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(54) **Oil free screw compressor**

Ölfreier Schraubenverdichter

Compresseur à vis sec

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an oil free screw compressor in which oil is prevented from entering a compression chamber formed by a pair of male screw rotor and a female screw rotor, such as disclosed in US5413467.

2. Description of the Related Art

[0002] There are two types of screw compressors in which a pair of screw rotors are combined to form a compression chamber. One is an oil-injected screw compressor in which a lubricating oil is supplied to a compression chamber in order to cool the compressor and to enable the smooth drive of the pair of rotors. The other is an oil free screw compressor which avoids the contact of a pair of rotors by driving them via timing gears and prevents oil from entering a compression chamber.

[0003] In industrial fields such as electronics, food, and chemistry where mixing of oil is regarded unfavorable, there is a great demand for oil free screw compressors. However, it is said that an electric power expense of an air compressor occupies as much as about 25% of electric power expenses in a plant facility. Therefore, a compressor with little power consumption and high energy efficiency is called for.

[0004] Japanese Patent Unexamined Publication No. 63-45488 discloses an example of the conventional oil free screw compressor described above. According to the screw compressor of Japanese Patent Unexamined Publication No. 63-45488, in order to avoid a problem that the power of the compressor increases when part of the cooled discharge gas is returned to a suction side, at a portion closer to the discharge port side than a position of a wall part of a rotor chamber in communication with the discharge port and, at the same time, in a space of the rotor chamber near the discharge port or at the discharge port immediately after the start of discharging, branch passages branched on the exit side of discharge gas cooling means in the discharge passage is allowed to merge.

[0005] Further, although it is not an oil free screw compressor, an example of the oil-injected screw compressor is described in Japanese Patent Unexamined Publication No. 2008-82273. According to the compressor of Japanese Patent Unexamined Publication No. 2008-82273, in order to suppress the increase in power consumption etc., a recess is formed in a wall face opposed to an end face on the rotor discharge side of a casing. Further, a compression chamber is brought into communication with the recess immediately before the compression chamber is isolated from the discharge port and such communication is kept until a volume of the compression

chamber becomes substantially zero.

[0006] In the oil free screw compressor according to Japanese Patent Unexamined Publication No. 63-45488, a discharged gas is cooled at a position as close as possible to the discharge port so that a discharge temperature is kept low and a rise in suction pressure is suppressed to reduce power. However, in the oil free screw compressor of Japanese Patent Unexamined Publication No. 63-45488, enough consideration has not been given to an increase in power caused by excessive compression etc. resulting from the working gas remaining near the discharge port, namely, the excessive compression etc. caused by a complex shape of the discharge port.

[0007] Moreover, the oil-injected screw compressor according to Japanese Patent Unexamined Publication No. 2008-82273 permits a lubricating oil given to bearings to enter the compression chamber, and oil is separated outside the compressor. Therefore, a main body of the compressor is simply structured. On the other hand, in order to prevent the oil from entering the compression chamber, the oil free screw compressor requires a highly efficient shaft sealing apparatus. As a result, since the rotor becomes longer, in order to suppress vibration in a high-speed rotating apparatus, a length of the casing in a depth direction of the end face is considerably restricted.

[0008] Further, when the invention as it is disclosed by Japanese Patent Unexamined Publication No. 2008-82273 is applied to the oil free screw compressor, according to a position or a shape of a slot formed in a depth direction of the end face of the rotor, a volume of the compressed air on the discharge side leaking into the compression chamber being ready for suction may be increased. When the amount of leak increases, performance of the oil free screw compressor is naturally degraded.

SUMMARY OF THE INVENTION

[0009] The present invention is made in view of the above problems of the conventional art. Therefore, an object of the present invention is to prevent the problems, in an oil free screw compressor, such as excessive compression etc. which might be caused by closing of the discharge port before a volume of the compression chamber becomes zero. Another object of the present invention is to suppress an increase in power consumption caused by the excessive compression etc. or an excessive rise in temperature of the compressed air. Still another object of the present invention is to realize a discharge port capable of efficiently discharging a compressed air from the discharge port until the timing with which the volume of the compression chamber becomes zero with use of inexpensive manufacturing means. The present invention aims to achieve at least one of the objects described above.

