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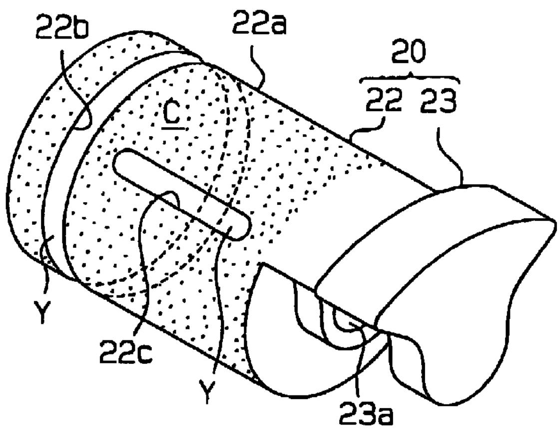
(54) Piston for compressor

(57) A piston (20) having a groove (22b, 22c) that is formed on a surface of a piston workpiece (20W) and a method for forming the groove (22b, 22c) on the piston (20). A head (22) of the piston (20) is accommodated in a corresponding cylinder bore. A first groove (22b, 22c) and a second groove (22b, 22c) are formed on the peripheral surface (22a) of the piston (20). The first groove (22b, 22c) scrapes lubricant oil from the inner surface of the cylinder bore and the second groove (22b, 22c) conveys the oil to the crank chamber. A coating layer (C) is formed on the peripheral surface (22a)of the head (22). The coating layer (C) is not formed on the areas that are designated for the first and second grooves (22b, 22c) on the peripheral surface (22a) of the head (22) of the piston workpiece (20W). Accordingly, the first and second grooves (22b, 22c) have a depth equal to the thickness of the coating layer (C). Since the coating layer (C) is used to form the grooves (22b, 22c), the grooves (22b, 22c) can be formed by a printing process with a printing apparatus.

Fig.2A



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a piston of a piston type compressor for vehicle air-conditioning system.

[0002] Japanese Unexamined Publication No. 10-26081 describes the following piston type compressor.

[0003] A drive shaft is rotatably supported in a housing and is rotated by an external power source. A swash plate is coupled to the drive shaft to rotate integrally in the housing. As shown in Fig. 11A, a piston 101 includes a head 102 and a neck 103. The head 102 of each piston 101 is received in a corresponding cylinder bore of the housing. Each piston 101 is coupled to the swash plate through shoes, which engage the neck 103 of each piston 101. Rotation of the drive shaft is converted into reciprocation of each piston 101 through the swash plate and the shoes, which compresses refrigerant gas in the corresponding cylinder bore.

[0004] As shown in Fig. 11A, an annular groove 102b is formed in a peripheral surface 102a of each piston 101. Lubricant oil, which is contained in the refrigerant gas, adheres to the inner surface of each cylinder bore. The annular groove 102b scrapes oil from the inner wall of the corresponding cylinder bore during reciprocation of each piston 101. A longitudinal groove 102c, which is oblong, extends from the vicinity of the annular groove 102b toward the neck 103 of each piston 101. The longitudinal groove 102c guides lubricant oil from the annular groove 102b to the crank chamber. During reciprocation of each piston 101, lubricant oil is desirably supplied to the crank chamber through the annular groove 102b and the longitudinal groove 102c to lubricate each part in the crank chamber.

[0005] Other grooves may be formed on the peripheral surface 102a in addition to the annular groove 102b and the longitudinal groove 102c. For example, a groove for adjusting the flow of blowby gas from the cylinder bore to the crank chamber or a groove for holding a piston ring may be formed on the surface 102a.

[0006] As shown in Fig. 11B, the annular groove 102b and the longitudinal groove 102c are directly formed in the surface 102a before a lubricant coating layer is coated on the surface 102a. This is also true of other grooves for blowby gas and the piston ring. The head 102 of each piston 101 may be hollow to reduce its weight. In this case, if the inner diameter of the hollow bore is too large, the portions of the first and second grooves 102b, 102c are relatively thin. To maintain the strength of the head 102, the head 102 must have a desirable thickness, which limits reduction of weight in each piston 101.

[0007] When the piston 101 is manufactured by forging or casting, and when the first and second grooves 102b, 102c are formed by metal molds, the dimensions of the grooves 102b, 102c are varied by varying the metal molds.

SUMMARY OF THE INVENTION

[0008] An objective of the present invention is to provide a piston having a groove that is not directly formed on its surface.

[0009] To achieve the above objective, the present invention provides a piston structure as follows. A piston workpiece has a head and a neck. A designated area exists on a peripheral surface of the head of the piston workpiece. A groove is formed on the designated area. A coating layer is formed on the peripheral surface of the head of the piston workpiece such that the thickness of the coating layer is thinner in the designated area than in the other peripheral surface of the head.

[0010] Other aspects and advantages of the present invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] 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 cross sectional view of a variable displacement compressor;

Fig. 2A is a perspective view of a piston according to a first embodiment of the present invention;

Fig. 2B is a partial enlarged cross-sectional view of the piston of Fig. 2A;

Fig. 2C is an enlarged cross-sectional view of the encircled portion 2C of Fig. 2B;

Fig. 2D is an enlarged cross-sectional view of the encircled portion 2D of Fig. 2B;

Fig. 3 is a diagrammatic view of a roll coating apparatus;

Fig. 4 is a front view showing a transfer roll and a piston in the roll coating apparatus of Fig. 3;

Fig. 5 is a diagrammatic view showing a screen printing apparatus of a second embodiment;

Fig. 6 is a plan view showing a screen and a piston in the screen printing apparatus of Fig. 5;

Fig. 7 is a perspective view of a piston showing another embodiment;

Fig. 8 is a perspective view of a piston showing another embodiment;

Fig. 9 is a perspective view of a piston showing another embodiment;

Fig. 10 is a perspective view of a piston showing another embodiment;

Fig. 11A is a perspective view of a prior art piston; and

Fig. 11B is a partial enlarged cross-sectional view of the piston of Fig. 11A.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] First and second embodiments of the present invention will now be described. The description of the second embodiment will focus on the differences from the first embodiment, and the same reference numbers are used to refer to parts that are similar to those in the first embodiment.

