(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 091 121 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
11.04.2001 Bulletin 2001/15

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

(21) Application number: **00121768.6**

(22) Date of filing: **05.10.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **06.10.1999 JP 28563399**

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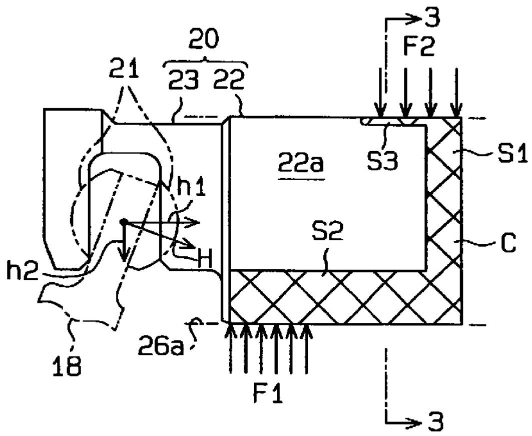
(54) Film coated piston

(57) A coating film (C) is formed on the circumferential surface (22a) of a piston (20). When forming the film (C), film material (Z) is transferred onto only part of the circumferential surface (22a) by a transfer printing machine such as a screen printer (40) or a roll coater (50). Therefore, unlike spray coating, the piston (20) need not be masked, which facilitates the application of the film material (Z). Further, the film material (Z) is not wasted.

Fig.2



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a piston suitable for a compressor, and more particularly, to a piston that is coated with a coating film.

[0002] In a typical compressor, a refrigerant gas is compressed by reciprocation of pistons in cylinder bores. The circumferential surfaces of the pistons wear since they slide against the inner walls of the cylinder bores. To prevent such abrasion, it has been proposed to apply an abrasion-resistant film on the circumferential surface of each piston.

[0003] As a method of applying a coating material, spray coating is generally known. However, in spray coating, portions that need not be coated must be masked. The procedures of masking and unmasking are intricate. Therefore, the spray coating method makes the manufacture of pistons more difficult intricate.

SUMMARY OF THE INVENTION

[0004] It is an objective of the present invention to achieve easily application of a coating material on a piston.

[0005] To achieve the foregoing and other objective and in accordance with the purpose of the present invention, a piston having a circumferential surface that contacts the inner wall of a cylinder bore is provided. Only part of the circumferential surface is coated with a transferred film.

[0006] The present invention may also be embodied as a method for forming a coating film on a circumferential surface of a piston that contacts the inner wall of a cylinder bore. The method includes transferring film material to only part of the circumferential surface.

[0007] Other aspects and advantages of the 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

[0008] 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:

Figure 1 is a cross-sectional view of the variable displacement compressor according to a first embodiment of the present invention;

Figure 2 is a side elevation of a piston of the compressor shown in Figure 1;

Figure 3 is a cross-sectional view taken along the line 3-3 in Figure 2;

Figure 4 is a diagrammatic view showing a screen printer;

Figure 5 is a plan view of a screen employed in the screen printer shown in Figure 4;

Figure 6 is a diagrammatic view of a roll coater of a second embodiment of the present invention;

Figure 7 is a perspective view of a transferring roll employed in the roll coater shown in Figure 6;

Figure 8(a) is a side elevation view of a piston in another embodiment of the present invention;

Figure 8(b) is a cross-sectional view taken along the line 8(b)-8(b) in Figure 8(a);

Figure 8(c) is a plan view showing a screen employed for forming a film on the piston shown in Figure 8(a);

Figure 9(a) is a side elevation of a piston in another embodiment of the present invention;

Figure 9(b) is a cross-sectional view taken along the line 9(b)-9(b) in Figure 9(a); and

Figure 9(c) is a plan view showing a screen employed for forming a film on the piston shown in Figure 9(a).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] As shown in Figure 1, a front housing member 11 is connected to the front end of a cylinder block 12, which is also a center housing member. A rear housing member 13 is connected to the rear end of the cylinder block 12 through a valve plate assembly 14. The front housing member 11, the cylinder block 12 and the rear housing member 13 constitute a compressor housing.

[0010] A crank chamber 15 is defined by the front housing member 11 and the cylinder block 12. A drive shaft 16, which passes through the crank chamber 15, is rotatably supported by the front housing member 11 and the cylinder block 12. The drive shaft 16 is connected to a vehicular engine (not shown), or external drive source, through a clutch mechanism such as an electromagnetic clutch.

[0011] A rotor 17 is fixed to the drive shaft 16 within the crank chamber 15. A swash plate 18 is supported on the drive shaft 16 such that the swash plate 18 inclines with respect to the axis L of the drive shaft 16. A hinge mechanism 19 pivotally connects the swash plate 18 to the rotor 17. The hinge mechanism 19 rotates the swash plate 18 integrally with the rotor 17 and guides the inclination of the swash plate 18 with respect to the drive shaft 16.

