



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11)

EP 1 475 538 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

10.11.2004 Bulletin 2004/46

(51) Int Cl.7: **F04C 15/00, F04C 2/16**

(21) Application number: **04010825.0**

(22) Date of filing: **06.05.2004**

(84) Designated Contracting States:

**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IT LI LU MC NL PL PT RO SE SI SK TR**

Designated Extension States:

AL HR LT LV MK

(30) Priority: **08.05.2003 GB 0310516**

(71) Applicant: **Automotive Motion Technology
Limited
Andover, Hampshire SP10 3TS (GB)**

(72) Inventors:

- **Beaven, Robert William
Thornbury Bristol, BS35 1SW (GB)**
- **Werson, Michael John
Eastleigh SO53 1LU (GB)**

(74) Representative: **Lucking, David John
FORRESTER & BOEHMERT
Pettenkoferstrasse 20-22
80336 München (DE)**

(54) **Pump**

(57) A pump (10) including a pumping element (20), which is mounted for relative rotation in a housing (14), rotation of the pumping element (20) causing fluid to be pumped from an outlet (40) provided in the housing (14), the pumping element (20) including an axially extending bearing part (34a), and there being a sealing part (30) provided at the outlet (40), the sealing part (30) including an opening which is generally axially aligned with the

axis of rotation (A) of the pumping element (20) and which provides a main flow path for fluid flow through the outlet (40), and the sealing part (30) including an axially extending bearing part (30b), which lies adjacent to the bearing part (34a) of the pumping element (20), axially extending surfaces of the two bearing parts (30b, 34a) providing a seal between the outlet (40) and the pumping element (20).

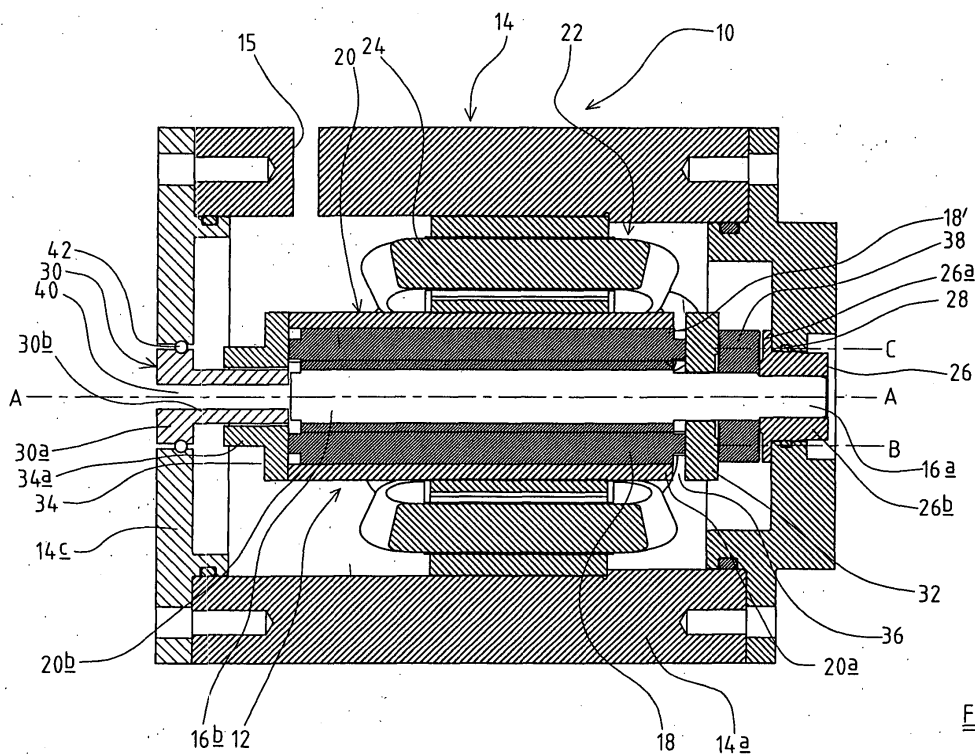


FIG 1

EP 1 475 538 A2

Description

[0001] This invention relates to a pump, and more particularly to a pump including a pumping element which is rotatable in a pumping chamber to pump fluid to an outlet in the pumping chamber.

