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(54) **SCREW COMPRESSOR**

(57) A screw compressor comprising a male rotor (2) and a female rotor (3) enclosed in a casing (4) inside which they counter-rotate, to drive the male rotor from a motor, a gas passes through an intake duct (5) created between the two rotors, and the rotation closes this intake duct and the compressed gas is pushed towards a delivery (6), each rotor includes a rotation shaft (21,31)

which rotates in the case thanks to special bearings which is surrounded by helical propellers (22,32) which engage each other, the propellers being made in such a way as to reduce progressively the space between rotors and casing, so that the gas sucked in by the suction duct compresses in the direction of the delivery (6), the helical propellers are made of a polymeric material.

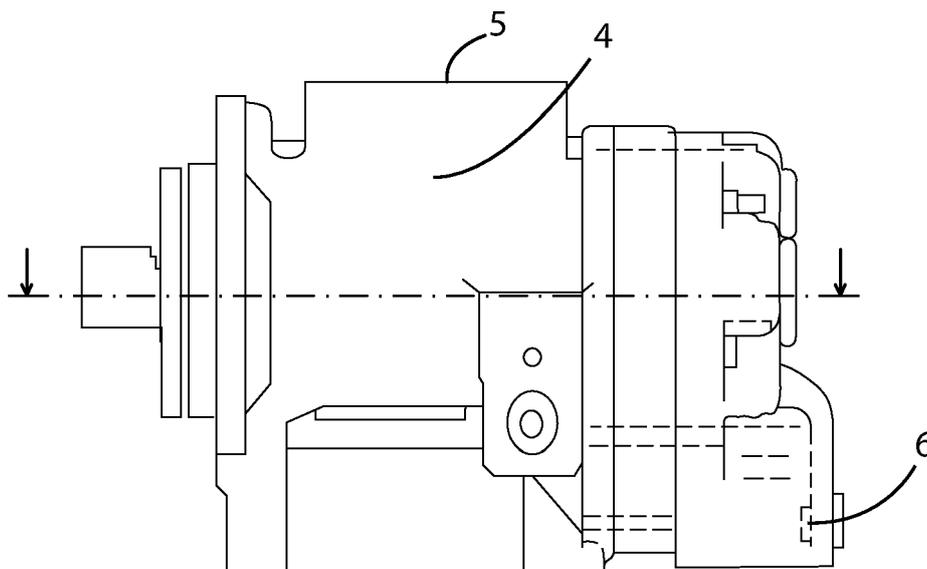


Fig. 1

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Description

[0001] The screw compressor is a rotary volumetric compressor consisting of two parallel rotors fitted externally with several helical profiles (screws) such that they can engage in each other. The two rotors are housed in a stator consisting of two longitudinally intersecting cylinders, in which the rotors turn with a clearance that cannot be reduced beyond a certain limit.

[0002] The rotor shafts are supported by rolling bearings, and generally one rotor leads the other by meshing the same helical profiles. Sometimes both can be controlled by a pair of external gears, to reduce the friction otherwise present. During rotation, the profiles of the screws uncover an intake gap, located at one end of the stator, through which air or gas enters to fill the volume between the profiles up to the maximum extension thereof.

[0003] On the opposite side, the profiles penetrate each other, reduce the volume and compress the gas enclosed therein until the delivery gap is uncovered. The operation of the screw compressor is based on the counter-rotating action of two helical rotors that compress the gas or air taken from the intake duct and bring it towards the delivery duct. During this path the space is reduced and, consequently, the pressure rises.

[0004] The screw compressor is very popular thanks to the diffusion of the technology of its construction. Many manufacturers and assemblers offer this product in many different variants: single-stage, two-stage for high pressure with and without oil for oil-free applications. The speed of rotation is normally higher than that of the motor to which it is connected due to gearboxes or the ratio of pulleys when a belt is present.

[0005] These types of industrial compressors deliver gas or compressed air continuously, are very well controllable, extremely efficient and silent (in terms of safety at work, environmental protection and noise emissions).

[0006] The current technology involves the use of metallic materials (spheroidal cast iron or steel) for the production of screws and the correct operation of the compressor is linked to the presence of clearances between the profile of the screws and the screws with the compression chamber. However, the presence of such clearances still leads to a lower efficiency of the machine due to the leakages that bring gas from high-pressure zones (delivery) and lower-pressure zones (intake).