First Embodiment

[0013] As shown in Fig. 1, a front housing member 11 is fixed to the front end of a cylinder block 12, which serves as a center housing member. A rear housing member 13 is fixed to the rear end of the cylinder block 12 through a valve plate 14. The front housing member 11, the cylinder block 12 and the rear housing member 13 form a housing of a compressor.

[0014] A crank chamber 15 is defined between the front housing member 11 and the cylinder block 12. A drive shaft 16 is rotatably supported by the front housing member 11 and the cylinder block 12 to pass through the crank chamber 15. The drive shaft 16 is connected to a vehicle engine (not shown) through a clutch mechanism such as an electromagnetic clutch. Accordingly, engagement of the electromagnetic clutch causes the drive shaft 16 to rotate when the engine is operating.

[0015] A rotor 17 is secured to the drive shaft 16 in the crank chamber 15. A swash plate, which serves as a cam plate, is supported by the drive shaft 16. A hinge mechanism 19 is located between the rotor 17 and the swash plate 18. The swash plate 18 is coupled to the rotor 17 through the hinge mechanism 19 to rotate integrally with the drive shaft 16 and to incline with respect to the drive shaft 16.

[0016] Cylinder bores 12a (only one shown) are formed in the cylinder block 12 about the axis L of the drive shaft 16. A single head piston 20 is accommodated in each cylinder bore 12a. Each piston 20 is coupled to the swash plate 18 through shoes 21. Accordingly, rotation of the drive shaft 16 is converted into reciprocation of each piston 20 in the corresponding cylinder bore 12a.

[0017] A suction chamber 27 and a discharge chamber 28 are defined in the rear housing member 13. The valve plate includes suction ports 29, suction valves 30, discharge ports 31, and discharge valves 32. Refrigerant gas in the suction chamber 27 is drawn into each cylinder bore 12a through the corresponding suction port 29 and the corresponding suction valve 30. Refrigerant gas in each cylinder bore 12a is compressed to reach a predetermined pressure by the reciprocation of the corresponding piston 20 and is discharged into the discharge chamber 28 through the corresponding discharge port 31 and the corresponding discharge valve 28.

[0018] A pressurizing passage 33 connects the discharge chamber 28 to the crank chamber 15. A bleed passage 34 connects the crank chamber 15 to the suction chamber 27. A displacement control valve 35, which is an electromagnetic valve, is located on a pressurizing passage 33. The control valve 35 includes a valve body 35a and a solenoid 35b. The valve body 35a opens and closes the pressurizing passage 33. The solenoid 35b is excited and de-excited to operate the valve body 35a.

[0019] The control valve 35 varies the opening size of the pressurizing passage 33, which varies the flow rate of pressurized refrigerant gas to the crank chamber 15. The pressure in the crank chamber 15 is varied by the amount of refrigerant gas that flows into the crank chamber 15, the amount of blowby gas from the cylinder bores 12a, and the amount of refrigerant gas that flows out of the crank chamber 15 to the suction chamber 27 through the bleed passage 34. Accordingly, the difference between the pressure in the crank chamber 15 and the pressure in the cylinder bores 12a is varied, which varies the inclination of the swash plate 18. This varies the stroke of each piston 20 and adjusts the displacement.

[0020] The structure of each piston 20 will now be described.

[0021] As shown in Fig. 2A through Fig. 2D, each piston 20 includes a head 22 and a neck 23, which are integrally joined. The head 22 is received in the corresponding cylinder bore 12a, and the neck 23 is located in the crank chamber 15. The head 22 is cylindrical and hollow. Each piston 20 is made of aluminum alloy, which is lighter than iron, by forging or casting. A pair of shoe seats 23a are formed in the neck 23. A pair of shoes 21 are received by the shoe seats 23 in the neck 23. The periphery of the swash plate 18 is received by the shoes 21.

[0022] Lubricant oil is contained in the refrigerant gas. Lubricant oil is separated from refrigerant gas in each cylinder bore 12a due to inertia and the difference of specific gravity. A first groove 22b, which is annular in this embodiment, is formed on the peripheral surface 22a of each piston 20. The first groove 22b scrapes lubricant oil from the inner surface of the corresponding cylinder bore 12a when the corresponding piston 22 reciprocates. A second groove 22c, which is longitudinal in this embodiment, extends from the vicinity of the first groove 22b toward the neck 23 in the peripheral surface 22a. The second groove 22c guides lubricant oil from the first groove 22b to the crank chamber 15.

[0023] The first groove 22b is not connected to the second groove 22c. The reason for this is to properly adjust the pressure in the crank chamber 15. That is, it is necessary to reduce the amount of blowby gas that flows from the cylinder bores 12a to the crank chamber 15 through the grooves 22b, 22c.

[0024] In this way, lubricant oil in each cylinder bore 12a is positively supplied to the crank chamber 15 during the reciprocation of the corresponding piston 22. Lubricant oil in the crank chamber 15 lubricates parts such as bearings, shaft seals, swash plate 18, shoes 21, which are located in the crank chamber 15.

[0025] As represented by dots in Fig. 2A, a coating layer C is formed on the peripheral surface 22a of each piston 20. The coating layer C is made of fluororesin such as PTFE (polytetrafluoroethylene), which serves as a solid lubricant. The thickness of the coating layer C ranges from 20 μm to 80 μm. The coating layer C reduces the coefficient of friction of the peripheral surface 22a. Therefore, the durability of each piston 22 and the corresponding cylinder bore 12a is improved.