[0002] Pumps including a pumping element which is rotatable in a pumping chamber are known and one example is a pump in which the pumped fluid is carried between the screw threads on one or more rotors such that the liquid is displaced in a direction generally parallel to the axis of rotation of the or each rotor. Such a pump is generally referred to as a screw pump.

[0003] Where more than one rotor is provided, the pump is generally known as an intermeshing screw pump. In this case, the main rotor is provided with one or more helical grooves and at least one auxiliary rotor is provided with one or more corresponding helical ridges. The rotors are mounted in a pumping chamber within a housing such that their longitudinal axes are parallel and their helical screw threads mesh. Thus rotation of one rotor with respect to the housing causes the other rotor or rotors to rotate about its/their longitudinal axis or axes.

[0004] Fluid is drawn into the pump at an inlet or suction end of the pump between the counter-rotating screw threads. As the rotors turn, the meshing of the threads produces fluid chambers bounded by the threads and the pump housing. Fluid becomes trapped in the fluid chambers and continued rotation of the screws causes the fluid chambers to move from the inlet end of the pump to a high pressure outlet end of the pump. High pressure fluid is ejected from the pump at the outlet end as fluid is displaced from the fluid chambers. Flow of pumped fluid is thus parallel to the longitudinal axes of the rotors.

[0005] Rotation of the rotors with respect to the housing may be achieved by connecting one of the rotors to a driving means such as an electrical motor, such that operation of the motor causes the rotor to rotate about its longitudinal axis. Alternatively, relative rotation may be achieved by connecting the pumping housing to the driving means, or incorporating the pump housing with a motor rotor, such that the pump housing rotates about the longitudinal axis of a central, fixed, rotor.

[0006] In each case, it is preferable that the outlet is axially aligned with the axis of rotation of the main rotor, so that fluid need not change flow direction as it exits the pump, as a change in direction could impede flow of fluid out of the pump, and may lead to a reduction in the pressure of the fluid.

[0007] It is also preferable, however, where the pump housing rotates around the central rotor, that a bearing for the pump housing is provided at both the inlet and outlet ends of the pump housing, in order to ensure the stability and smooth running of the pump housing. Typically, the pump housing bears on the central rotor, ends of which extend out of the pump housing and engage

with an outer housing, in which case it is not possible for an outlet to be axially aligned with the longitudinal axis of the central rotor.

[0008] Moreover, where the pump housing rotates around the central rotor, it is necessary to provide a seal between a pump outlet and the pump housing to ensure that the high pressure fluid passes through the pump outlet. Conventional sealing arrangements typically restrict axial movement of the rotating pumping element with respect to the remainder of the pump, and thus any differential thermal axial expansion of the pump housing relative to the remainder of the pump cannot readily be accommodated.

[0009] According to the present invention, we provide a pump including a pumping element, which is mounted for relative rotation in a housing, rotation of the pumping element causing fluid to be pumped from an outlet provided in the housing, the pumping element including an axially extending bearing part, and there being a sealing part provided at the outlet, the sealing part including an opening which is generally axially aligned with the axis of rotation of the pumping element and which provides a main flow path for fluid flow through the outlet, and the sealing part including an axially extending bearing part, which lies adjacent to the bearing part of the pumping element, axially extending surfaces of the two bearing parts providing a seal between the outlet and the pumping element.

[0010] Sealing between the relatively rotatable pumping element and the housing is thus achieved by means of the axially extending bearing parts, i.e. by means of the interaction between two axially extending surfaces. This sealing arrangement can therefore more readily accommodate differential axial expansion of the pumping element with respect to the housing, and does not introduce undesirable axial loading on the pumping element.

[0011] Moreover, by virtue of the invention, a bearing for the pumping element, may be provided adjacent the outlet without interfering with flow of fluid through the outlet along the axis of rotation of the pumping element.

[0012] Preferably, a fluid flow path is provided for flow of a limited amount of fluid into a bearing chamber between the two bearing parts.

[0013] Such fluid flow is limited so that the bearing parts provide a substantially, but not completely, fluid tight seal between the outlet and the pumping element. Flow of some pumped fluid into the bearing chamber between the two bearing parts provides a hydrodynamic bearing for the rotating pumping element, which may reduce energy losses due to friction between the main rotor and the bearing.

[0014] Preferably, a resilient support part is provided between the sealing part and the housing, the resilient support part permitting some movement of the sealing part with respect to the housing. Preferably the resilient support part permits some movement of the sealing part generally normal to the axis of rotation of the pumping element, as well as axially.