[0010] In order to achieve the above described object,

according to a feature of the present invention, there is provided an oil free screw compressor according to claim 1, which may in particular comprise: a pair of male and female screw rotors in which two or more twisted teeth are formed; a casing which receives both the rotors and in which a suction port and a discharge port are formed; bearings which rotatably support shaft end parts of both the rotors and are held in the casing; timing gears which are mounted on one shaft end part of both the rotors and which allow both the rotors to rotate in synchronism without contacting with each other; and a shaft sealing apparatus which is disposed between each of the bearings and teeth of the rotors and which prevents oil from entering a meshing portion of the rotors, wherein there is provided a slot, next to the discharge port of the casing, which comes into communication with the discharge port with timing where a volume of a compression chamber formed by both the rotors and the casing becomes substantially zero as both the rotors rotate.

[0011] In regard to the above feature, the slot extends from a periphery of a position where a tooth bottom circle of the female rotor overlaps with a tooth top circle of the male rotor to a line which connects centers of both the rotors. Further, the slot extends outward from a tooth top part of the male rotor and its width is greater than its depth in an axial direction. Still further, the slot is preferably formed by cutting to prevent the leak from a discharge side to a suction side.

[0012] According to the present invention, on the oil free screw compressor, there is provided means to be in communication with the discharge port until the volume of the compression chamber becomes substantially zero, which can prevent problems such as excessive compression etc. and can also suppress an increase in power consumption to be caused by the excessive compression etc. or an excessive rise in temperature of the compressed air. Further, it is possible to efficiently discharge the compressed air from the discharge port until the timing with which the volume of the compression chamber becomes zero with use of an inexpensive manufacturing method.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 is a transverse cross sectional view showing a principal part of one embodiment of an oil free screw compressor according to the present invention;

Fig. 2 is a cross sectional view taken along line A-A of Fig. 1;

Fig. 3 is a cross sectional view taken along line B-B of Fig. 1;

Fig. 4 is a cross sectional view taken along line C-C of Fig. 1; and

Figs. 5(a) and 5(b) are a top cross sectional view and a front cross sectional view of one embodiment

of the oil free screw compressor of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] With reference to the drawings, one embodiment of the oil free screw compressor of the invention will be described. First, with reference to Figs. 5 (a) and 5(b), an outline of the oil free screw compressor will be explained. Fig. 5(a) is the top cross sectional view of the oil free screw compressor 50 and Fig. 5(b) is the front cross sectional view. The oil free screw compressor 50 has a pair of male screw rotor 1 and a female screw rotor 2, which are received in bores formed in a casing 3. The bores are structured such that two cylindrical spaces are provided next to each other in a direction orthogonal to the axial direction, and their shaft centers are in parallel with each other.

[0015] Shaft ends on one side of the rotors 1 and 2 are rotatably supported by bearings 11 and 12, and shaft ends on the other side are rotatably supported by bearings 13 and 14. The bearings 11 to 14 are held in the casing 3. A lubricating oil is supplied to the bearings 11 to 14. The screw compressor 50 according to the present invention is an oil free compressor. Therefore, in order to prevent the lubricating oil from entering a compression chamber to be described later, shaft sealing apparatuses 31 to 34 are provided closer to a central side than bearings in the axial direction.

[0016] A pinion gear 21 is mounted on one shaft end of the female rotor 2, and the pinion gear 21 engages with a motor (not shown). Timing gears 22 and 23 are mounted on the male and female rotors 1 and 2. The male and female rotors rotate in synchronism through both the timing gears 22 and 23 engaging with each other.

[0017] Middle portions of the male and female rotors 1 and 2 in the axial direction have large diameters. The large-diameter portions of the rotors 1 and 2 are held with little clearances between themselves and inner wall surfaces of the bores formed in the casing 3. On the large-diameter portions of the rotors 1 and 2, there are formed two or more slots or teeth in a spiral manner. According to the present embodiment, the male rotor 1 has four teeth and the female rotor 2 has six slots. While keeping a little clearance, the teeth of the male rotor 1 engage with the slots of the female rotor 2.

