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(54) **AN ASSEMBLY FOR COMPENSATING AXIAL FORCES IN A ROTATING FLOW MACHINE AND A MULTI-STAGE CENTRIFUGAL PUMP**

(57) Invention relates to an assembly (10) for compensating axial forces in a rotating flow machine (100) comprising

- a housing (18),
- a shaft (14) arranged rotatably to the housing (18),
- a rotationally symmetrical balancing part (20) arranged to and coaxially with the shaft (14) in the housing (18),
- the balancing part (20) having a first axial end (20.1) and a second axial end (20.2),
- a first mechanical slide ring sealing (12.1) arranged between the balancing part (20) and the housing (18) at the first axial end (20.1),
- a second mechanical slide ring sealing (12.2) arranged between the balancing part (20) and the housing (18) at

the second axial end (12.2),

- the first and the second mechanical slide ring sealings (12.1,12.2) are arranged so as to seal an intermediate space (26), extending axially between the mechanical slide ring sealings (12.1,12.2), the intermediate space (26) being bordered by the slide ring sealings (12.1,12.2), the balancing part (20) and the housing (18), and
- a first fluid communication port (28) opening into the intermediate space (26),
- the first fluid communication port (26) being connected to a source of pressurized barrier fluid (29). Invention relates also to a multi-stage centrifugal pump comprising such an assembly.

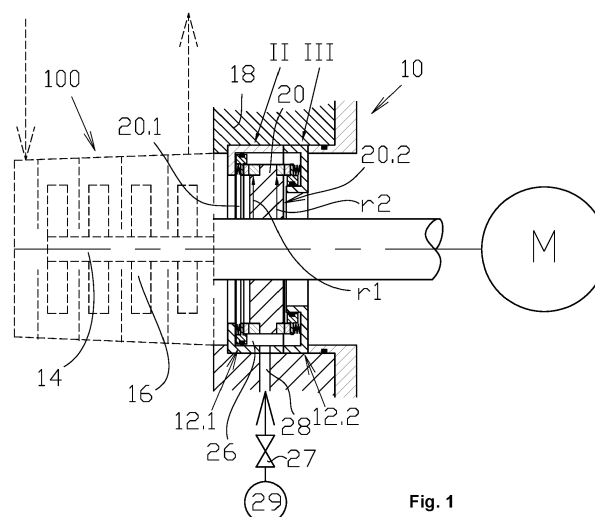


Fig. 1

Description

Technical field

[0001] The present invention relates to an assembly for compensating axial forces in a rotating flow machine.

[0002] The present invention relates also to a multi-stage centrifugal pump.

Background art

[0003] Centrifugal flow machines, such as centrifugal pumps, are provided with an impeller wheel arranged into a housing by means of a rotatably supported shaft. During the operation of such centrifugal flow machines axial forces are subjected to the shaft. Such axial forces can be minimized by suitably designing the slow machine. Remaining forces are transmitted to the housing via a thrust bearing. Balancing axial forces is particularly relevant to multi-stage centrifugal flow machine where each stage results in an axial force component i.e. thrust to the system. The net axial thrust of an impeller is the difference between forces acting on back and front shrouds. There are number of hydrodynamic effects that can alter these forces. For instance, ring leakage or impeller axial positioning relative to the volute or diffuser can alter the pressure distribution between the impeller and sidewall gaps. Relatively small changes in pressure are greatly magnified by the large projected shroud surface areas. The result can be very large shifts in axial thrust in either direction.

[0004] It is known as such to use a so called balancing drum of minimizing the axial forces subjected to the bearings. Balancing drum is a part connected to a drive shaft of the machine, which drum has a cylindrical outer surface parallel with a center axis of the shaft of the centrifugal flow machine. The housing of the centrifugal flow machine is provided with a cylindrical space for the balancing drum. There is a clearance gap arranged between the balancing drum and the space in the housing. The purpose of the gap is to provide a flow restriction providing a pressure difference over the balancing drum. However, the clearance gap makes it possible for the process fluid to flow through the gap to some extent and therefore the efficiency of the centrifugal flow machine is decreased. Thus, it is often so that using the balancing drum cannot totally eliminate the need of a thrust bearing.

[0005] An object of the invention is to provide an assembly for compensating axial forces in a rotating flow machine which performance is considerably improved compared to the prior art solutions.