[0015] By virtue of the provision of such a resilient support part, a degree of misalignment of the pumping element with respect to the housing can be accommodated.

[0016] The pumping element may include a pump housing in which are mounted a main rotor and at least one auxiliary rotor, the rotors each being provided with at least one generally helical screw thread and being arranged in the housing such that the screw threads mesh, the axis of rotation of the pumping element coinciding with a longitudinal axis of the main rotor. In one embodiment, the main rotor may be fixed, wherein the pump housing is configured such that rotation of the pump housing causes the or each auxiliary rotor to orbit about the longitudinal axis of the main rotor.

[0017] Meshing of the screw threads thus causes the auxiliary rotors to rotate about their longitudinal axis, which causes pumping of fluid as described above.

[0018] An embodiment of the invention will now be described with reference to the accompanying drawing in which is shown an illustrative side view of a pump according to the invention.

[0019] Referring now to the figure, there is shown a pump assembly 10 including a pump 12 and an outer housing 14 providing a fluid reservoir. The pump 12 includes a plurality of rotors 16, 18, 18' mounted in a pump housing 20 for rotation relative to the pump housing 20, the rotors 16, 18, 18' each carrying at least one screw thread, the rotors being arranged in the pump housing 20 such that the screw thread mesh, and rotation of one of the rotors 16, 18, 18' causes rotation of the other rotors 16, 18, 18'.

[0020] The outer housing 14 includes a side wall 14a which encloses a generally cylindrical space, and first 14b and second 14c end plates which partially close the first and second ends of the side wall 14a respectively. The end plates 14b, 14c are connected to the side wall 14a by means of a plurality of bolts (not shown) which are spaced around the circumference of the side wall 14a. The pump housing 20 is enclosed within the outer housing 14.

[0021] An inlet port 15 is provided in the side wall 14a of the outer housing 14 adjacent to the second end plate 14c.

[0022] By virtue of the provision of the pump housing 20 within the outer housing 14, the pump assembly 10 is relatively compact and is thus suited for use in applications where space is restricted.

[0023] In this example, three rotors 16, 18, 18' are provided - a central rotor 16 and two outer rotors 18, 18'. The rotors 16, 18, 18' are elongate with longitudinal axes A, B, and C respectively, and each carries a screw thread.

[0024] The rotors 16, 18, 18' are arranged in the pump housing 20, with the central rotor 16 between the two outer rotors 18, 18' such that the screw threads mesh. The longitudinal axes A, B and C of the rotors 16, 18, 18' are generally all parallel, and thus rotation of the cen-

tral rotor 16 relative to the pump housing 20 about axis A causes the outer rotors 18, 18' to rotate about their longitudinal axes, B and C respectively.

[0025] In this example, the rotors 16, 18, 18' are each provided with two generally helical threads which each extend along substantially the entire length of the rotor 16, 18, 18', and which are interposed such that when the rotor 16, 18, 18' is viewed in transverse cross-section, one thread is diametrically opposite the other.

[0026] Also in this example, the central rotor 16 has the shape of a generally cylindrical shaft with the threads in the form of two generally helical ridges, extending radially outwardly of the shaft. The outer rotors 18, 18' each have the shape of a generally cylindrical shaft with the threads, in the form of two generally helical grooves, extending radially inwardly of each shaft. It is possible, however, for the threads of the outer rotors 18, 18' to have the form of helical ridges, and the threads of the central rotor 16 to have the form of generally helical grooves.

[0027] The pump housing 20 is generally cylindrical with an aperture for receiving the rotors 16, 18, 18' extending longitudinally of the housing 20 between an inlet end 20a and an outlet end 20a of the housing 20. The aperture is shaped such that, when contained within the housing 20, the longitudinal axis A, B, C of the rotors 16, 18, 18' extend generally parallel to the longitudinal axis of the housing 20, and there is minimum clearance between the walls of the aperture and the rotors 16, 18, 18' whilst still permitting rotation of the rotors 16, 18, 18' about their axes A, B, C. The aperture is typically formed by machining.

[0028] First 16a and second 16b end portions of the central rotor 16 extend from the pump housing 20 and engage with the first 14b and second 14c end plates of the outer housing 14, thus preventing rotation of the central rotor 16 about its longitudinal axis relative to the outer housing 14.