[0018] On one side (right side in Fig. 5) of the male rotor 1 and the female rotor 2, there is formed a suction port which leads the air taken in through the suction port to the compression chamber formed by both the rotors 1 and 2 and the casing 3. On the opposite side of both the rotors 1 and 2 in the axial direction, there is formed a discharge port 4 which leads the compressed air from the compression chamber formed by both the rotors 1 and 2 and the casing 3 to the outside of the compressor.

[0019] With reference to a transverse cross sectional view of the screw compressor 50 in Fig. 1 and Figs. 2 and 4 showing cross sections of parts in Fig. 1, the dis-

charge port 4 will be explained in detail. Fig. 2 is a cross sectional view taken in the direction of arrows along line A-A of Fig. 1 and shows a periphery of the discharge port of the male rotor 1. Fig. 3 is a cross sectional view taken in the direction of arrows along line B-B of Fig. 2 and shows a portion where the male and female rotors 1 and 2 engage with each other and a periphery of the discharge port 4. Fig. 4 is a cross sectional view taken in the direction of arrows along line C-C of the periphery of the portion where the male and female rotors 1 and 2 engage with each other and shows a horizontal cross section.

[0020] In the oil free screw compressor 50, air is introduced into the casing 3 through a suction pipe. Then, as the rotors 1 and 2 rotate, a volume of the compression chamber formed by the pair of male and female rotors 1 and 2 and the casing 3 receiving both the rotors 1 and 2 is expanded and taken inside the compressor. Subsequently, the compression chamber is completely closed by the casing 3 around a point where the compression chamber comes to have a maximum volume. As the rotors 1 and 2 further rotate, the compression chamber is contracted, thereby raising the air pressure.

[0021] Corresponding to a state where the compression chamber is contracted to a predetermined volume, the discharge port is formed in accordance with tooth profiles of the rotors 1 and 2 in an end face portion in the axial direction of the rotors 1 and 2 near the outer-diameter part. The compressed air is discharged from this discharge port. In consideration of deformation due to a level of processing accuracy, thermal expansion, and air pressure as well as a bearing clearance, between the male rotor 1 and the female rotor 2 as well as between both the rotors 1 and 2 and the casing 3, clearances are formed so that they do not come into contact with each other. In the oil free screw compressor 50, when air escapes through the clearances, its performance is degraded. Therefore, when the clearances are made as small as possible, its performance is improved. Even so, the shape of the casing 3 cannot help becoming complex, and the casing is generally made by casting. The suction port and the discharge port are also formed by casting. However, a portion which has to be made with high precision is produced by machining.

[0022] In particular, as for the discharge port 4, in order to avoid an increase in power consumption due to excessive compression and a rise in temperature of compressed air, it is desirable to form an opening so that the compressed air can be discharged until the timing with which the volume of the compression chamber becomes zero. However, it is difficult to form the opening by casting or machining. Also, it may increase the manufacturing cost. Therefore, the clearances are allowed in the end faces of the rotors 1 and 2. The compressed air escapes through the clearances. Therefore, even if the discharge port is not kept opened until the timing with which the volume of the compression chamber becomes zero, the excessive compression can be substantially prevented.

[0023] The excessive compression can be prevented by the above conventional method. However, since the compressed air constantly escapes from the end face, the performance is inevitably degraded. In view of the above, according to the present invention, the excessive compression is also prevented while reducing the leak from the end face with use of a simple structure.

[0024] Since the explanation below is a theoretical one, the male rotor 1 and the female rotor 2 are regarded to be in contact through respective tooth faces. As described above, in the actual oil free screw compressor, when tooth faces come into contact with each other, friction, wear, vibration, and noise are caused. Therefore, clearances are formed to such an extent as the tooth faces not coming into contact with each other even when thermal expansion is taken into account. However, the clearances are very small. Therefore, in substantial consideration, it may be regarded that the tooth faces come into contact with each other.