[0006] An object of the invention is to provide a multi-stage pump in which axial forces are compensated in an improved manner.

Disclosure of the Invention

[0007] Objects of the invention can be met substantial-

ly as is disclosed in the independent claims and in the other claims describing more details of different embodiments of the invention.

[0008] According to an embodiment of the invention an assembly for compensating axial forces in a rotating flow machine comprises

a housing,

a shaft arranged rotatably to the housing,

a rotationally symmetrical balancing part arranged to and coaxially with the shaft in the housing, wherein the balancing part having a first axial end and a second axial end,

a first mechanical slide ring sealing arranged between the balancing part and the housing at the first axial end, a second mechanical slide ring sealing arranged between the balancing part and the housing at the second axial end, wherein

the first and the second mechanical slide ring sealings are arranged so as to seal an intermediate space, extending axially between the mechanical slide ring sealings, the intermediate space being bordered by the slide ring sealings, the balancing part and the housing, and a first fluid communication port opening into the intermediate space,

the first fluid communication port being connected to a source of pressurized barrier fluid.

[0009] This way the balancing part may be arranged to balance axial forces effectively without undue leakage. The presence of pressurized barrier fluid in the intermediate space decreases the pressure difference over the first mechanical slide ring sealing which in turn decreases the stress caused to the sealing rings and increases operational lifetime of the mechanical sealing. Respectively, the presence of pressurized barrier fluid decreases the pressure difference over the second mechanical slide ring sealing.

[0010] According to an embodiment of the invention the assembly comprises a second communication port communication port opening into the intermediate space, and that the assembly comprises a fluid circulation channel connecting the first fluid communication port and the second communication port with each other.

[0011] This way there may be arranged a substantially closed looped of fluid circulation which may be utilized for e.g. cooling the system.

[0012] According to an embodiment of the invention the assembly comprises a second communication port communication port opening into the intermediate space, and that the assembly comprises a fluid circulation channel connecting the first fluid communication port and the second communication port with each other and the fluid circulation channel is connected to a source of pressurized fluid.

[0013] According to an embodiment of the invention the assembly comprises a second communication port opening into the intermediate space and the second fluid communication port is connected to a fluid discharge system.

[0014] According to an embodiment of the invention the assembly comprises a second communication port opening into the intermediate space, and that the assembly comprises a fluid circulation channel connecting the first fluid communication port and the second communication port with each other and the fluid circulation channel is connected to a source of pressurized fluid,

[0015] According to an embodiment of the invention the assembly comprises a second communication port opening into the intermediate space and the second fluid communication port is connected to a fluid discharge system and the circulation channel is fluidly connected to the rotating flow machine's working fluid space between its inlet and outlet.

[0016] This way the rotating flow machine's working fluid may act as the barrier fluid and external source of fluid is not needed.

[0017] According to an embodiment of the invention the housing of the balancing part comprises a cylindrical inner surface, and the balancing part comprises a cylindrical outer surface, the cylindrical inner surface of the housing and the cylindrical outer surface of the balancing part form radial slide bearing between the balancing part and the housing.

[0018] According to an embodiment of the invention the housing of the balancing part comprises a cylindrical inner surface, and the balancing part comprises a cylindrical outer surface, the cylindrical inner surface of the housing and the cylindrical outer surface of the balancing part form radial slide bearing between the balancing part and the housing, and the slide bearing surfaces are comprised of removable sleeves having their axial length equal to the first and the second axial length.

[0019] According to an embodiment of the invention the first mechanical slide ring sealing comprises: a first stationary sealing ring supported to the housing in axially movable manner, a spring element causing axial force to the first stationary sealing ring urging the first stationary sealing ring towards the balancing part, and that the second slide ring sealing comprises: a second stationary sealing ring supported to the housing in axially movable manner, a spring element causing axial force to the second stationary sealing ring urging the second stationary sealing ring towards the balancing part.

[0020] According to an embodiment of the invention the balancing part is provided with a ring member configured to co-operate with the first stationary sealing ring and the second stationary sealing ring.

[0021] Improved balancing of axial forces can be solved by a multi-stage centrifugal pump having a drive shaft and more than one impellers arranged to the drive shaft, comprising an assembly for compensating axial forces according to the invention.