[0026] As shown in Figs. 2B-2D, the annular groove 22b and the longitudinal groove 22c are not formed in the peripheral surface of a piston workpiece 20W (before the application of the coating layer C). Accordingly, prior to application of the coating layer C, the peripheral surface 22a is a continuous cylindrical surface, which includes areas Y designated for the first and second grooves. The first and second grooves 22b, 22c are formed on the designated areas Y of the peripheral surface 22a after the formation of the coating layer C. In other words, the first and second grooves 22b, 22c are formed by not applying the coating layer to the designated areas Y of the peripheral surface 22a. Therefore, the depth of the first and second grooves 22b, 22c is equal to the thickness of the coating layer C as shown in Fig. 2b.

[0027] As shown in Fig. 2C and 2D, the rims of the first and second grooves have curves R. In Figs. 2B-2D, the thickness of the coating layer C is exaggerated for purposes of illustration.

[0028] A method for forming the first and second grooves 22b, 22c will now be described.

[0029] Fig. 3 diagrammatically shows a roll coating apparatus 41. The roll coating apparatus 41 includes a pan 42, a metal roll 43, a comma roll 44, a transfer roll 45, a work holder 46 and a driving mechanism 47. A coating material Z is stored in the pan 42. The metal roll 43 is partly immersed in the coating material Z. The transfer roll 45 is made of synthetic rubber. The work holder 46 rotatably holds the piston workpiece 20W. The driving mechanism 47 rotates the rolls 43-45 and the work holder 46. The coating material Z includes solid lubricant such as PTFE (polytetrafluoroethylene), adhesive such as binder resin, solvent such as N-methylpyrrolidone, and fillers.

[0030] When the rolls 43-45 and the work holder 46 (for holding the piston workpiece 20W) are rotated by the driving mechanism 47, the coating material Z in the pan 42 adheres to the metal roll 43. The comma roll 44 adjusts the thickness of the coating material Z that has adhered to the metal roll 43. Then, the coating material that has adhered to the metal roll 43 is applied to the transfer roll 45. The coating material Z on the transfer roll 45 is transferred onto the peripheral surface 22a of the workpiece 20W as it is pressed against the transfer roll 45.

[0031] As shown in Fig. 4, a first recess 45b for forming the first groove 22b is annularly formed in the peripheral surface 45a of the transfer roll 45. Also, a second recess 45c for forming the second groove 22c is formed on the peripheral surface 45a of the transfer roll 45. The second recess 45c extends in the axial direction from the vicinity of the first recess 45b. The first and second recesses 45b, 45c do not contact the peripheral surface 22a of the workpiece 20W. That is, the coating material Z is not applied to the designated areas Y of the workpiece 20W that correspond to the first and second recesses 45b, 45c.

[0032] The driving mechanism 47 includes a synchronizing mechanism that synchronizes the rotation of the transfer roll 45 with the rotation of the work holder 46 such that the second recess 45c corresponds to the designated area Y for the second groove 22c.

[0033] After the coating material Z is applied to the peripheral surface 22a of the workpiece 20W, the workpiece 20W is removed from the work holder 46. Then, a solvent in the coating material Z is removed in a drying step and the coating material Z is heated in a heating step. The curves R of the rims of the first and second grooves 22b, 22c are formed by grinding after the burning step.

[0034] The present invention has the following advantages.

(1) The coating layer C is formed on the peripheral surface 22a of the workpiece 20W, except for the designated areas Y for the first and second grooves 22b, 22c. Thus, the first and second grooves 22b, 22c, which have a depth corresponding to the thickness of the coating layer C, are formed at the designated areas Y. In other words, the workpiece 20W has only the designated areas Y for the first and second grooves 22b, 22c, which require no machining. Accordingly, when the head 22 of the workpiece 20W is hollow, the locations where the first and second grooves are formed is no thinner than

the rest of the head 22. As a result, there is no need to increase the thickness of the head 22, which permits the weight of the piston 20 to be reduced.

The depth of the first and second grooves 22b, 22c can be easily varied by varying the thickness of the coating layer C by adjusting the roll coating apparatus 41. When it is necessary to vary the width of the first and second grooves 22b, 22c or to form different grooves as shown in Figs. 7-10, only the transfer roll 45 of the roll coating apparatus 41 needs to be replaced. Therefore, there is no need to vary the workpiece 20 when varying the shape of the grooves. Accordingly, a single mold for molding the pistons 20 can be commonly used regardless of the shape of the grooves.

(2) The first and second grooves 22b, 22c are formed by not applying the coating layer C to the designated areas Y of the workpiece 20W. Since the designated areas Y do not contact the inner surface of the cylinder bore 12a, it is not necessary to apply the coating layer C to the designated areas Y. Accordingly, the coating material Z is not wasted by not applying the coating layer C to the designated areas Y for the first and second grooves 22b, 22c, which reduces the cost of manufacturing the pistons 20.

(3) The coating layer C is formed by transferring the coating material Z to the workpiece 20W. Accordingly, masking, which is required in spray coating, is not necessary. That is, the coating material Z can be applied to only the required parts of the peripheral surface 22a. Accordingly, there is no need for a masking step and the coating material Z is not wasted. Also, since the coating material Z does not scatter in the transferring method, there is no need to form barrier walls around the apparatus 41, which is required for spray coating. In this way, the coating layer C is formed at a relatively low cost, which lowers the cost of the pistons 20.

(4) The curves R are formed on the rims of the first and second grooves 22b, 22c that face in the longitudinal, or axial, direction of reciprocation of each piston 20. Accordingly, peeling of the coating layer C caused by the contact between the inner surface of each cylinder bore and angular corners of coating layer C is avoided, which improves the durability of the coating layer C.