[0025] In Fig. 1, DIR indicates a direction in which the rotors 1 and 2 rotate. When the male rotor 1 rotates in synchronism with the female rotor 2, an advance face SF1, which is a tooth face of the male rotor 1 and a face which first comes into contact with a tooth 8sur) face of the female rotor 2, engages with a tooth face SF2 of the female rotor 2, which forms a compression chamber 7 between themselves and an inner wall face of the casing 3. As the male and female rotors 1 and 2 rotate, the compression chamber 7 moves to a discharge side from a suction side in the axial direction. At that time, the compression chamber is divided by an imaginary contact line called a seal line between the male rotor 1 and the female rotor 2. When a rear end of the seal line reaches a suction end-wall part 3a of both the rotors 1 and 2, the volume of the compression chamber 7 becomes substantially zero. Fig. 1 shows a state where the volume of the compression chamber 7 has become zero.

[0026] That is, the male rotor 1 and the female rotor 2 are in contact with each other at points P1, P2, and P3 on the tooth face. The compression chamber is formed between the advance face SF1, whose both ends are partitioned by the points P1 and P2, of the male rotor 1 and the tooth face SR2 of the female rotor 2. On the other hand, another compression chamber 8 is formed by the tooth face SR1 opposed to an advance face PF1 of the male rotor 1, the advance face SF2 of the female rotor 2, and the points P2 and P3.

[0027] In the conventional art, the discharge port is formed corresponding to the change in the shape of the compression chamber. As shown in Fig. 2, a discharge passage 31 for connection to the compression chamber is formed near an end face on the discharge side of the rotors 1 and 2 in a lower portion of the casing 3. As shown by a dashed line in Fig. 2, a side wall portion of the casing 3 is opened to a profile formed by the anti-advance face SR1 of a tooth which engages after the male rotor 2, a tooth bottom circle of the male rotor 2, the face SR2 opposite to the advance face of the teeth which engage

after the female rotor 2, a tooth bottom circle of the female rotor 2, and tooth top circles of the male and female rotors 1 and 2.

[0028] Furthermore, according to the present invention, as described above, in order to prevent the excessive compression without degrading the performance, a discharge port processing slot 6 is formed so as to be able to discharge compressed air even when the volume of the compression chamber becomes substantially zero. The processing slot 6 will be explained in detail below.

[0029] As shown in Fig. 1, the processing slot 6 is located near a meshing portion of a tooth top of the male rotor 1 and a tooth bottom of the female rotor 2. In order to prevent the leak of air from the discharge side to the suction side, the processing slot 6 is located on an outer side of the male rotor 1 than the outer diameter of the tooth top so that the discharge port 4 does not come into communication with the compression chamber 8 in a state of being ready for suction. Furthermore, in order that the compression chamber 7 in a fully discharged state can be in communication with the discharge port 4 as much as possible, the processing slot 6 is positioned outside the outer diameter of the tooth top of the male rotor 1 by a clearance of about d (see Fig. 2) between the end face of the rotor 1 on the discharge side and the casing 3.

[0030] In order to reduce the leak of the compressed air to the shaft sealing apparatus 34 of the female rotor 2, a width of the processing slot 6 is made to be as small as possible. Although the depth of the processing slot 6, namely, a dimension e in the axial direction is restricted because the shaft sealing apparatus 34 is provided, it may be about half the width d of the slot (see Fig. 4). A length W of the processing slot 6 is set to be from a corner portion of the above described discharge port 4, namely, a portion where the tooth bottom part of the female rotor 2 overlaps with the tooth top part of the male rotor 1 to a line which connects the shaft centers of the male rotor 1 and the female rotor 2.

[0031] Specifications of the processing slot 6 is defined as described above because of the following reasons: If the length W of the processing slot 6 is longer than that, namely, if it exceeds the line connecting the centers of the male rotor 1 and the female rotor 2, it joins with a slot for starting suction. Therefore, the compressed air is returned to the suction side. Also, the depth e of the processing slot is defined by taking workability into consideration. Further, if the width d of the processing slot 6 is widened excessively, the slot becomes too close to a hole of the shaft sealing part of the female rotor 2 and the compressed air flows into the shaft sealing part. Because of these reasons, the dimension of the processing slot 6 is defined as above.