[0007] As mentioned above, the compression ratios can be increased by injection of lubricating oil, which helps both the surfaces of the profiles in contact, which acts as a refrigerant to maintain temperature limits suitable for the materials used, and as a sealing fluid between the elements in relative motion between them.

[0008] Patent CN1032383 describes propellers with a steel shaft, aluminium body and fibre-filled polyamide coating; this composition of different materials is used to ensure a reduction in the overall weight of the finished body, to take full advantage of the special characteristics

of the polymeric materials and also to use a higher-performing lubricating fluid.

[0009] For this purpose, patent CN107448383A uses water as lubricant and not-filled PEEK (polyether ether ketone) to coat the rotor.

[0010] In the patents cited, the production of the rotor, both as a coating and as a finished piece is obtained by injection molding.

[0011] The present invention aims to improve the performance of a compressor of this type by using entirely polymeric material for the propellers.

[0012] An aspect of the present invention concerns a screw compressor having the characteristics of claim 1.

[0013] Further features of the present invention are contained in the dependent claims. The characteristics and advantages of the present invention will become more apparent from the following description of an embodiment of the invention, provided by way of non-limiting example, with reference to the schematic attached drawings, wherein:

- figure 1 illustrates a screw compressor in side view according to the present invention;
- figure 2 illustrates a section of the compressor of figure 1 taken along line A-A;
- figure 3 illustrates a cross-section of the compressor of figure 1;
- figure 4 illustrates the male rotor and the female rotor of the compressor of figure 1;
- figures 5a, 5b and 5c illustrate, for male and female rotors respectively, and for the coupled rotors, the means for locking the axial displacement;
- figure 6 schematically illustrates the various parts of the screw compressor;
- figure 7 schematically illustrates a detail of a separate lubrication system for the mechanical parts (bearings, seals and gears) of the compressor.

[0014] With reference to the mentioned figures, the screw compressor according to the present invention comprises two rotors or helical screws, respectively male rotor 2 and female rotor 3 enclosed in a casing 4 inside which they counter-rotate. A gas passes through an intake duct 5 created between the two rotors, and the rotation closes this duct at the intake and the compressed gas is pushed towards a delivery 6.

[0015] Each rotor includes a rotation shaft 21 and 31 which rotates in the case thanks to special bearings which is surrounded by propellers 22 and 32 which engage with each other. The propellers are made in such a way as to reduce progressively the space between rotors and stator, so that the gas sucked in by the suction duct compresses in the direction of the delivery 6.

[0016] The two rotors are usually designed with different profiles. The male rotor is usually provided with convex lobes, while the female rotor has usually concave cavities. It is thanks to these characteristics that they are engage on to each other. A special motor supplies the

compressor with the necessary supply. The motor is used to impart the rotation to the male rotor, which in turn drives the female rotor. The casing is provided with special bearings that are used to keep the rotors in the correct position. They are located at the ends of both rotors, of which they ensure the uniform rotation and constant balance.

[0017] There are also intake and discharge valves, which regulate the initial recovery and the removal of gas from the compressor. The intake valve opens to allow gas to enter the system, while the discharge valve receives the compressed gas at the end of the process.

[0018] According to the present invention the propellers 22 and 32 are made of a polymeric material.

[0019] The choice of a polymeric material for the realization of the propellers, in fact, brings significant advantages on the performance side, exploiting the behaviour in temperature and the greater deformability of the material itself, able to lead to a reduction of the clearance among the propellers during operation. Unlike metals, in fact, it is possible to have a greater contact, therefore adaptation of the profiles during the meshing process, in relation to the properties of surface friction and non-stick reduction.

[0020] Furthermore, in order to minimize the fatigue and/or deformation problems of the propeller shaft, in relation to more critical application conditions, in terms of mechanical resistance, the central body of the screw, in particular the shaft 21 and 31 including external projections, can be produced in a more resistant material and subsequently mechanically connected to the polymeric helical parts.

[0021] The polymeric propellers can be produced starting from a 3D molding process (e.g. FDM) or from a solid profile.

[0022] The production process of the propellers can include both the use of FDM (Fused Deposition Modeling) and the mechanical processing of a solid cylinder.