(5) In the following second embodiment, a screen printing apparatus 51 is used. The screen of the screen printing apparatus 51 must be replaced after a certain number of printings. However, the transfer roll 45 of the roll coating apparatus 41 can be continuously used for a relatively long period by periodically cleaning it. Therefore, the operating cost of the roll coating apparatus 41 is relatively low.

Second Embodiment

[0035] Fig. 5 and 6 show a second embodiment of the present invention. In the second embodiment, a screen printing apparatus 51 is used instead of the roll coating apparatus 41 to apply the coating material Z to the peripheral surface of the piston workpiece 20W.

[0036] The screen printing apparatus 51 includes a work holder 52 for holding the workpiece 20W, a screen 53 having a meshed transfer pattern 53a, a driving mechanism 54 for moving the screen 53 linearly and for rotating the work holder 52, and a squeegee 55 that can contact the upper surface of the screen 53.

[0037] To apply the coating material Z to the peripheral surface 22a of the workpiece 20W, the coating material Z is first supplied to the upper surface of the screen 53 by a supplying means (not shown). Then, the driving mechanism 54 rotates the work holder 52 and slides the screen 53. At this time, the squeegee 55 contacts the upper surface of the screen 53, and the screen 53 is held between the squeegee 55 and the peripheral surface 22a. Accordingly, the coating material Z is pressed against the screen 53, passes through the transfer pattern 53a, and is applied to the peripheral surface 22a of the workpiece 20W according to the pattern 53a.

[0038] As shown in Fig. 6, the transfer pattern 53a of the screen 53 does not permit the coating material Z to pass through the screen 53 to the designated areas Y of the workpiece 20W for creating the first and second grooves 22b, 22c. That is, the screen 53 includes a first masking 53b for forming the first (annular) groove 22b and a second masking 53c for forming the second (longitudinal) groove 22c. The driving mechanism has a synchronizing mechanism, which synchronizes the movement of the work holder 52 with that of the screen 53 to cause the second masking 53c to coincide with the designated area Y for the second groove 22c.

[0039] Accordingly, the coating material Z is not applied to the designated areas Y of the workpiece 20W. As a result, the first and second grooves 22b, 22c are formed at the designated areas Y of the work piece 20W after the coating layer C is formed.

[0040] The present embodiment has the advantages (1)-(4) of the first embodiment. The present invention can further be embodied as follows.

[0041] As shown in Fig. 7, the second groove 22c may be connected to the first groove 22b. In this case, oil that was collected by the first groove 22b can be efficiently supplied to the crank chamber 15.

[0042] Other types of grooves may be formed on each piston 20. As shown in Fig. 8, a groove 22d may be formed to adjust the flow of blowby gas from the cylinder bore 12a to the crank chamber 15. The groove 22d connects the corresponding cylinder bore to the crank chamber 15. The groove 22d can be made in the same way as the grooves 22b, 22c of the first embodiment or the second embodiment.

[0043] As shown in Fig. 9, a plurality of longitudinal grooves 22d may be formed according to the manufacturing method of the first embodiment or the second embodiment. The grooves 22d, which adjust the flow of the blowby gas, are formed on the piston 20 at equal angular intervals.

[0044] As shown in Fig. 10, the piston 20 may have two grooves 22d that are inclined with respect to the axis of the piston 20 and intersect one another. The grooves 22d also adjust the flow of blowby gas. Since the grooves 22d are inclined, lubricant oil is scraped from the inner surface of the cylinder bore 12a and supplied to the crank chamber 15 by the grooves 22d.

[0045] The coating layer C may also be formed on the designated areas Y of the workpiece 20W. In this case, the coating layers C that are formed on the designated areas Y must be thinner than the remaining coating layer C. The first and second grooves 22b, 22c are formed by the difference of thickness.

[0046] The coating material Z may be applied to the workpiece 20W by spray coating or dip coating. In these cases, part of the workpiece that does not require coating is masked.

[0047] The coating layer C may be made of molybdenum disulfide that contains graphite or of tin plating. The coating material Z may be any of a number of materials as long as it decreases friction between the piston head 22 and the inner surface of the cylinder bore 12a and improves the durability of the piston 20.

[0048] The present invention may also be applied to a piston having a piston ring. In this case, a ring groove receiving the piston ring may be formed by the difference of thickness of the coating layer C between a designated area for the ring groove and the undesignated area on the surface of the piston workpiece.

[0049] The present invention may also be applied to a single-headed piston in a fixed displacement compressor.

[0050] The present invention may also be applied to a double-headed piston in a fixed displacement compressor.

[0051] In the above mentioned fixed displacement compressor, the pistons may be driven by a wave cam.

[0052] The present invention may also be embodied in the piston of a piston-type pump such as a hydraulic pump or an air pump.

[0053] The present invention may further be embodied in a piston of reciprocation type internal combustion engines.

[0054] It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Therefore, the present examples and embodiments 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 and equivalence of the appended claims.

[0055] A piston (20) having a groove (22b, 22c) that is formed on a surface of a piston workpiece (20W) and a method for forming the groove (22b, 22c) on the piston (20). A head (22) of the piston (20) is accommodated in a corresponding cylinder bore. A first groove (22b, 22c) and a second groove (22b, 22c) are formed on the peripheral surface (22a) of the piston (20). The first groove (22b, 22c) scrapes lubricant oil from the inner surface of the cylinder bore and the second groove (22b, 22c) conveys the oil to the crank chamber. A coating layer (C) is formed on the peripheral surface (22a) of the head (22). The coating layer (C) is not formed on the areas that are designated for the first and second grooves (22b, 22c) on the peripheral surface (22a) of the head (22) of the piston workpiece (20W). Accordingly, the first and second grooves (22b, 22c) have a depth equal to the thickness of the coating layer (C). Since the coating layer (C) is used to form the grooves (22b, 22c), the grooves (22b, 22c) can be formed by a printing process with a printing apparatus.

