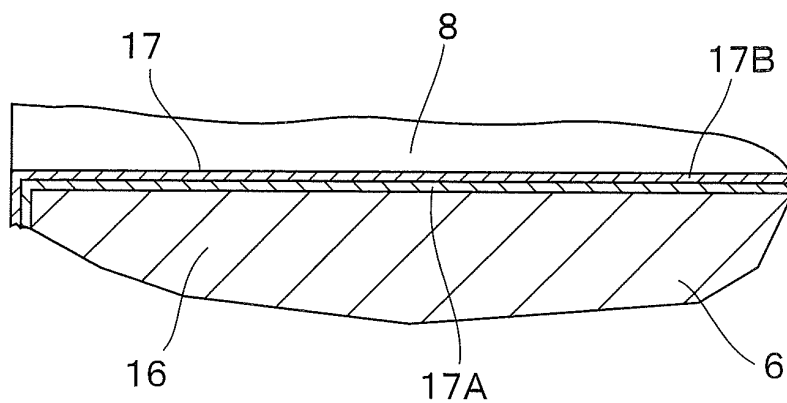


Fig.19

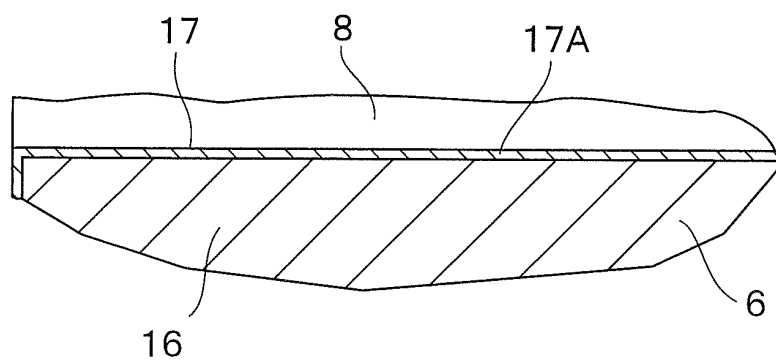
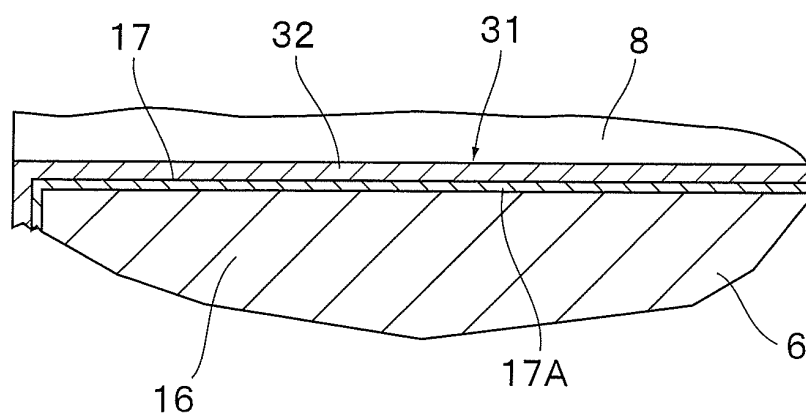


Fig.20



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/063586

A. CLASSIFICATION OF SUBJECT MATTER <i>F04B1/24(2006.01)i, F03C1/24(2006.01)i, F04B53/00(2006.01)i, F04B53/14(2006.01)i, F04B53/16(2006.01)i</i> According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) <i>F04B1/24, F03C1/24, F04B53/00, F04B53/14, F04B53/16</i> Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2011 Kokai Jitsuyo Shinan Koho 1971-2011 Toroku Jitsuyo Shinan Koho 1994-2011 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2005-201220 A (Hitachi Construction Machinery Co., Ltd.), 28 July 2005 (28.07.2005), entire text; all drawings (Family: none)	1-4
Y	JP 2000-227083 A (Matsushita Electric Industrial Co., Ltd.), 15 August 2000 (15.08.2000), entire text; all drawings (Family: none)	1-4
Y	JP 4-36458 A (Toshiba Corp.), 06 February 1992 (06.02.1992), entire text; all drawings (Family: none)	1-4
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 01 September, 2011 (01.09.11)		Date of mailing of the international search report 13 September, 2011 (13.09.11)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/063586

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2009-507160 A (Mahle International GmbH), 19 February 2009 (19.02.2009), entire text; all drawings & US 2008/0256794 A1 & EP 1920175 A1 & WO 2007/025533 A1	1-4

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