[0022] According to an embodiment of the invention a multi-stage centrifugal pump comprising an assembly for compensating axial forces comprising a second communication port opening into the inter-

mediate space, and the assembly comprises a fluid circulation channel connecting the first fluid communication port and the second communication port with each other, wherein the circulation line is connected to a stage of the pump between a first and a last stage of the pump.

[0023] According to an embodiment of the invention the circulation line is connected to the centrifugal pump at a location which provides 30-70% of the maximum pressure of the pump.

[0024] The exemplary embodiments of the invention presented in this patent application are not to be interpreted to pose limitations to the applicability of the appended claims. The verb "to comprise" is used in this patent application as an open limitation that does not exclude the existence of also unrecited features. The features recited in depending claims are mutually freely combinable unless otherwise explicitly stated. The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims.

Brief Description of Drawings

[0025] In the following, the invention will be described with reference to the accompanying exemplary, schematic drawings, in which

Figure 1 illustrates an assembly for compensating axial forces in a rotating flow machine according to an embodiment of the invention,

Figure 2 illustrates a detail II of the figure 1,

Figure 3 illustrates a detail III of the figure 1,

Figure 4 illustrates an assembly for compensating axial forces in a rotating flow machine according to another embodiment of the invention,

Figure 5 illustrates an assembly for compensating axial forces in a rotating flow machine according to another embodiment of the invention,

Figure 6 illustrates an assembly for compensating axial forces in a rotating flow machine according to another embodiment of the invention, and

Figure 7 illustrates an assembly for compensating axial forces in a rotating flow machine according to still another embodiment of the invention.

Detailed Description of Drawings

[0026] Figure 1 depicts schematically an assembly 10 for compensating axial forces in a rotating flow machine 100 according to an embodiment of the invention. The assembly is preferably an integral part of the rotating flow machine. The rotating flow machine 100 is depicted in

schematic way but it may be for example a multi-stage pump where the axial force may be at a magnitude that balancing sole by bearings is not economical. In general, the assembly 10 is provided for compensating axial forces caused by operation of the rotating flow machine 100. The multi-stage pump 100 itself is not explained in more detailed manner. The centrifugal multi-stage pump 100 is provided with a drive shaft 14 to which a number of impellers 16 are attached. The drive shaft is provided with suitable bearing for providing rotatably supporting the shaft to a housing 18 of the assembly and the rotating flow machine 100 in general. The shaft may be driven by an electric motor M directly or via a coupling. There is a balancing part 20 arranged to the shaft 14, or an extension thereof, such that the balancing part is rigidly attached to the shaft 14. The balancing part is configured to balance, or at least assist balancing of axial forces caused by the impellers to the shaft 14 when the pump 100 is in operation. The balancing part 20 is arranged inside the housing 18. The inner space of the housing 18 for the balancing part 20 is such that there is a space formed between the balancing part 20 and housing 18, the space being substantially annular space which is parallel to the axial direction of the shaft 14. The balancing part 20 may be an integral part of the shaft or releasably attached coaxially to the shaft such that it rotates along with the shaft 14. The balancing part 20 has a first axial end 20.1 and a second axial end 20.2. The first axial end 20.1 has an axial face projection having a radius r_1 , which together with the diameter of the shaft defines the projection area of the first axial end 20.1. The projection area in turn, together with a prevailing pressure, defines the axial force exerted to the first end of the balancing part 20, in a manner known as such to a skilled person in the art. The balancing part may be constructed as an assembly of separate part if so desired.

[0027] The assembly 10 is provided with a first mechanical slide ring sealing 12.1 arranged between the balancing part 20 and the housing 18 at the first axial end of the balancing part 20, and a second mechanical slide ring sealing 12.2 arranged between the balancing part and the housing 18 at the second axial end 20.2 of the balancing part 20. The first and the second mechanical slide ring sealings 12.1, 12.2 are arranged so as to seal an intermediate space 26 axially between the mechanical slide ring sealings 12.1, 12.2. The intermediate space 26 is bordered by the slide ring sealings 12.1, 12.2, the balancing part 20 and the housing 18. Even if not shown here, the assembly 10 may comprise even more than two successive mechanical slide ring sealings and respectively intermediate spaces between each pair of mechanical slide ring sealings. There is a first fluid communication port 28 arranged to the housing 18, which first fluid communication port 28 opens into the intermediate space 26. The first fluid communication port 28 is connected to a source of pressurized barrier fluid 29 such that pressurized barrier fluid may be controllably led into the intermediate space 26 between the mechanical slide