[0029] The first end portion 16a of the central rotor 16, which extends from the inlet end 20a of the pump housing 20, is mounted in a support collar 26 which is received in an aperture provided in the first end plate 14b of the outer housing 14. The support collar 26 is received in a generally circular aperture in the first end plate 14b and has an radially outwardly extending flange part 26a which extends from an end of the support collar to engage with a surface of the first end plate 14b which is inside the outer housing 14, the flange part 26a thus preventing the support collar 26 from being pushed out of the aperture in the first end plate 14b from inside the outer housing 14a. The first end 16a of the central rotor 16 is mounted in an aperture in a main body part 26b of the support collar 26. The aperture and first end 16a of the central rotor 16 are both provided with at least one flat surface when viewed in transverse cross-section and thus rotation of the central rotor 16 about its longitudinal axis A relative to the support collar 26 is prevented.

[0030] A first resilient support part 28 is provided between the support collar 26 and the end plate 14b, which in this example is a rubber O-ring which is mounted in a groove provided in the first end plate 14b around the circumference of the support collar receiving aperture. The support collar 26 is supported by the O-ring 28, and thus, by deformation of the O-ring, some movement of the support collar 26 relative to the outer housing 14 in any direction normal to the longitudinal axis A of the central rotor 16 is permitted.

[0031] The provision of the resilient support part 28 may reduce transmission of vibrations from the pump rotors 16, 18, 18' to the outer housing 14, and may thus reduce the noise generated by the pump assembly 10. In addition, any mechanical misalignment of the central rotor 16 with respect to the remainder of the pump assembly 10 can be accommodated by deformation of the resilient support part 28. The resilient support part 28 also provides a substantially fluid tight seal between the central rotor 16 and the outer housing 14.

[0032] The second end 16b of the central rotor 16, is unsupported, and does not extend beyond the outlet end 20b of the pump housing 20.

[0033] First 32 and second 34 generally annular pump end plates are provided at the inlet 20a and outlet 20b ends of the pump housing 20, the first end portion 16a of the central rotor 16 extending through a generally central aperture in the first pump end plate 32.

[0034] In this example, the first pump end plate 32 is connected to the inlet end 20a of the pump housing 20 such that the end plate 32 rotates with the pump housing 20, typically by means of bolts. Sufficient clearance is provided between the first end plate 32 and the central rotor 16 so that rotation of the housing 20 with respect to the central rotor 16 is permitted.

[0035] An annular ball or roller bearing 38 is mounted around the first end portion 16a of the central rotor 16 between the first pump end plate 32 and the support collar 26, and thus prevents movement of the pump housing 20 with respect to the central rotor 16 towards the first end plate 14b of the outer housing 14. In this example, the bearing 38 includes a first race which is located around the central rotor 16, and a second race, against which the first end plate 32 bears. A step is provided in an exterior surface of the first end plate 32 so that the first end plate 32 bears only on the second race, and does not contact the first race. The second race may thus either rotate about the longitudinal axis A of the central rotor 16 with the pump housing 20, whilst the first race is stationary, or both races may rotate about the longitudinal axis A of the central rotor 16 with the pump housing 20.

[0036] Inlet apertures 36 are provided at intervals around the circumference of the pump housing 20 between the inlet end 16a of the pump housing 20 and the first pump end plate 32, which permit fluid to flow from the fluid reservoir to the pump rotors 16, 18, 18'.

[0037] The second pump end plate 34 is connected

to the outlet end 20a of the pump housing 20, and the generally central aperture in the second pump end plate 34 provides an outlet for high pressure fluid from the pump housing 20 which is axially aligned with respect to longitudinal axis of the central rotor 16. The second pump end plate 34 is provided with a first bearing part 34a which extends axially with respect to the longitudinal axis of the central rotor 16, and which has a generally annular transverse cross-section.

[0038] The ends of the outer rotors 18, 18' bear against the two pump end plates 32, 34, and thus the pump end plates 32, 34 provide plain bearings for the outer rotors 18, 18'. Moreover, the start and end of each thread provided on the rotors 16, 18, 18' is spaced from each end of the rotors 16, 18, 18'. Spacing of the threads from the pump end plates 32, 34 results in the formation of fluid reservoirs at the inlet 20a and outlet 20b ends of the pump housing 20.