[0032] The above embodiments of the invention as well as the appended claims and figures show multiple characterizing features of the invention in specific combinations. The skilled person will easily be able to consider further combinations or sub-combinations of these fea-

tures in order to adapt the invention as defined in the in the claims to his specific needs.

5 Claims

1. An oil free screw compressor comprising:

a pair of male and female screw rotors (1, 2) in which two or more twisted teeth are formed; a casing (3) which receives both the rotors (1, 2) and in which a suction port and a discharge port are formed; bearings (11 - 14) which rotatably support shaft end parts of said both the rotors (1, 2) and are held in the casing (3); timing gears (22, 23) which are mounted on one shaft end part of said both the two rotors (1, 2) and which allow both the rotors (1, 2) to rotate in synchronism without contacting with each other; and a shaft sealing apparatus (31 - 34) which is disposed between each of said bearings (11, 12, 13, 14) and teeth of said rotors (1, 2) and which prevents oil from entering a meshing portion of the rotors (1, 2), **characterized in that** wherein there is provided a slot (6), in the casing (3) and outside the outer diameter of the tooth top of the male rotor (1), which comes into communication with the discharge port and with an area formed near a tooth top of the male rotor (1) and a tooth bottom of the female rotor (2), where a volume of a compression chamber (7) formed by both the rotors (1, 2) and the casing (3) becomes substantially zero as said both the rotors (1, 2) rotate, and said slot (6) extends from a periphery of a position where a tooth bottom circle of the female rotor (2) overlaps with a tooth top circle of the male rotor (1) to a line which connects centers of both the rotors (1, 2), wherein said slot (6) extends outward from a tooth top part of said male rotor (1) and its width is greater than its depth in an axial direction.

2. The oil free screw compressor according to claim 1, wherein said slot (6) is formed by cutting to prevent the leak from a discharge side to a suction side.

Patentansprüche

1. Ölfreier Schraubenverdichter, der umfasst:

einen Rotor mit einer konvexen Schraube und einen Rotor mit einer konkaven Schraube (1, 2), in denen zwei oder mehr gewindeförmige Zähne ausgebildet sind; ein Gehäuse (3), das die beiden Rotoren (1, 2) aufnimmt und in dem eine Ansaugöffnung und eine Auslassöffnung ausgebildet sind; Lager (11 - 14), in denen die Wel-

lenendteile der beiden Rotoren (1, 2) drehbar gelagert sind und die in dem Gehäuse (3) aufgenommen sind; Stirnräder (22, 23), die an einem Wellenendteil der beiden Rotoren (1, 2) angebracht sind und die eine synchrone Rotation der beiden Rotoren (1, 2) erlauben, ohne dass sie miteinander in Kontakt kommen, und eine Wellendichtungsvorrichtung (31 - 34), die zwischen jedem der Lager (11, 12, 13, 14) und den Zähnen der Rotoren (1, 2) angeordnet ist und die verhindert, dass Öl in einen Eingriffsabschnitt der Rotoren (1, 2) eintritt,

dadurch gekennzeichnet, dass

in dem Gehäuse (3) und außerhalb des äußeren Durchmessers des Zahnkopfes des konvexverzahnten Rotors (1) ein Spalt (6) vorgesehen ist, der mit der Auslassöffnung und mit einem nahe einem Zahnkopf des konvexverzahnten Rotors (1) und einem Zahnboden des konkavverzahnten Rotors (2) gebildeten Bereich in Verbindung kommt, wobei ein durch die beiden Rotoren (1, 2) und das Gehäuse (3) gebildetes Volumen einer Verdichtungskammer (7) im Wesentlichen gleich Null wird, wenn sich die beiden Rotoren (1, 2) drehen, und sich der Spalt (6) von einer Peripherie an einer Position, wo sich ein Zahnboden-Kreis des konkavverzahnten Rotors (2) mit einem Zahnkopf-Kreis des konvexverzahnten Rotors (1) überlappt, zu einer Linie erstreckt, welche die Mitten der beiden Rotoren (1, 2) verbindet, wobei sich der Spalt (6) von einem Zahnkopf-Teil des konvexverzahnten Rotors (1) nach außen erstreckt und seine Breite größer ist als seine Tiefe in einer Axialrichtung.