[0012] A plurality of cylinder bores 26 (only one cylinder bore is shown in Figure 1) is defined in the cylinder block 12. The bores 26 surround the axis L of the drive shaft 16. A single-head piston 20 is contained in each cylinder bore 26. Each piston 20 is connected to the swash plate 18 through a pair of shoes 21. Rotation of the drive shaft 16 is converted through the swash plate 18 and the shoes 21 into reciprocating motion of the pistons 20.

[0013] A suction chamber 27 and a discharge chamber 28 are defined in the rear housing member 13. A suction port, an suction valve 30, a discharge port 31, and a discharge valve 32 are defined in the valve plate assembly 14 for each cylinder bore 26. When the piston 20 moves from the top dead center position to the bottom dead center position, a refrigerant gas is drawn from the suction chamber 27 into the cylinder bore 26 through the suction port 29 and the suction valve 30. When the piston 20 moves from the bottom dead center position to the top dead center position, the refrigerant gas is compressed in the cylinder bore 26 and is discharged through the discharge port 31 and the discharge valve 32 into the discharge chamber 28.

[0014] A supply passage 33 connects the discharge chamber 28 to the crank chamber 15 to conduct refrigerant gas from the discharge chamber 28 to the crank chamber 15. An air bleed passage 34 connects the crank chamber 15 to the suction chamber 27 to conduct refrigerant gas from the crank chamber 15 into the suction chamber 27. A control valve mechanism 35, which is an electromagnetic valve, is located in the supply passage 33. The control valve 35 is provided with a valve element 35a for regulating the supply passage 33 and a solenoid 35b for operating the valve element 35a.

[0015] The control valve 35 adjusts the valve opening of the supply passage 33 to change the flow rate of high-pressure refrigerant gas conducted from the discharge chamber 28 to the crank chamber 15. The variation of the pressure in the crank chamber 15 changes the inclination angle of the swash plate 18. This changes the stroke of the piston 20 and the displacement of the compressor.

[0016] Next, the piston 20 will be described specifically. As shown in Figures 1 to 3, the piston 20 has a hollow cylindrical head 22 that fits in the cylinder bore 26 and a skirt 23 that extends from the head 22 into the crank chamber 15. The skirt 23 functions as a connecting section that connects the head 22 to the swash plate 18. That is, the skirt 23 has a pair of opposed bearing seats 23a for receiving the shoes 21, respectively. The swash plate 18 fits between the shoes 21 of each pair.

[0017] Since the cylindrical head 22 is hollow, the pistons 20 are light and have lower inertia. This reduces the force acting on the skirt 23 and improves the durability of the pistons 20. It is essential that the stroke of each piston 20 be changed smoothly as the inclination angle of the swash plate 18 is changed. Since the pistons 20 used in this embodiment are light and have low inertia, the pistons 20 have a smaller effect on the motion of changing the inclination angle of the swash plate 18, which improves the response of adjusting the displacement.

[0018] As shown in Figures 2 and 3, an abrasion-resistant coating film C is formed on part of the circumferential surface 22a of the head 22. The circumferential surface 22a includes a coated area and an uncoated area. The coating film C is based on a solid lubricant such as PTFE (polytetrafluoroethylene) and has a thickness of 20 to 40 μm. The thickness of the coating film C depicted in Figure 3 is exaggerated.

[0019] The coated area includes a circumferential region S1, which surrounds the head 22, and two local regions S2 and S3, which extend axially from the region S1 toward the skirt 23. The circumferential region S1 is located in the distal end of the head 22. The circumferential region S1 contacts the inner wall 26a of the cylinder bore 26 along the entire piston circumference to seal the clearance between the head 22 and the inner wall 26a.

[0020] The shapes of the local regions S2 and S3 are as follows. As shown in Figure 3, assume an imaginary line D intersects the central axis L of the drive shaft 16 and the central axis B of the piston 20. The line D intersects the circumferential surface 22a at intersection points P1 and P2. The point P1, which is located farther from the central axis L of the drive shaft 16 than the point P2, is referred to as the twelve o'clock position. When the piston 20 is viewed from the side where the rotation R of the drive shaft 16 is clockwise, that is, when the piston 20 is viewed from the left side of Figure 1, the local region S2 is located between the vicinity of the four o'clock position and vicinity of the eight o'clock position, and the local region S3 is located around the twelve o'clock position. The local region S2 extends axially from the distal end to the proximal end of the head 22. The local region S3 extends for a relatively short distance from the distal end of the head 22, as shown in Figure 2. The left end of the local region S3 is not angled but is rounded (as viewed from the perspective of Figure 2).

[0021] As shown in Figure 2, when the piston 20 is located at the top dead center position, a great compressive reaction force acts on the piston 20. The swash plate 18 receives this compressive reaction force. Thus, the piston 20 receives a reaction force H corresponding to the compressive reaction force from the swash plate 18, and the reaction force H is perpendicular to the swash plate 18. The reaction force H includes an axial component force h1, which is parallel to the axis B of the piston 20, and a component force h2, which is radial. The radial component force h2 tends to tilt the piston 20.