ring sealings 12.1, 12.2. In the embodiment of the figure 1 the source of pressurized barrier fluid 29 is connected to the first fluid communication port 28 via a control means 27, comprising a valve, so that the pressure in the intermediate space 26 can be, and is maintained at a level lower than the maximum pressure of the fluid in the rotating flow machine and higher than the minimum pressure of the fluid in the rotating flow machine. As the slide ring sealings now seal the flow connection between the first axial end 20.1 and the second axial end 20.2 of the balancing part 20 it is also possible to make the balancing part 20 axially shorter, meaning the axial distance between the first axial end 20.1 and the second axial end 20.2, than a conventional balancing drum, because the annular gap between the balancing part and the housing 18 has practically no role in sealing the flow connection between the first axial end 20.1 and the second axial end 20.2 of the balancing part 20. The barrier fluid is selected suitably taken into account e.g. the properties of the working fluid in the rotating flow machine 100. The source of pressurized fluid 29 may be the pump 100 itself or an external fluid source, such as a source of pressure water.

[0028] As is depicted in the embodiment in the figure 1, being a multi-stage high pressure pump having a set of series coupled impellers, the stage of highest pressure effects on the first axial end 20.1 of the balancing part 20 while the second axial end 20.2 of the balancing part 20 is against the inlet pressure of the multi-stage pump (connection not shown). The pressure difference over the balancing part 20, i.e. between the first axial end 20.1 and the second axial end 20.2 of the balancing part 20 can be maintained by the mechanical slide ring sealings 12.1, 12.2. The assembly can be utilized also one-stage centrifugal pump.

[0029] The second axial end 20.2 has an axial face projection having a radius r_2 , which together with the diameter of the shaft defines the projection area of the second axial end 20.2. The projection area in turn, together with a prevailing pressure, defines the axial force exerted to second end of the balancing part 20. In the figure 1 the radiuses r_1 and r_2 at the ends of the balancing part 20 are equal but they may be also different depending on the design of the assembly. The radiuses refer to the inner radius of the mechanical slide ring sealing. The balancing part 2 is at least at its ends rotationally symmetrical in respect to the shaft 14, so as to facilitate the installation of mechanical sealings 12.1, 12.2 to the ends of the balancing part 20. The balancing part has advantageously of substantially cylindrical form.

[0030] It can be said that that centrifugal flow machine 100 comprises a first fluid region at a first axial side, behind the first axial end 20.1 of the balancing part 20 and a second fluid region at a second axial side behind the second axial end 20.2 of the balancing part and, when the centrifugal flow machine is operating, the fluid pressure is higher at the first fluid region than at the second fluid region. In the figure 1 the second axial end 20.2 is bordered to the surrounding atmosphere.

[0031] Figure 2 shows the detail II of the figure 1 where the first mechanical slide ring sealing 12.1 is shown in more detailed manner. The first mechanical slide ring sealing 12.1 comprises a first stationary sealing ring 1211 supported to the housing 18 in axially movable, but non-rotatable manner. There is provided a first support sleeve 181 which is attached to the body part 18 and to which first support sleeve 181 the first stationary sealing ring 1211 is supported. The assembly comprises a first carrier ring 1212 to which the first stationary sealing ring 1211 is supported. The first carrier ring 1212 is supported by the first support sleeve 181 in axially movable manner. The first carrier ring 1212 is provided with a seal, such as an O-ring 1213, which seals the gap between the first carrier ring 1212 and the first support sleeve 181. Both the first carrier ring 1212 and the first stationary sealing ring 1211 are supported in axially movable, but non-rotatable manner. There is a first spring element 1214 causing axial force to the first stationary sealing ring urging the first stationary sealing ring towards the balancing part. As is depicted in the figure 2 the pressure at the space which the first end 20.1 of the balancing part borders, creates a pressing force against the first carrier ring 1212 such that it assists the first spring element 1214 to cause axial force to the first stationary sealing ring 1211. The sealing rings form a primary consisting of two extremely flat faces, one fixed, one rotating, running against each other. The seal faces are pushed together using a combination of hydraulic force from the sealed fluid and spring force from the seal design. In this way a seal is formed to substantially prevent leaking. The faces are kept lubricated by maintaining a thin film of fluid between the seal faces.