2. Ölfreier Schraubenverdichter nach Anspruch 1, bei dem der Spalt (6) durch spanabhebende Formgebung erzeugt ist, um den leckartigen Durchtritt von der Auslassseite zur Ansaugseite zu verhindern.

Revendications

1. Compresseur à vis sans huile comprenant :

une paire de rotors à vis mâle et femelle (1, 2) dans lesquels deux dents torsadées ou plus sont formées ; un carter (3) qui reçoit les deux rotors (1, 2) et dans lequel un orifice d'aspiration et un orifice de décharge sont formés ; des paliers (11 - 14) qui supportent en rotation des parties d'extrémité d'arbre desdits deux rotors (1, 2) et sont maintenus dans le carter (3) ; des engrenages de synchronisation (22, 23) qui sont montés sur une partie d'extrémité d'arbre desdits deux rotors (1, 2) et qui permettent que les deux rotors (1, 2) tournent en synchronisme sans contact l'un avec l'autre ; et un appareil (31 - 34) d'étan-

chéité d'arbre qui est disposé entre chacun desdits paliers (11, 12, 13, 14) et desdites dents desdits rotors (1, 2) et qui empêche que de l'huile ne pénètre dans une partie d'engrènement des rotors (1, 2), **caractérisé en ce que**

dans lequel il est prévu une fente (6), dans le carter (3) et à l'extérieur du diamètre extérieur du sommet de dents du rotor mâle (1), qui vient en communication avec l'orifice de décharge et avec une zone formée à proximité d'un sommet de dents du rotor mâle (1) et d'un fond de dents du rotor femelle (2), où un volume d'une chambre de compression (7) formée par les deux rotors (1, 2) et le carter (3) devient sensiblement zéro lorsque lesdits deux rotors (1, 2) tournent, et ladite fente (6) s'étend d'une périphérie d'une position où un cercle de fonds de dents du rotor femelle (2) chevauche un cercle de sommets de dents du rotor mâle (1) jusqu'à une ligne qui connecte des centres des deux rotors (1, 2), dans lequel ladite fente (6) s'étend vers l'extérieur depuis une partie de sommet de dents dudit rotor mâle (1) et sa largeur est plus grande que sa profondeur dans un sens axial.

2. Compresseur à vis sans huile selon la revendication 1, dans lequel ladite fente (6) est formée par découpe pour empêcher la fuite d'un côté décharge jusqu'à un côté aspiration.