[0022] Therefore, the film of the local region S2 is pressed against the inner wall 26a of the cylinder bore 26 with a force corresponding to the radial component force h2. In other words, the local region S2 receives from the inner wall 26a of the cylinder bore 26 a lateral reaction force F1 corresponding to the component force h2. The local region S3 receives from the inner wall 26a of the cylinder bore 26 a lateral reaction force F2 corresponding to the component force h2. The local regions S2 and S3 thus cover the specific zones of the circumferential surface 22a at which the lateral forces generated by the compressive action of the piston 20 act.

[0023] The coating film C formed on the local regions S2 and S3 resists abrasion of the circumferential surface 22a at the locations where the lateral forces are greatest. Further, the coating film C formed on the local regions S2 and S3 not only enables smooth and stable reciprocation of the piston 20 but also prevents the piston 20 from tilting within the cylinder bore 26. This prevents the coating film C from peeling. The coating film C of the annular region S1 forms a seal between the inner wall 26a of the cylinder bore 26 and the head 22.

[0024] As described above, the coating film C is formed only at necessary locations. Thus, there is no waste of the coating material, and the weight increase of the piston 20 attributed to the film C is minimized. Thus, the piston 20 is light, durable and inexpensive to manufacture.

[0025] Next, a process for forming a coating film C on the piston 20 will be described. In this embodiment, a transfer printing machine is used for forming a coating film C. Figure 4 shows a screen printer 40 as the transfer printing machine. The screen printer 40 is provided with a work holder 41, a screen 43 having a meshed portion 42, a drive section 44 and a squeegee 45. The work holder 41 holds an uncoated piston 20 (hereinafter referred to as piston workpiece 20′). The drive section 44 drives the screen 43 horizontally and rotates the work holder 41. The squeegee 45 can be brought into contact with and spaced away from the upper surface of the screen 43.

[0026] As shown in Figure 5, the meshed portion 42 of the screen 43 for forming a transfer pattern has a shape conforming to the circumferential region S1 and the local regions S2 and S3. In other words, the shape of the meshed portion 42 shows the circumferential region S1 and the local regions S2 and S3 laid out in a plane. The meshed portion 42 includes a strip portion 42a, which corresponds to the circumferential region S1, and projection portions 42b and 42c, which correspond to the local regions S2 and S3, respectively. The strip portion 42a extends in the direction in which the screen 43 is fed. The projecting portions 42b and 42c extend perpendicular to the direction in which the screen 43 is fed.

[0027] As shown in Figure 4, a film material Z is applied to the upper surface of the screen 43 from a feeding unit (not shown). The film material Z is based on a solid lubricant such as PTFE (polytetrafluoroethylene) and further includes an adhesive such as a binder resin, a solvent such as N-methylpyrrolidone, and a filler.

[0028] Next, the drive section 44 turns a piston workpiece 20' with the work holder 41 and feeds the screen 43 horizontally. The squeegee 45 is located at a position where it is brought into contact with the upper surface of the screen 43, so that the screen 43 is nipped between the squeegee 45 and the outer circumferential surface 22a of the piston workpiece 20′. Thus, the squeegee 45 presses the film material Z against the screen 43 to transfer the material Z through the meshed portion 42 shown in Figure 5 onto the outer circumferential surface 22a of the piston workpiece 20′ . As a result, the film material Z is applied to the outer circumferential surface 22a in a pattern corresponding to the meshed portion 42.

[0029] The coated piston workpiece 20′ is dismounted from the work holder 41, which is followed by a drying step, in which a solvent in the film material Z is removed, a baking step, in which the film material Z is heated, and an adjustment step, in which the thickness of the film material Z is adjusted by grinding or the like. The completed piston 20 has a coating film C as shown in Figure 2.

[0030] In this embodiment, the film material Z is transferred to the piston 20 by the screen printer 40. The film material Z can be applied easily to the desired part of the outer circumferential surface 22a by choosing the pattern of the meshed portion 42 of the screen employed in the screen printer 40. Thus, there is no need to mask the piston 20, and the operation of applying the film material Z is simplified. In addition, since the film material Z is not wasted, this manufacturing method is less expensive than a spraying method.

[0031] Figures 6 and 7 show a second embodiment of the present invention. This embodiment is different from that shown in Figures 1 to 5 in that the film material Z is transferred to the piston 20 using a roll coater 50.

[0032] As shown in Figure 6, the roll coater 50 is provided with a material pan 51, a metal roll 52, a comma roll 53, a transfer roll 55, a work holder 56 and a drive section 57. The material pan 51 stores film material Z. The metal roll 52 is partly dipped in the film material Z. The transfer roll 55 is made of synthetic rubber and has a raised area 54 forming a transfer pattern. The work holder 56 holds a piston workpiece 20′. The drive section 57 rotates the rolls 52, 53 and 55 and the work holder 56.