Claims

1. A piston (20) comprising:

   a piston workpiece (20W) having a head (22) and a neck (23);
   a designated area (Y) on a peripheral surface (22a)of the head (22) of the piston workpiece (20W), wherein a groove (22b, 22c) is formed on the designated area (Y); and
   a coating layer (C), which is formed on the peripheral surface (22a)of the head (22) of the piston workpiece (20W) such that the thickness of the coating layer (C) is thinner in the designated area (Y) than in the other peripheral surface (22a)of the head (22).

2. The piston (20) according to claim 1, wherein the coating layer (C) is not formed on the designated area (Y) for the groove (22b, 22c).

3. The piston (20) according to claim 1 or 2, wherein the coating layer (C) is formed by a solid lubricant material.

4. The piston (20) according to claim 1 or 2, wherein the thickness of the coating layer (C) ranges from 20 to 80 μm.

5. The piston (20) according to claim 1 or 2, wherein the head (22) of the piston workpiece (20W) is hollow.

6. The piston (20) according to claim 1 or 2, wherein rims of the groove (22b, 22c) that face in a direction of piston (20) reciprocation are curved.

7. The piston (20) according to claim 1 or 2, wherein the coating layer (C) is formed by applying a coating material to the piston workpiece (20W) by a roll coating apparatus.

8. The piston (20) according to claim 7, wherein the roll coating apparatus includes:

   a pan (42) for storing the coating material (Z);
   a supply roller (43), part of which is immersed in the coating material in the pan;
   a comma roller (44) for adjusting thickness of the coating material that adhered to the supply roller;
   a transfer roller (44), which is pressed against the comma roller, wherein a recess (45b, 45c) that corresponds to the designated area (Y) is formed in the peripheral surface (45a) of the transfer roller to form the groove (22b, 22c) in the peripheral surface (22a) of the head (22) of the piston (20);
   a work holder (46) for rotatably holding the piston workpiece (20W);
   a driving mechanism (47), which rotates the supply roller, the comma roller, the transfer roller, and the work holder, respectively.

9. The piston (20) according to claim 1 or 2, wherein the coating layer (C) is formed by applying the coating material to the piston (20) work piece by a screen printing apparatus (51).

10. The piston (20) according to claim 9, wherein the screen printing apparatus includes;

   a work holder for rotatably holding the piston workpiece (20W);
   a screen, which has a masking portion (53b, 53c) that corresponds to the designated area (Y) to form the groove (22b, 22c) on the peripheral surface (22a)of the head (22) of the piston workpiece (20W);
   a driving mechanism (54), which moves the screen linearly and rotates the work holder; and
   a squeegee (55), which can contact the upper surface of the screen.

Fig.1

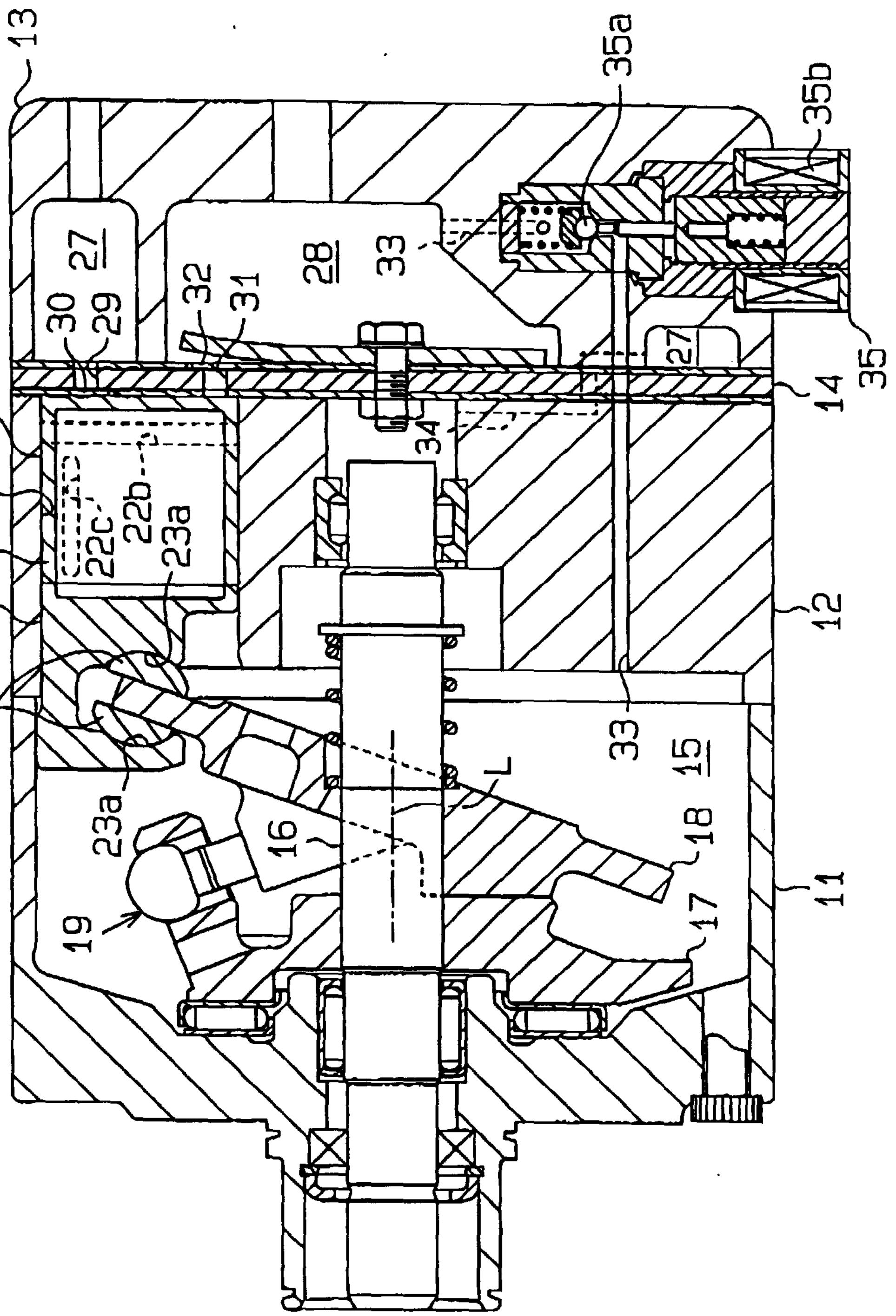
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Fig.2A