FIG. 1

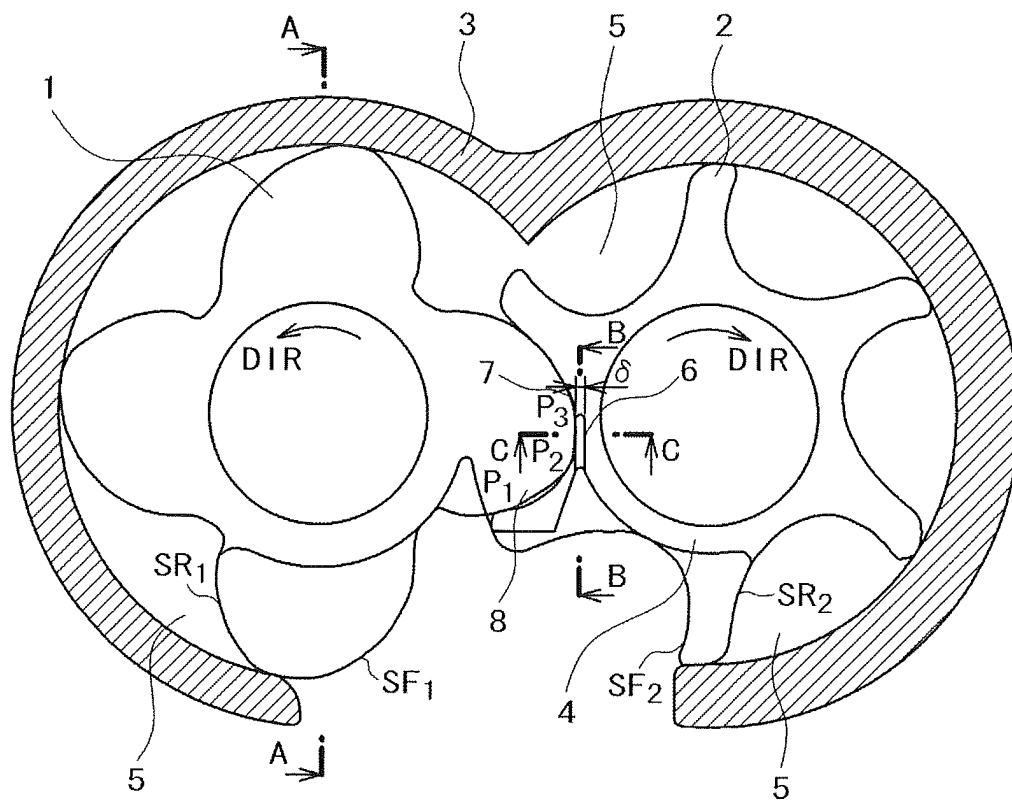


FIG. 2

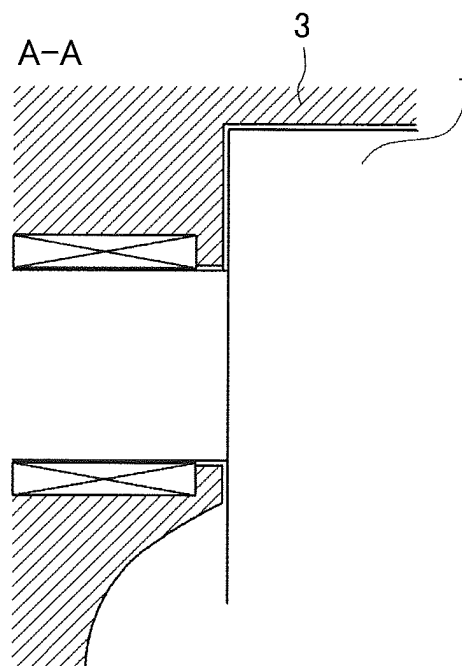


FIG. 3

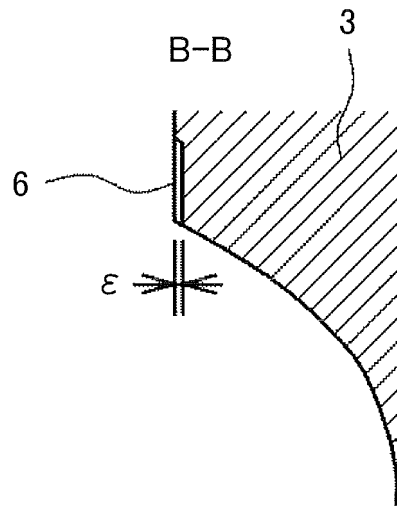


FIG. 4

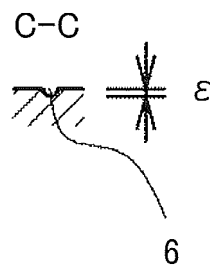