[0039] The first bearing part 34a bears on a sealing part 30 mounted in a generally circular outlet port 40 provided in the second end plate 14c of the outer housing 14. The sealing part 30 includes a generally central aperture which is axially aligned with the longitudinal axis A of the central rotor 16, and which permits flow of fluid through the outlet port 40 in the outer housing 14.

[0040] A radially outward facing surface of a first end 30a of the sealing part 30 is provided with a groove in which is received a second resilient biasing part 42, in this example, a rubber O-ring. The O-ring 42 provides a substantially fluid tight seal between the second end plate 14c of the outer housing 14 and the sealing part 30, and also permits limited movement of the sealing part 30 with respect to the outer housing 14 in a direction generally normal to the longitudinal axis A of the central rotor 16.

[0041] The provision of the second resilient support part 42 may also reduce transmission of vibrations from the pump rotors 16, 18, 18' to the outer housing 14, and may thus reduce the noise generated by the pump assembly 10. In addition, any mechanical misalignment of the central rotor 16 with respect to the remainder of the pump assembly 10 can be accommodated by deformation of the second resilient support part 42.

[0042] A second end 30b of the sealing part 30 provides a second bearing part which has a generally annular transverse cross-section, and which, in this example, has a sufficiently small outer diameter for the second end 30b to fit within the outlet aperture in the first bearing part 34a. The sealing part 30 thus supports and provides a bearing for the second end 20b of the pump housing 20.

[0043] It would be possible, however, for the second end 30b of the sealing part 30 to have a sufficiently large inside diameter for the second end 30b to fit around the first bearing part 34a.

[0044] The first bearing part 34a and second bearing part 30b are configured such that there is a small clearance, typically of the order of between 10µm and 30µm,

between a radially inwardly facing surface of the first bearing part 34a and a radially outwardly facing surface of the second bearing part 30b, this gap forming a bearing chamber. Thus, whilst the interaction between the axially extending surfaces of the first 34a and second 30b bearing parts provides a substantially fluid tight seal between the outlet port 40 and the pump housing 20, some leakage of high pressure fluid at the outlet end 20a of the pump housing 20 between the first bearing part 34a and the second bearing part 30b into the bearing chamber is permitted. The clearance is, however, sufficiently small that significant leakage of high pressure fluid from the pump housing 20 is prevented.

[0045] Thus, engagement of the radially inwardly facing surface of the first bearing part 34a and the radially outwardly facing surface of the second bearing part 30b provides a seal between the pump housing 20 and the outer housing 14 to ensure that the high pressure fluid at the outlet end 20a of the pump housing 20 is directed to the outlet port 40 and does not return to the fluid reservoir in the outer housing 14. Since the bearing parts 34a, 30b extend axially with respect to the longitudinal axes A, B, C of the pump housing 20 and the rotors 16, 18, 18', thermal expansion of the pump housing 20 parallel to its longitudinal axis can be accommodated, and axial load on the pump housing 20 and rotors 16, 18, 18' from the bearings is substantially eliminated.

[0046] Driving means 22, in this example an electric motor, is provided to drive rotation of the rotors 16, 18, 18'. The electric motor 22 includes a stator 24 which is provided with a plurality of electrically conductive windings arranged around and generally coaxially with the pump housing 20. A plurality of magnets are mounted around an outer surface of the pump housing 20 and thus the pump housing 20 forms the motor rotor.

[0047] Integrating the pumping housing 20 with the motor rotor further decreases the size of the pump assembly 10.

[0048] The motor 22 is enclosed by the outer housing 14, and fluid in the fluid reservoir provided by the outer housing 14 may thus flow over and around motor stator 24 and rotor 20. Thus, the electrically conductive windings of the stator 24 may be cooled by the fluid in the fluid reservoir. Furthermore, by virtue of positioning the inlet port 15 in the outer housing 14 adjacent to the second end plate 14c, i.e. adjacent the outlet end 20b of the pump housing 20, fluid that is drawn into the outer housing 14 during operation of the pump 12 passes over the stator windings before entering the pump housing 20.

[0049] The pump assembly is operated as follows.

[0050] Activation of the motor 22 causes the motor rotor, i.e. the pump housing 20, to rotate about the central rotor 16. Such rotation of the pump housing 20 causes rotation of the outer rotors 18, 18' about the longitudinal axis A of the central rotor 16. As described above the screw threads provided on the outer rotors 18, 18' mesh with the screw threads on the central rotor 16, and as

result, the outer rotors 18, 18' are forced to rotate about their longitudinal axes B, C in addition to rotating about the longitudinal axis A of the central rotor 16.