[0033] As shown in Figure 7, the raised area 54 has a shape conforming to the circumferential region S1 and the local regions S2 and S3 of the piston 20. The raised area 54 includes a strip portion 54a, which corresponds to the circumferential region S1 and projecting portions 54b and 54c, which correspond to the local regions S2 and S3, respectively. The strip portion 54a extends about the entire periphery of the transfer roll 55. The projecting portions 54b and 54c extend from the strip portion 54a in the axial direction of the transfer roll 55. The shape that results when the raised area 54 laid out a plane matches the shape of the meshed portion 42 shown in Figure 5.

[0034] When the drive section 57 rotates the rolls 52, 53 and 55 and the work holder 56, the film material Z applied to the metal roll 52 is leveled by the comma roll 53 to have a predetermined thickness. The film material Z on the metal roll 52 is then applied to the raised area 54 of the transfer roll 55. Subsequently, the film material Z on the raised area 54 is transferred to the circumferential surface 22a of the piston workpiece 20′ as the raised area 54 contacts the circumferential surface 22a. Thus, the film material Z is applied to the circumferential surface 22a to form a pattern corresponding to the raised area 54.

[0035] Subsequently, as in the embodiment shown in Figures 1 to 5, the film is dried and baked. Finally, the film thickness is adjusted to complete the piston 20 shown in Figure 2.

[0036] The advantages of the embodiment shown in Figures 1 to 5 are also achieved.

[0037] The present invention can be further embodied as follows.

[0038] The coated area on the piston 20 is not limited to that shown in Figure 2 but can be changed as desired. For example, as shown in Figures 8(a) and 8(b), the end of the local region S2 may be rounded. Such a shape helps the piston 20 to reciprocate smoothly within the cylinder bore 26. Figure 8(c) shows a screen 43 provided with a meshed portion 42 conforming to the coated area shown in Figure 8(a).

[0039] In an embodiment shown in Figures 9(a) and 9(b), the circumferential region S1 is divided into two annular zones. The gap between the two annular zones functions to permit passage of refrigerant gas or to retain lubricating oil. Figure 9(c) shows a screen 43 provided with a meshed portion 42 conforming to the coated area shown in Figure 9(a).

[0040] The present invention can be applied to any type of compressor containing pistons including fixed displacement compressors, variable displacement compressors and double-head piston compressors.

[0041] 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 of the appended claims.

[0042] A coating film (C) is formed on the circumferential surface (22a) of a piston (20). When forming the film (C), film material (Z) is transferred onto only part of the circumferential surface (22a) by a transfer printing machine such as a screen printer (40) or a roll coater (50). Therefore, unlike spray coating, the piston (20) need not be masked, which facilitates the application of the film material (Z). Further, the film material (Z) is not wasted.

Claims

1. A piston having a circumferential surface (22a) that contacts the inner wall (26a) of a cylinder bore (26), characterized in that only part of the circumferential surface (22a) is coated with a transferred film (C).

2. The piston according to claim 1 characterized in that the piston (20) is used for a compressor, wherein the compressor includes a swash plate (18), which is supported by a drive shaft (16) in a crank chamber (15), wherein the piston (20) is coupled to the swash plate (18) by shoes (21), and wherein the swash plate (18) converts rotation of the drive shaft (16) to reciprocation of the piston (20).

3. The piston according to claims 1 or 2 characterized in that the coating film (C) includes an annular first portion located in the vicinity of the head end of the piston (20) and a second portion that extends from the first portion in the axial direction of the piston (20).

4. The piston according to claim 3 characterized in that the second portion is located on a region of the circumferential surface (22a) that receives relatively great force.

5. The piston according to claims 3 or 4 characterized in that the second portion includes a rounded distal end.

6. The piston according to claim 2 characterized in that the coating film (C) includes an annular first portion, which is located in the vicinity of the head end of the piston (20), and second and third portions that extend from the first portion in the axial direction of the piston (20), and wherein an imaginary radial line (D) intersects the axis (L) of the drive shaft (16) and the axis (B) of the piston (20), a point (P1) of intersection of the imaginary radial line (D) and the circumferential surface (22a) that is farthest from the axis (L) of the drive shaft (16) is defined as a twelve o'clock position, and wherein, when viewed from an end at which the drive shaft (16) appears to rotate clockwise, the second portion is located substantially between the four o'clock position and the eight o'clock position, and the third portion is located in the vicinity of the twelve o'clock position.