[0023] 3D molding, by means of FDM, has excellent piece finishes and a good production speed, but at the same time, the mechanical and chemical characteristics of the polymer remain unchanged. In the molding process, a further finishing step of the obtained rotor may be necessary, to ensure compliance with the geometric and dimensional tolerances of the piece necessary for the correct operation of the machine, in the transients and at operating speed.

[0024] The shaft is preferably made with a material different from that of the propellers, for example from a more resistant material, in order to absorb most of the bending load generated by compression and the torque imposed by the motor, minimizing the deformations that could be encountered by using a body made solely starting from the same material.

[0025] The shafts are mechanically connected to the respective propellers in order to transmit the torque of the motor through a suitable locking system. In order to obtain an effective transmission of the torque, this system comprises tabs and relative slots made both on the rotor

and on the shaft, with a variable number depending on the diameter of the shaft and of the torque value to be transmitted, up to the use of a splined shaft.

[0026] With regards to the transmission line of the axial and radial loads connected to the compression process itself, the coupling between propeller and shaft envisages the presence of contact surfaces designed to resist the forces at play. In particular, radial thrusts were taken into account by appropriately calibrating the diametrical coupling between shaft and propeller. From the point of view of the axial thrusts, from delivery towards intake, under operating conditions, means for locking the relative axial displacement between the two parts comprising a projection 211 and 311 on the shaft which fits a groove made in the propeller were created. In relation to the inverted axial thrusts (from intake towards the delivery), connected instead to transitory situations at the start-up of the direct coupling and gear machines, a locking ring 212 and 312 of the propeller side delivery on each rotor is provided. This system has the task of avoiding both the slippage between screw and shaft during torque transmission, and to prevent the axial translations of the rotor along the shaft in both directions, in relation to the loads generated by the mechanics of the meshing between the two rotors and by the fluid dynamics of the compression process itself, taking into account the expansions at play.

[0027] Considering the anisotropic behaviour of the material obtained by means of 3D molding, the internal stator bodies (rotor case-diametrical seat and delivery and suction planes) of the compressor can be coated with an abradable polymeric film. This film not only reduces the space between rotor and respective cylinder, further decreasing the leakages, but also ensures, in case of contact of the rotor with the above-mentioned surfaces, the formation of a groove, preventing plastic deformation or the breakage of the tooth of the rotor due to excessive overheating caused by the friction of the different materials. So the purpose of the polymeric film is also to create a thin "sacrificial" barrier between the rotors and the bodies of the compressor.

[0028] A suitable polymer that can be used for both male and female screws is PEEK (polyether ether ketone), filled with both long and short fibres, which has the right properties of compatibility both with the shaft and with the processed gases, as well as the mechanical and chemical properties such that it can be subjected to both 3D molding (such as FDM) and traditional mechanical machining, starting from the solid (bar or cylinder) and for geometric finishes.

[0029] Polyamides as well as polyolefins, suitably functionalised and/or filled with appropriate fillers and fibres, can also be used to obtain the profiles. These polymers must have properties of compatibility with both the processed fluids and the shafts on which they are installed, as well as an adequate affinity among them. A category of polymers suitable for coating stator bodies, on the other hand, are fluorinated or perfluorinated compounds, as well as the suitably functionalised polyolefins

and polyamides.

[0030] In addition to a chemical compatibility with the material of the propellers, in order to ensure good adhesion, this coating must also be fully compatible with the temperatures and the processed gases in order to avoid a premature and unwanted deterioration.

[0031] Sprays, powders or plasma can be used to apply the film.

[0032] The use of high-performance polymers makes it possible, in the case of oil-injected machines, to use higher-performing refrigerant fluid, as well as to improve the mechanical and functional behaviour in the presence of corrosive and/or aggressive gas components.

[0033] The polymeric propellers are therefore compatible with:

- process gas;
- lubricating fluid;
- operating conditions of the compressor (temperature, pressure, loads generated);

At the same time, in relation to the characteristics identified in relation to deformability under the conditions of use, they are able to reduce the previously mentioned clearances, in order to improve performance without however affecting the correct mechanical operation, thanks to a higher coefficient of thermal expansion of the polymer than the metal.