[0051] The consequent meshing and unmeshing of the screw threads causes fluid to be drawn into the inlet end 20a of the pump housing 20 between the threads at the first ends of the rotors 16, 18, 18'. As the rotors 16, 18, 18' turn, the meshing of the threads produces fluid chambers bounded by the threads and the pump housing 20. Fluid becomes trapped in the fluid chambers and continued rotation of the rotors 16, 18, 18' causes the fluid chambers to move from the first end of the rotors 16, 18, 18' to the second end of the rotors 16, 18, 18'. High pressure fluid is thus ejected from the pump housing 20 at the outlet end 20b via the apertures in the second pump end plate 34 and the sealing part 30, as a consequence of fluid being displaced from the fluid chambers as the screw threads at the second end of the rotors 16, 18, 18' mesh. The high pressure fluid then passes through the outlet port 40 and out of the outer housing 14.

[0052] Thus, fluid is pumped along the pump 12 in a direction generally parallel to the axis of rotation A of the central rotor 14. The provision of the outlet port 40 generally axially aligned with the axis of rotation A of the central rotor 16, thus ensures that the flow of pumped fluid in this direction continues as the high pressure fluid is ejected from the outer housing 14. In this way, pressure losses resulting from the ejected fluid being forced to change direction as it exits from the pump 12 are minimised.

[0053] Leakage of high pressure fluid into the bearing chamber between the bearing parts 34a, 30b allows the sealing part 30 to act as a hydrodynamic bearing for the second end 20b of the pump housing 20, which may assist in reducing energy losses due to friction between the sealing part 30 and the bearing part 34a.

[0054] There are some energy losses associated with the shear of the fluid between the bearing parts 34a, 30b, but the magnitude of such losses decreases significantly with decreasing shear radius. In conventional sealing arrangements, outlets are provided around the second end 16b of the central rotor 16 which engages with the outer housing 14, and the seal is effected between two surfaces generally normal to the axis of rotation A of the pump housing 20 around the outlet. Thus, the shear radius tends to be relatively high. By virtue of the provision of the outlet along the axis of rotation A, the shear radius, and hence shear losses, may be reduced in a pump according to the invention.

[0055] Owing to its compact design, a pump assembly 10 according to the invention is particularly useful in applications where high output pressure is required and space is restricted, such as in automotive applications, for example as an electrically operated power pack in which the pump 12 is activated to produce pressurised fluid and the pressurised fluid is used to move an actuator member.

[0056] It will be appreciated that the invention is not restricted to use in a pump of the configuration described above, and the invention may be applied to any pump in which it is desired to provide a seal between a rotating pumping member and an outlet in a housing, to ensure that pumped fluid is directed through the outlet.

tation of the pump housing (20a) causes the or each auxiliary rotor (18, 18') to orbit about the longitudinal axis of the main rotor (16).

Claims

1. A pump (10) including a pumping element (20), which is mounted for relative rotation in a housing (14), rotation of the pumping element (20) causing fluid to be pumped from an outlet (40) provided in the housing (14), the pumping element (20) including an axially extending bearing part (34a), and there being a sealing part (30) provided at the outlet (40), the sealing part (30) including an opening which is generally axially aligned with the axis of rotation (A) of the pumping element (20) and which provides a main flow path for fluid flow through the outlet (40), and the sealing part (30) including an axially extending bearing part (30b), which lies adjacent to the bearing part (34a) of the pumping element (20), axially extending surfaces of the two bearing parts (30b, 34a) providing a seal between the outlet (40) and the pumping element (20).
2. A pump (10) according to claim 1 wherein a fluid flow path is provided for flow of a limited amount of fluid into a bearing chamber between the two bearing parts (30b, 34a).
3. A pump (10) according to claim 1 or 2 wherein a resilient support part (42) is provided between the sealing part (30) and the housing (14), the resilient support part (42) permitting some movement of the sealing part (30) with respect to the housing (14).
4. A pump (10) according to claim 3 wherein the resilient support part (42) permits some movement of the sealing part (30) generally normal to the axis of rotation of the pumping element (20), and axially.
5. A pump (10) according to any preceding claim wherein the pumping element (20) includes a pump housing (20a) in which is mounted a main rotor (16) and at least one auxiliary rotor (18, 18'), the rotors (16, 18, 18') each being provided with at least one generally helical screw thread and being arranged in the housing (14) such that the screw threads mesh, the axis of rotation of the pumping element (A) coinciding with a longitudinal axis of a main rotor (16).
6. A pump (10) according to claim 5 wherein the main rotor (16) is fixed relative to the housing (14), and the pump housing (20a) is configured such that ro-