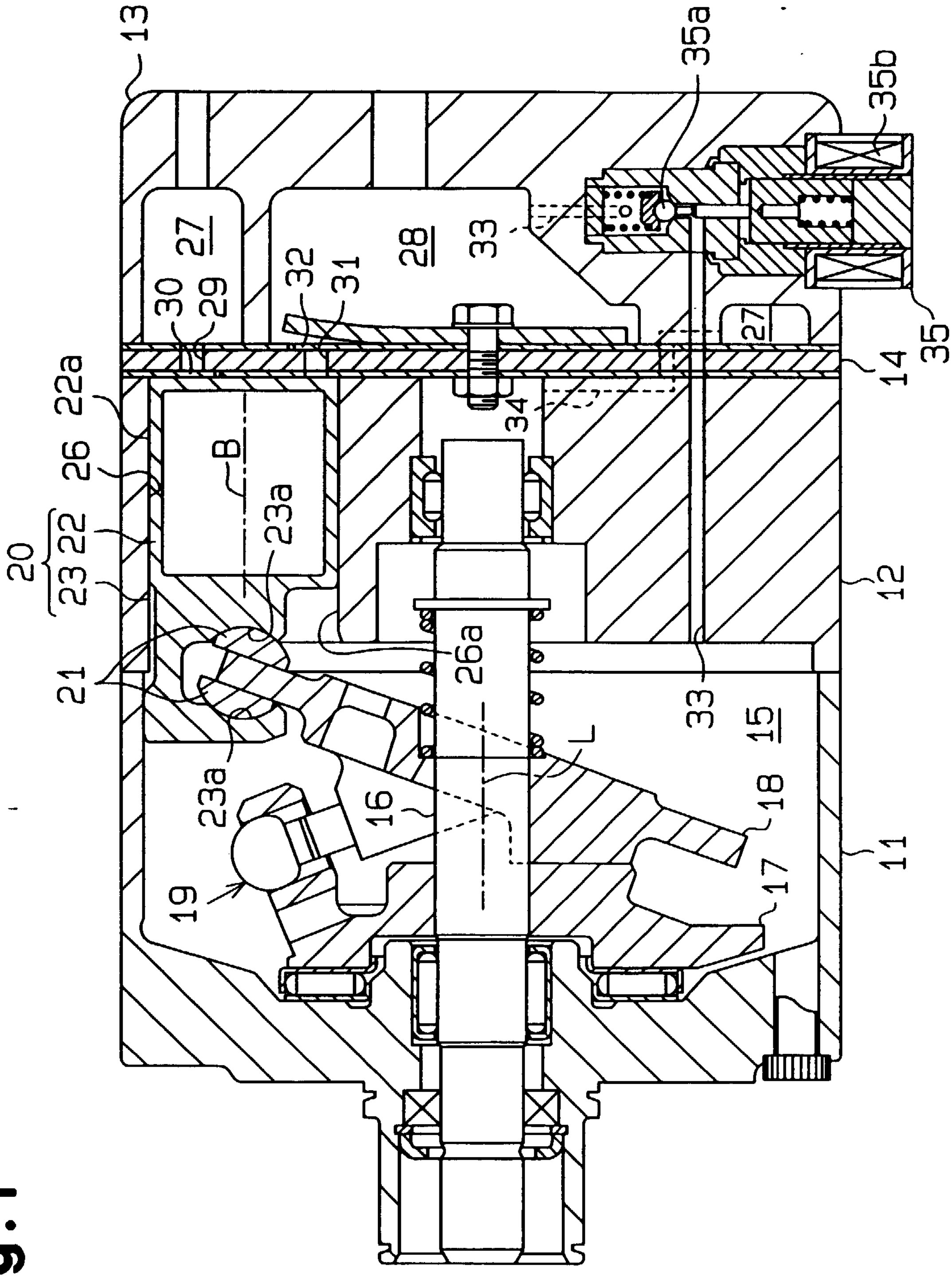
7. The piston according to any one of claims 3 to 6 characterized in that the first portion is divided into two annular sections, and wherein the annular sections are spaced by a predetermined axial distance.

8. A method for forming a coating film (C) on a circumferential surface (22a) of a piston (20) that contacts the inner wall (26a) of a cylinder bore (26), characterized by transferring film material (Z) to only part of the circumferential surface (22a).

9. The method according to claim 8 characterized in that the film material (Z) is transferred by a screen printer (40).

10. The method according to claim 8 characterized in that the film material (Z) is transferred by a roll

coater (50).



13
35a
35b
27
28
33
30
29
32
31
22a
26
B
23a
20
23
22
27
35
14
34
12
21
26a
33
15
L
23a
16
18
19
17
11