[0034] The choice of a polymeric material for the realization of the propellers, in fact, brings significant advantages on the performance side, exploiting the behaviour in temperature and the greater deformability of the material itself, able to lead to a reduction of the clearances among the propellers during operation. Unlike metals, in fact, a greater contact is possible, therefore adaptation of the profiles during the meshing process, in relation to the properties of surface friction and non-stick reduction.

[0035] These aspects are inevitably expressed, for the oil-injected machine version, in a more flexible choice of lubricant, which, on the rotor side, performs less and less both the function of anti-friction/anti-seize film during the mechanical meshing process and the function of clearance reduction, which is more effectively covered by materials/coatings.

[0036] In terms of quantity and functionality, therefore, the injected fluid becomes, as far as the compression chamber is concerned, primarily a thermodynamic vector, of temperature reduction in the process, in relation to purely energetic heat balances. Where it is not possible to change the characteristics of the fluid used also for lubrication of the other mechanical parts (e.g. bearings/gears/seals...) it is possible to resort to separate lubrication solutions. The screw compressor of the present invention can comprise lubrication channels 7, accessible from the outside, which transport the suitable lubricant to such mechanical parts such as bearings 71, gears, or seals 73. In this machine configuration, the chamber where the meshing takes place between the

rotors is to be isolated, thus being able to use different fluids for each specific purpose (only refrigerant for rotors or lubricant/refrigerant for other mechanical parts). This insulation is created by placing internal seals between the compression chamber and the bearings.

Claims

1. Screw compressor comprising a male rotor (2) and a female rotor (3) enclosed in a casing (4) inside which they counter-rotate, to drive the male rotor from a motor, a gas passes through an intake duct (5) created between the two rotors, and the rotation closes this duct at the intake and the compressed gas is pushed towards a delivery (6),

each rotor includes a rotation shaft (21,31) which rotates in the case thanks to special bearings which is surrounded by propellers (22,32) which engage each other, the screws being made in such a way as to reduce progressively the space between rotors and casing, so that the gas sucked in by the suction duct compresses in the direction of the delivery (6),
characterized in that the propellers are made of a polymeric material.

2. Compressor according to claim 1, wherein the shafts (21,31) of the rotors are made of a material more resistant than that of the propellers.
3. Compressor according to claim 1, wherein the shafts (21,31) are mechanically connected to the respective propellers (22,32) in order to transmit the torque of the engine through a suitable locking system.
4. Compressor according to claim 1, wherein said polymeric material of the propellers is PEEK.
5. Compressor according to claim 1, wherein the propellers are made by 3D molding.
6. Compressor according to claim 1, in which said 3D molding is carried out by means of the FDM technique.
7. Compressor according to claim 1, in which the internal stator bodies, rotor case-diametrical seat and delivery and suction planes are coated with an abrasible polymeric film.
8. Compressor according to claim 1, comprising lubrication channels (7), accessible from the outside, which carry suitable lubricant to bearings and / or gears and / or seals.
9. Compressor according to claim 1, comprising means

for locking the relative axial displacement between propellers and shafts comprising a projection (211,311) on the shaft which fits a groove made in the propeller and a locking ring (212,312) of the propeller side delivery.

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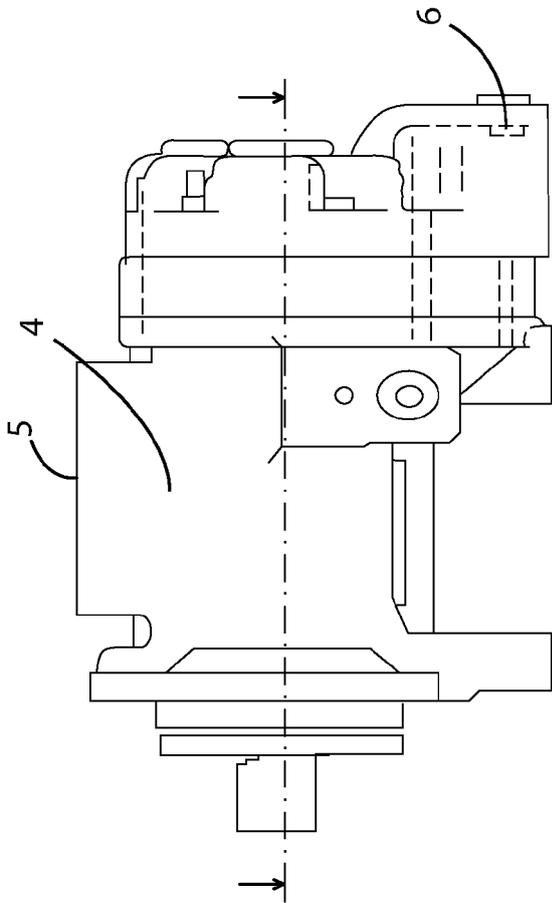