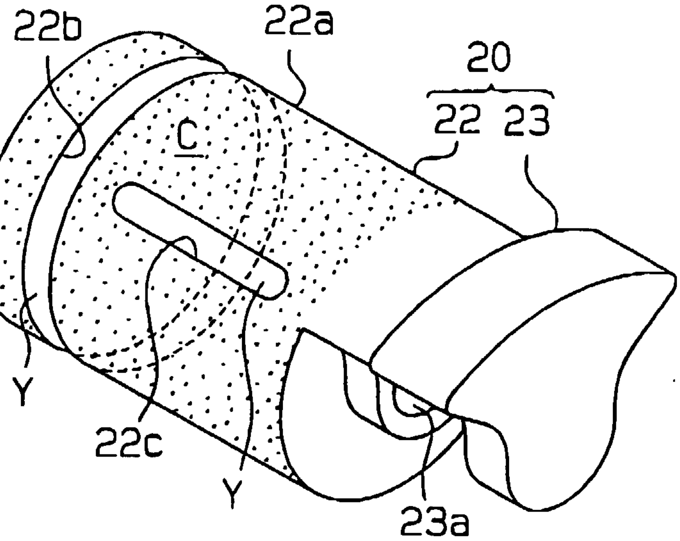


Fig.2C

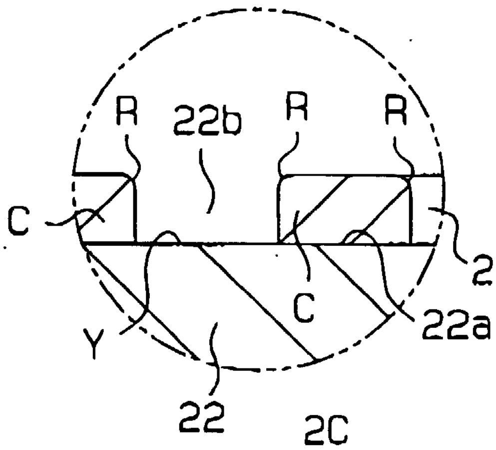
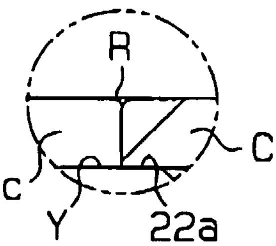