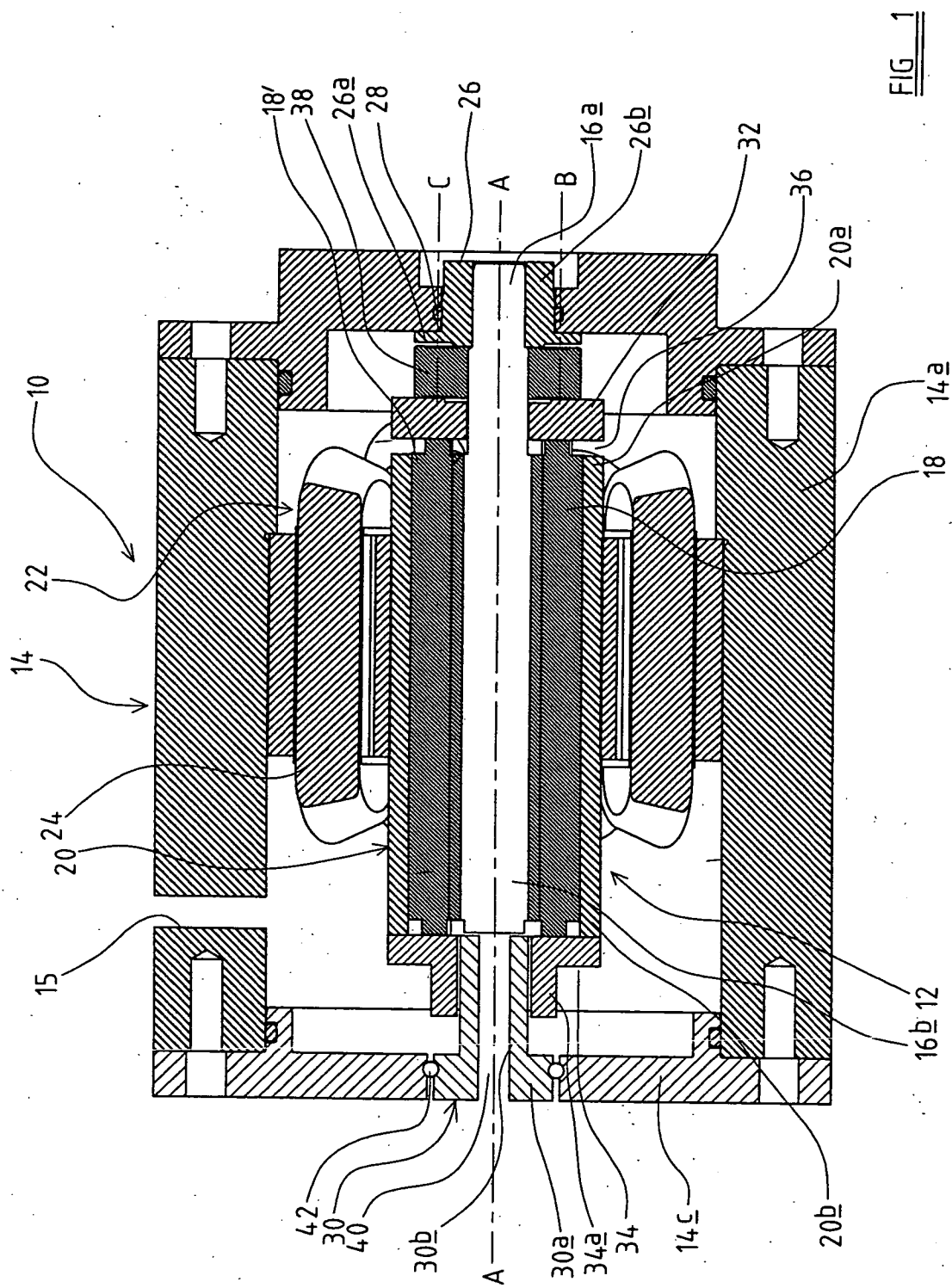


FIG. 1