Fig. 1

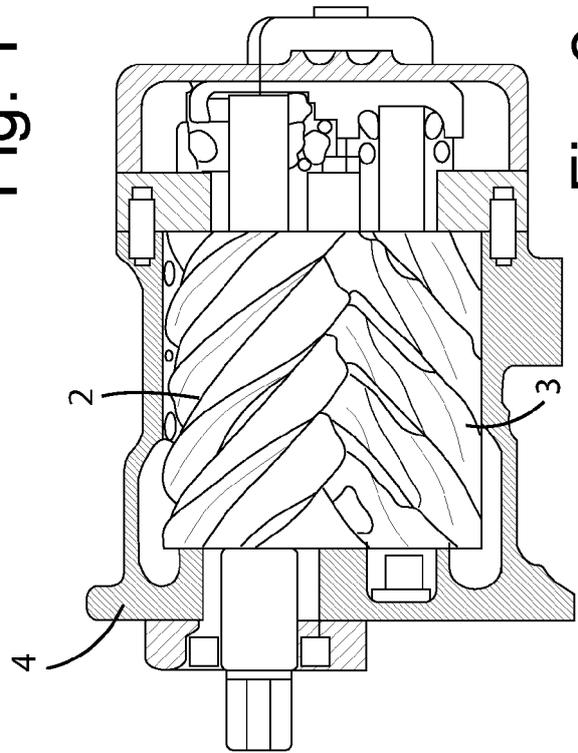


Fig. 2

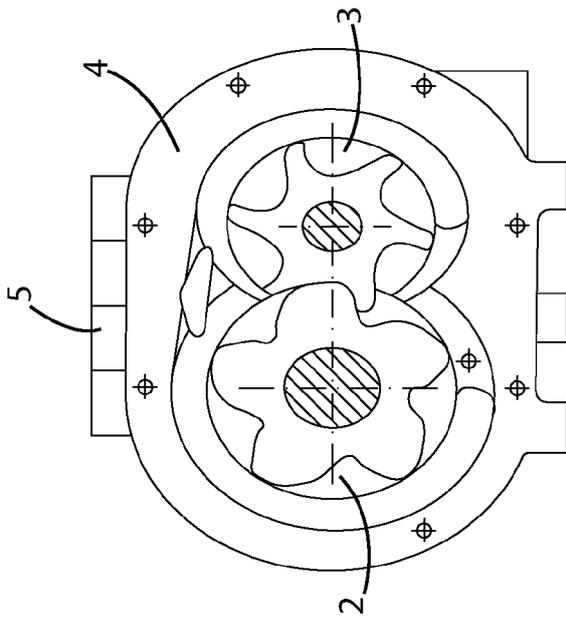


Fig. 3

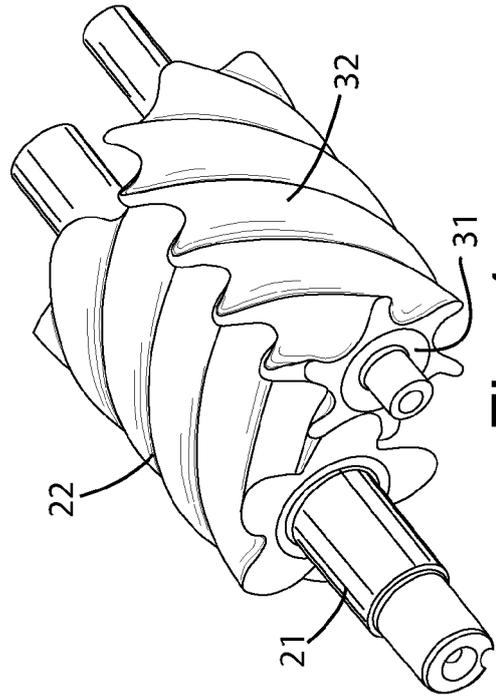


Fig. 4

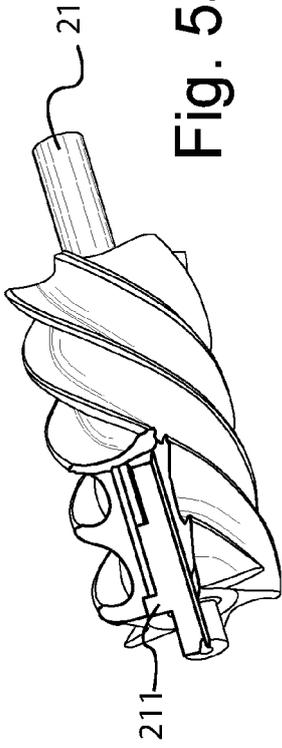


Fig. 5a

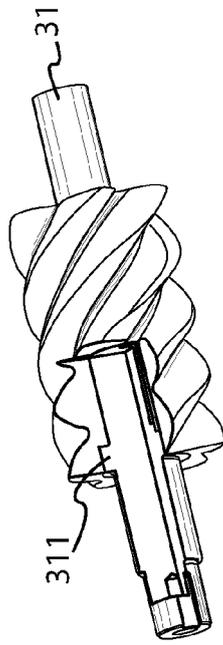