Fig.2D



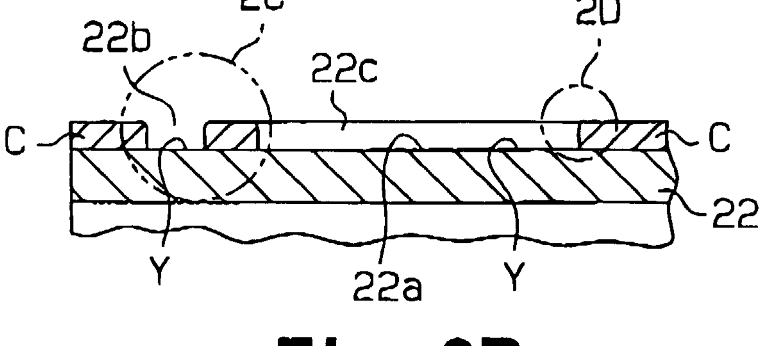


Fig.2B

Fig.3

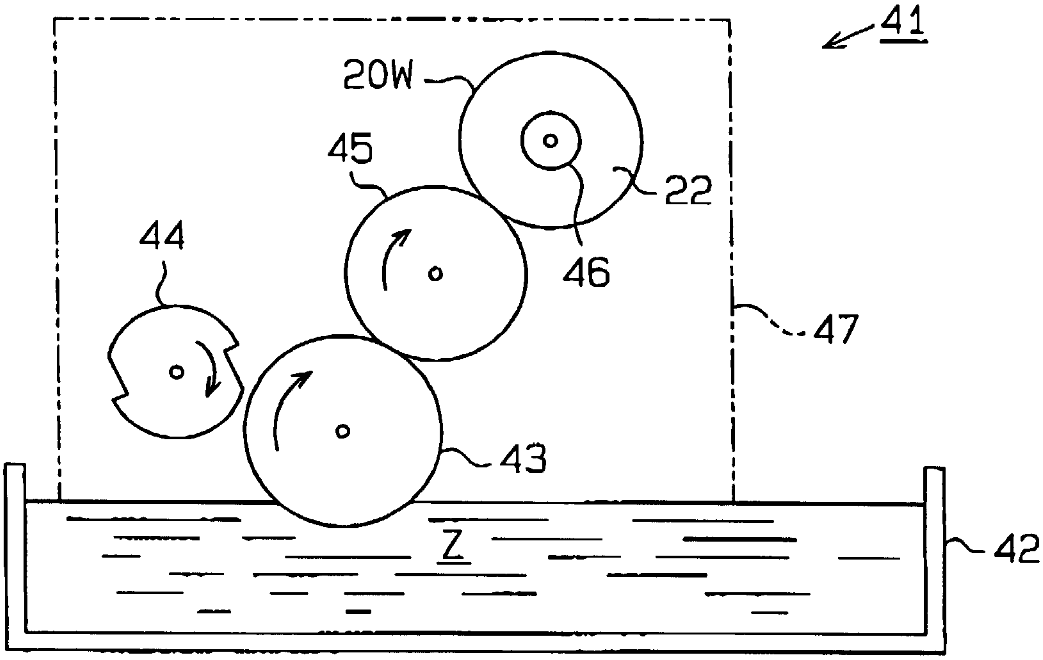


Fig.4

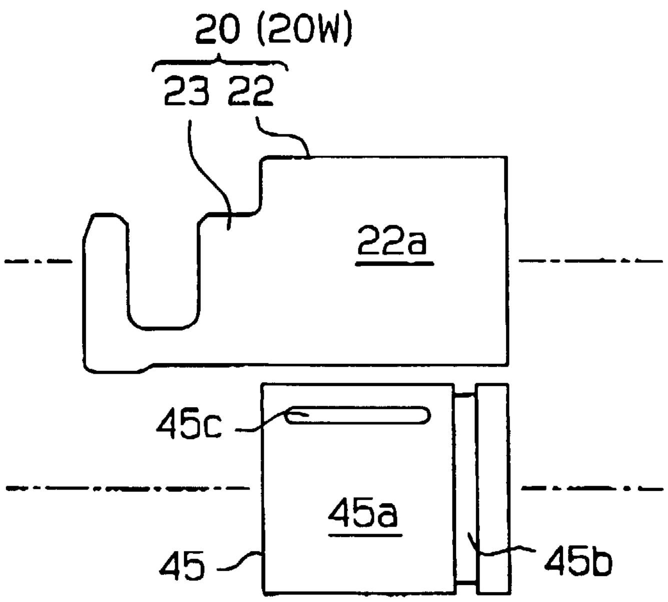


Fig.5

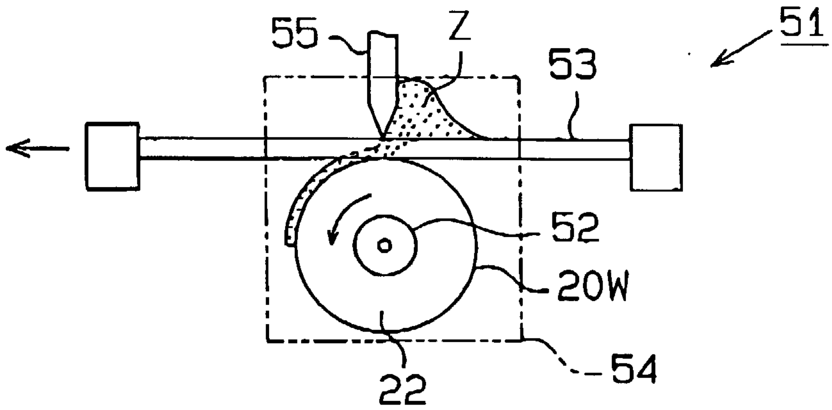


Fig.6

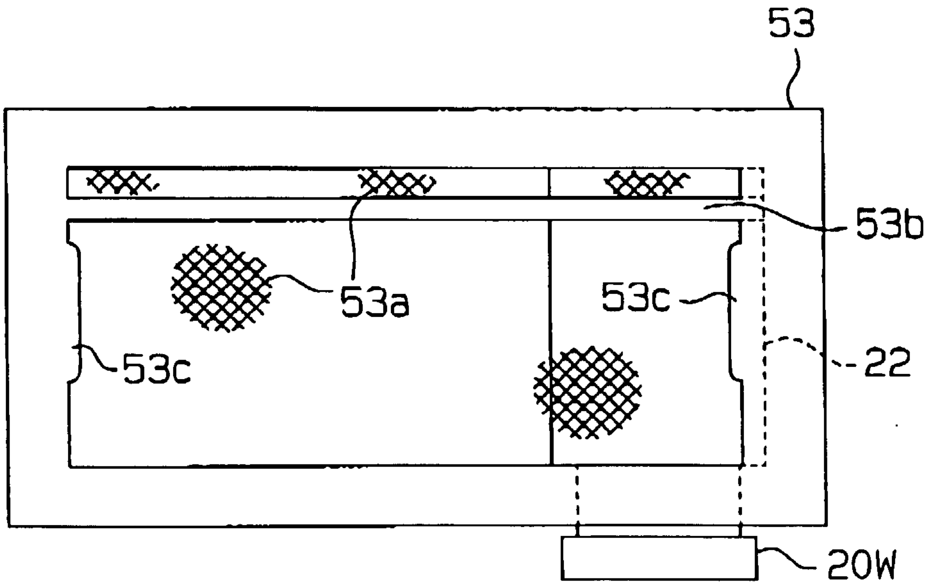