FIG. 5A

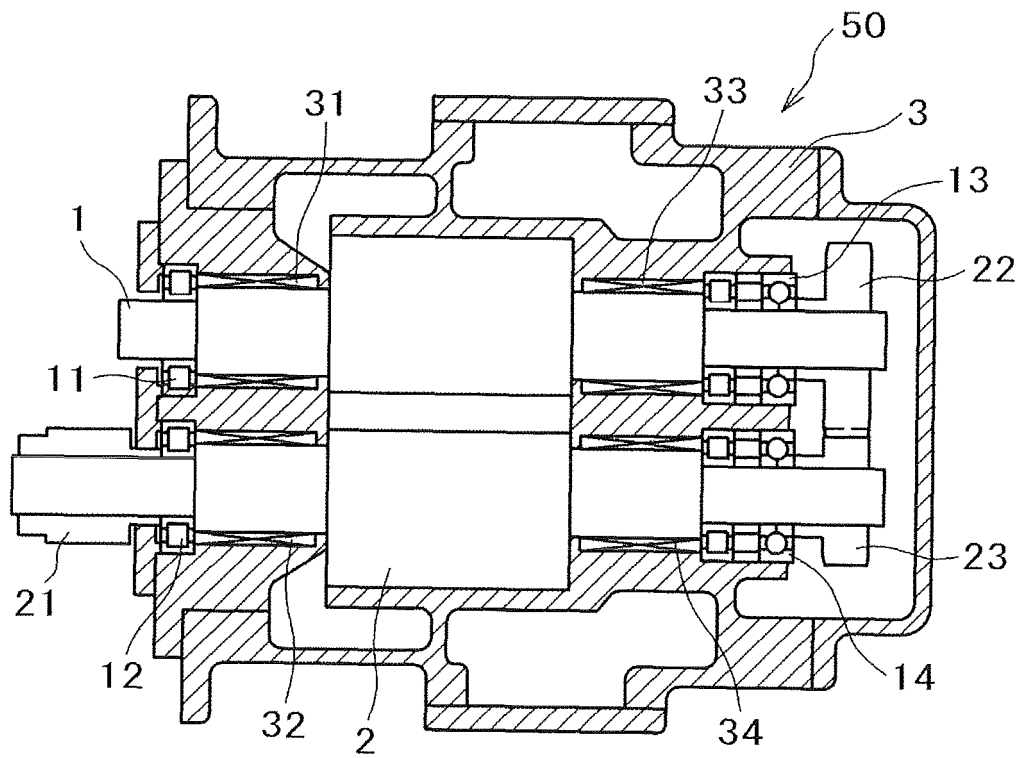
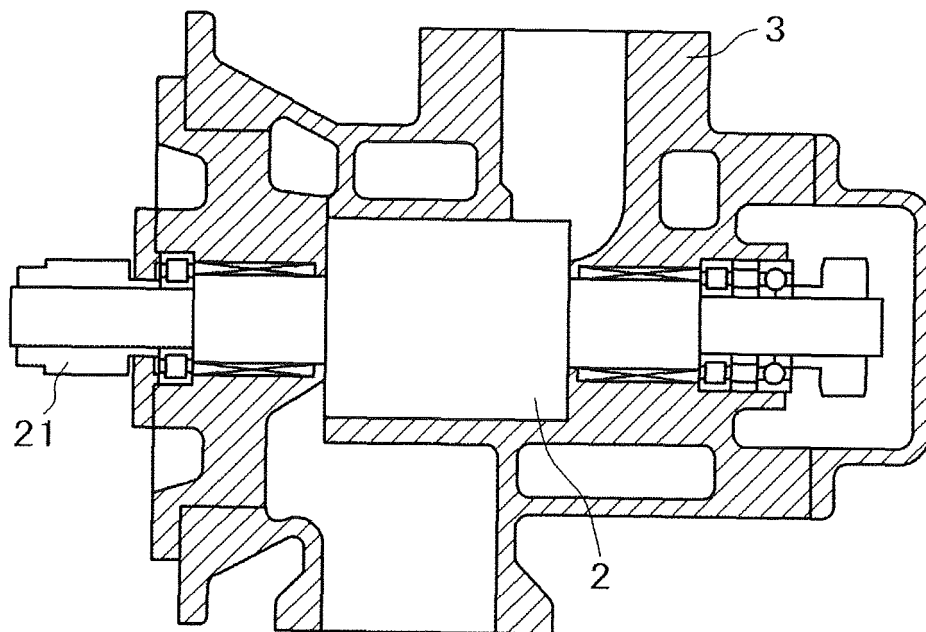


FIG. 5B



REFERENCES CITED IN THE DESCRIPTION

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