Fig.1

Fig.2

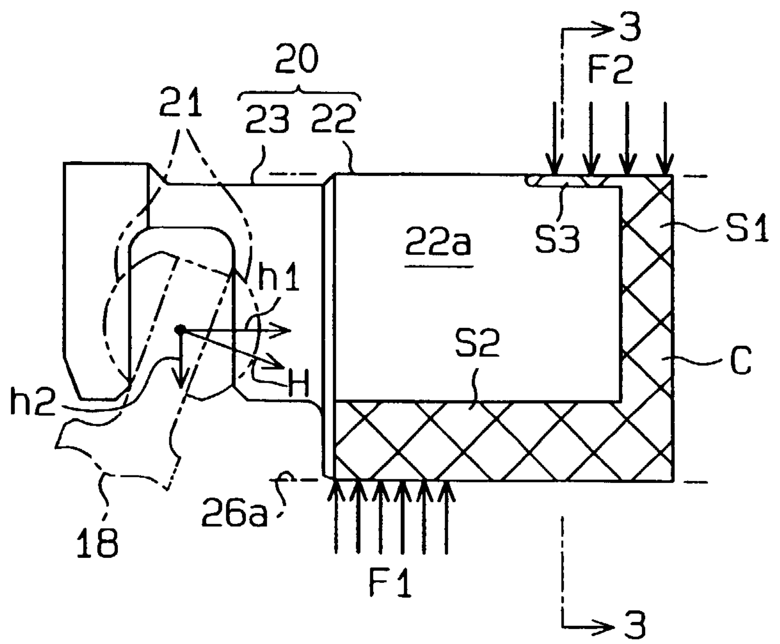

20
21
23 22
3
F2
22a
S3
S1
h1
S2
C
H
h2
26a
18
F1
3

Fig.3

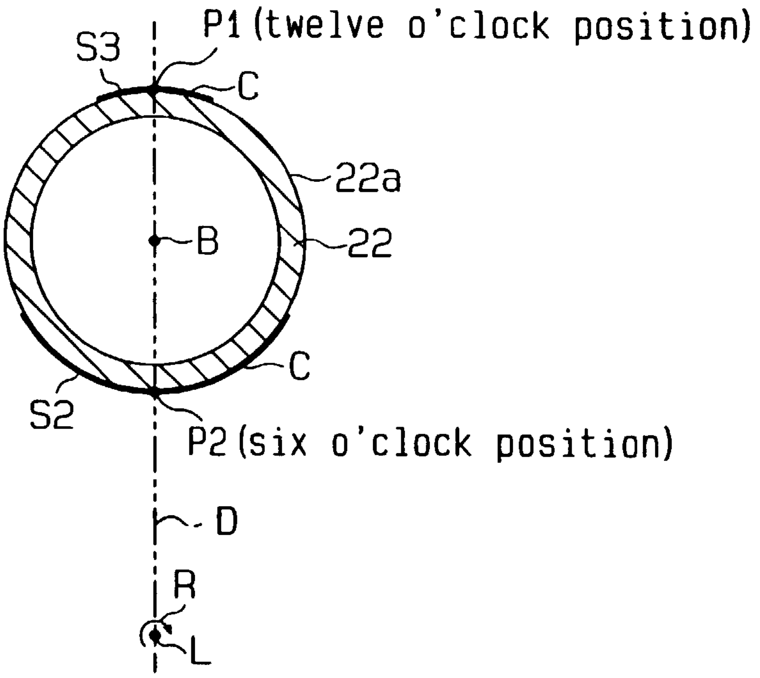

S3
P1 (twelve o'clock position)
C
22a
B
22
C
S2
P2 (six o'clock position)
D
R
L

Fig.4