Fig.7

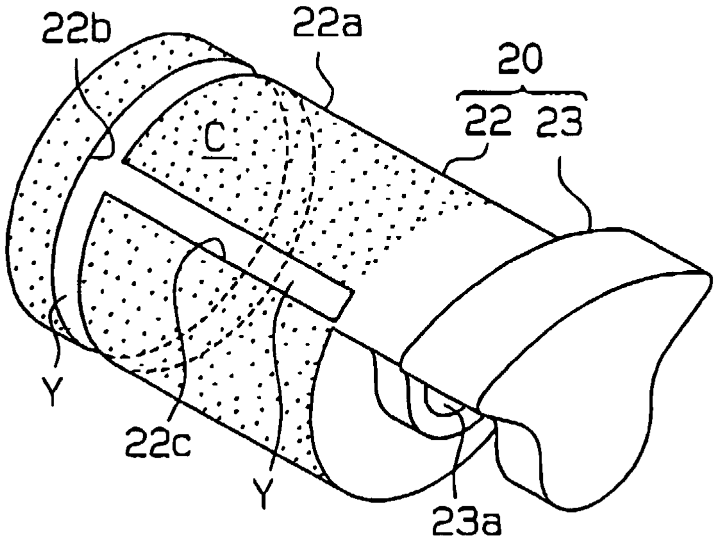


Fig.8

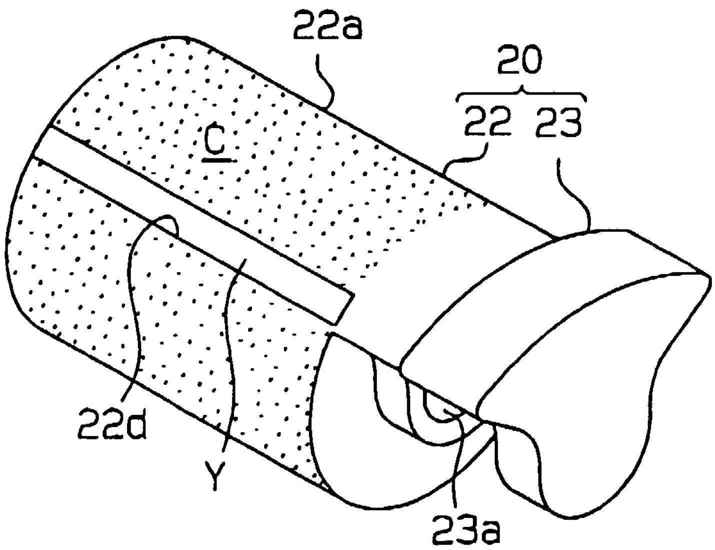


Fig.9

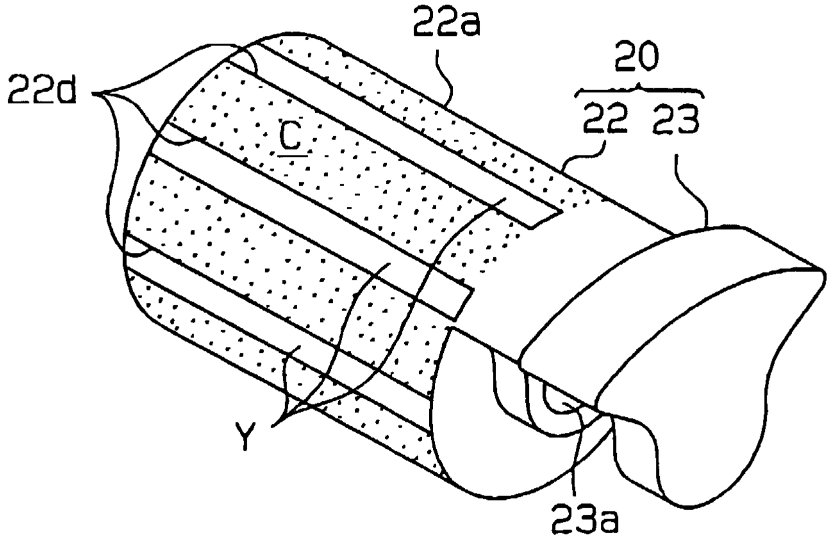


Fig.10

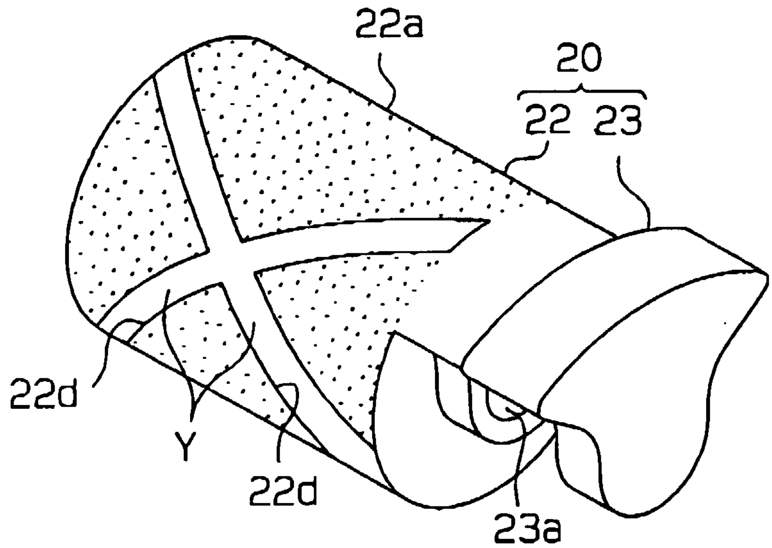


Fig.11A

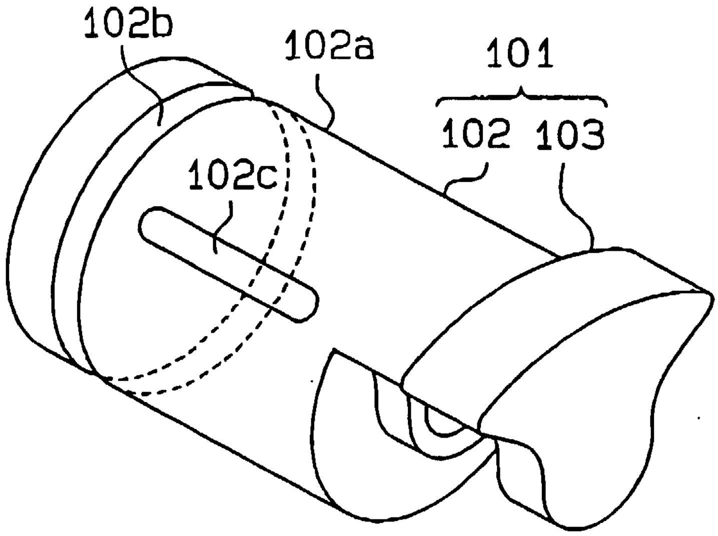


Fig.11B