Fig. 5b

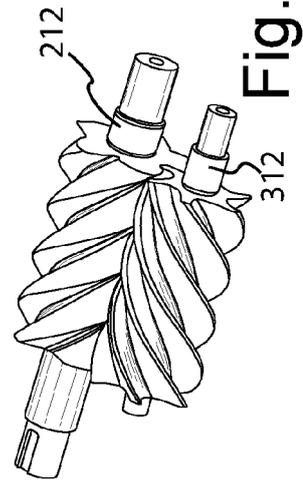


Fig. 5c

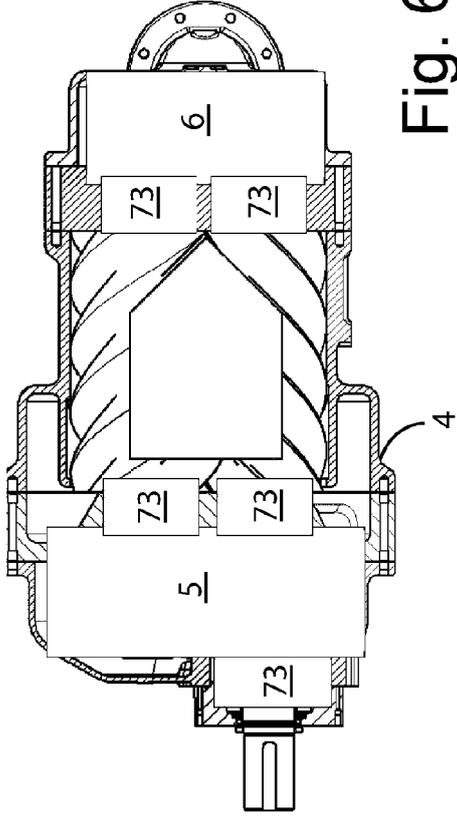


Fig. 6

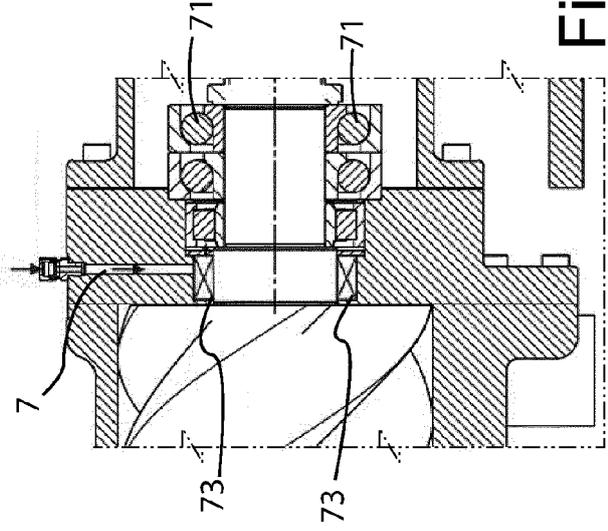


Fig. 7



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