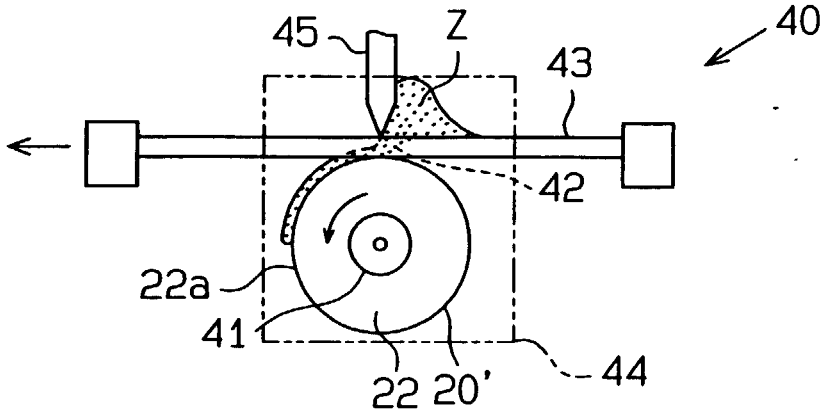


Fig.5

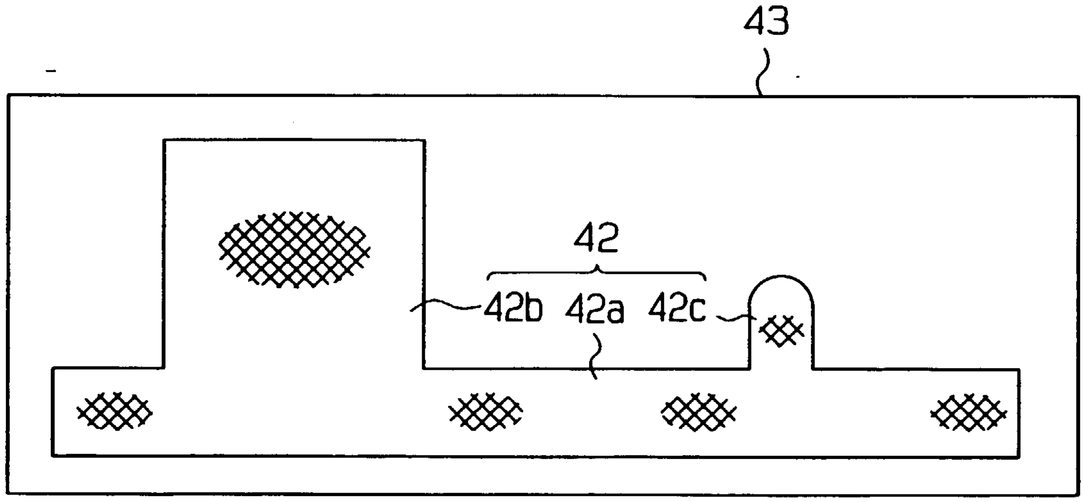


Fig.6

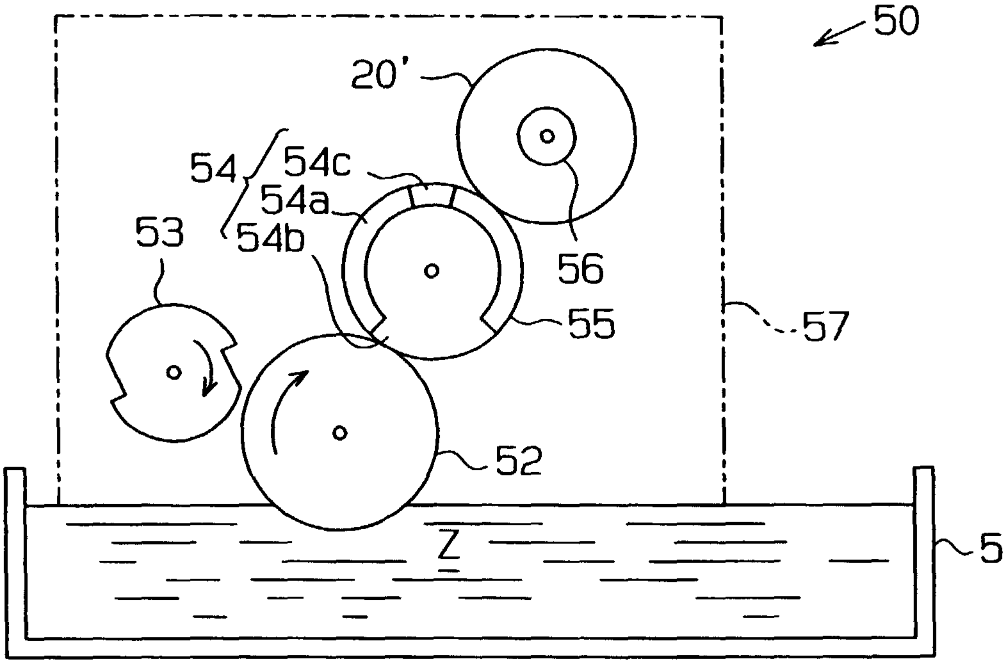


Fig.7

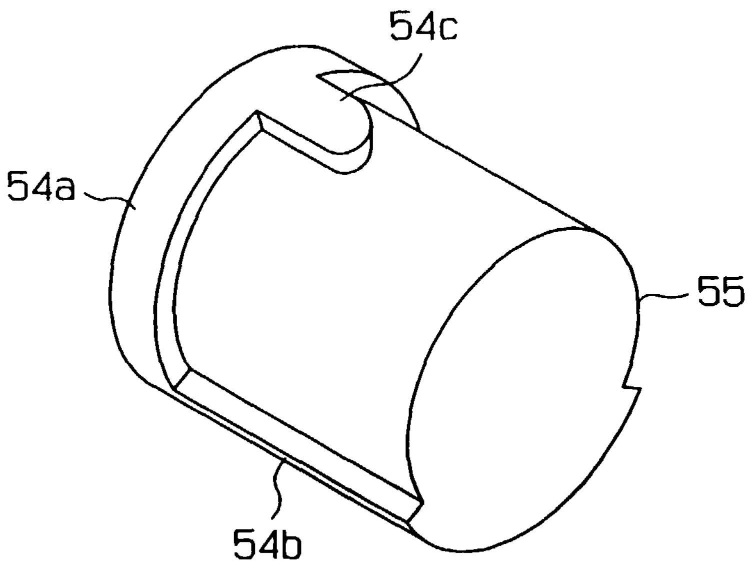


Fig.8(a)

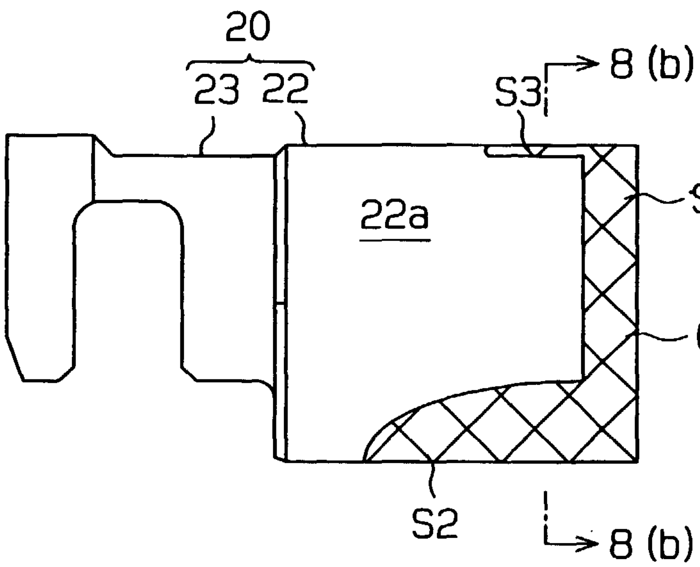


Fig.8(b)

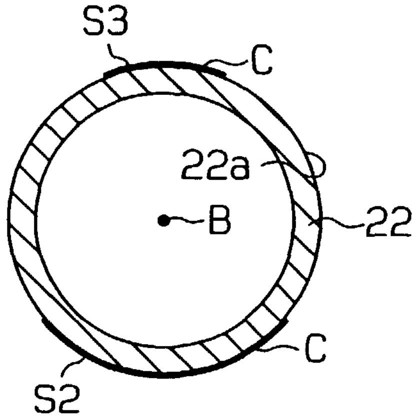


Fig.8(c)

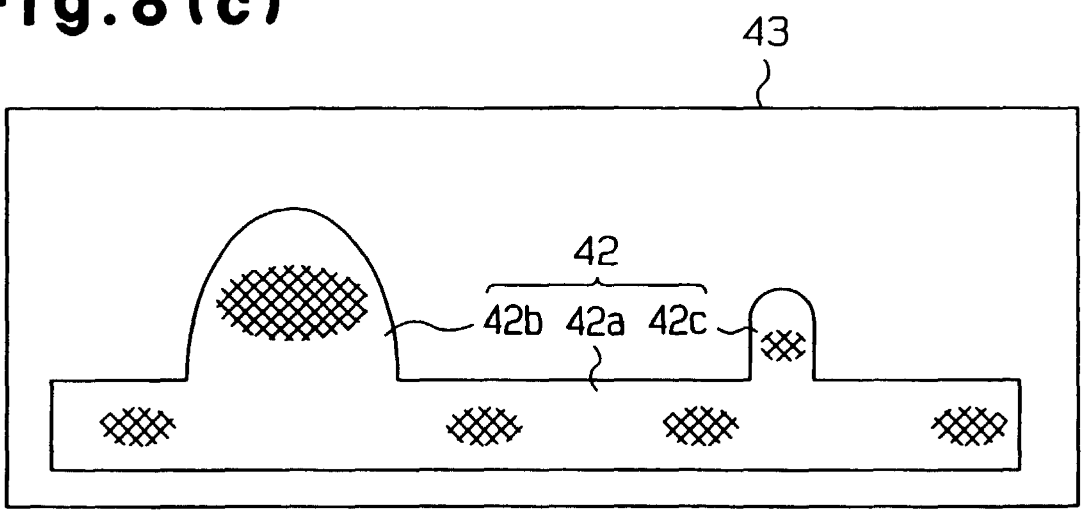


Fig.9(a)

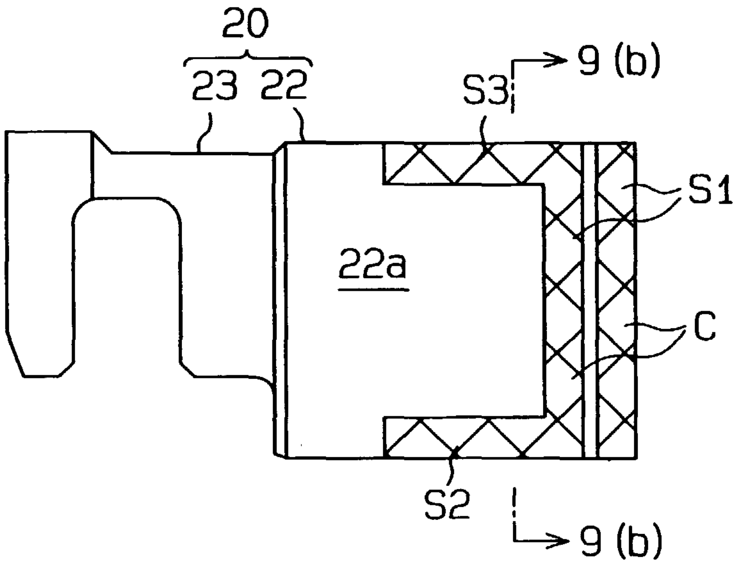


Fig.9(b)

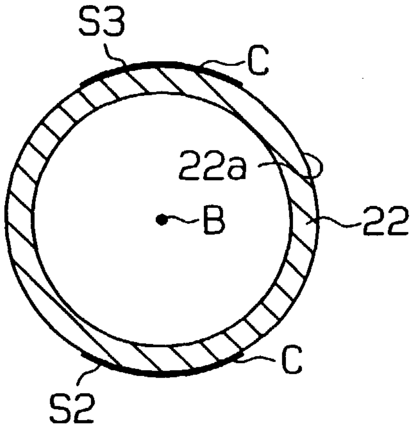


Fig.9(c)