[0032] The balancing part 20 is provided with a first rotating seal ring 201 which arranged to the first axial end 20.1 of the balancing part, at the first radius r_1 . There is an annular notch at the rim of the balancing part 20 to which the first rotating seal ring is attached so that it is rotating with the balancing part but is rigidly attached to the balancing part 20.

[0033] Figure 3 shows the detail III of the figure 1 where the second mechanical slide ring sealing 12.2 is shown in more detailed manner. The second mechanical slide ring sealing 12.2 comprises a second stationary sealing ring 1221 supported to the housing 18 in axially movable, but non-rotatable manner. There is provided a second support sleeve 182 which is attached to the body part 18 and to which second support sleeve 182 the second stationary sealing ring 1221 is supported. The assembly comprises a second carrier ring 1222 to which the second stationary sealing ring 1221 is supported. The second carrier ring 1222 is supported by the second support sleeve 182 in axially movable manner. The second carrier ring 1222 is provided with a seal, such as an O-ring 1223, which seals the gap between the second carrier ring 1222 and the second support sleeve 182. Both the second carrier ring 1222 and the second stationary sealing ring 1222 are supported in axially movable, but non-

rotatable manner. There is a second spring element 1224 causing axial force to the second stationary sealing ring urging the first stationary sealing ring towards the balancing part 20. As is depicted in the figure 3 the pressure at the intermediate space 26, creates a pressing force against the second carrier ring 1222 such that it assists the second spring element 1224 to cause axial force to the second stationary sealing ring 1221.

[0034] The balancing part 20 is provided with a second rotating seal ring 202 which arranged to the second axial end 20.2 of the balancing part 20, at the second radius r_2 . There is an annular notch at the rim of the balancing part 20 to which the second rotating seal ring is attached so that it is rotating with the balancing part but is rigidly attached to the balancing part 20.

[0035] Figure 4 depicts schematically an assembly 10 for compensating axial forces in a rotating flow machine 100 according to another embodiment of the invention. The assembly is substantially similar to that shown in the figure 1, however, provided with certain optional refinements. The rotating flow machine 100 is a multi-stage centrifugal pump which a fluid inlet 102 and a fluid outlet 104. The pumped fluid may be for example water in various practical application. The assembly 10 is arranged as an integral part of the multi-stage pump for compensating internal axial forces caused to its shaft by operation of the pump 100. The multi-stage pump 100 itself is not explained in more detailed. The multi-stage pump 100 is provided with a drive shaft 14 to which a number of impellers 16 are attached. The drive shaft 14 is provided with suitable bearings (not shown) for providing rotatably supporting the shaft to a housing 18. There is a balancing part 20 arranged to the shaft 14 which is similar to that shown in the figures 1, 2 and 3. Thus, the description of the features of the figures 1 to 3 is applicable also to the figure 4, at least what comes to the balancing part 20 and its operation. Here the balancing part 20 is axially longer than that shown in the figure 1 indicating that the axial length of the balancing part 20 may vary depending on the practical application.

[0036] The assembly 10 is provided with a first mechanical slide ring sealing 12.1 arranged between the balancing part and the housing 18 at the first axial end of the balancing part 20, and a second mechanical slide ring sealing 12.2 arranged between the balancing part and the housing 18 at the second axial end 20.2 of the balancing part 20. Correspondingly the mechanical slide ring sealings and their operation corresponds to the figure 1. There is a first fluid communication port 28 arranged to the housing 18, which first fluid communication port 28 opens into the intermediate space 26 between the mechanical slide ring sealings 12.1, 12.2. There is also a second fluid communication port 30 arranged to the housing 18. Depending on the actual structure, the fluid communications ports 28, 30 may extend through the first support sleeve 181 (see figs 2 and 3). Both the first fluid communication port 28 and the second fluid communication port 30 open into the intermediate space

26, preferably at different angular locations. Generally speaking, one of the fluid communication ports 28, 30 is connected to a source of pressurized barrier fluid 29 such that pressurized barrier fluid at predetermined pressure level may be controllably led to the intermediate space 26 axially between the mechanical slide ring sealings 12.1, 12.2. The other one is then connected to a barrier fluid discharge system of pressurized barrier fluid. More advantageously, which is shown in the figure 4, there is a fluid circulation channel 32 provided in the arrangement 10 such that the second fluid communication port 30 is in fluid communication with the first fluid communication port 28. This way the barrier fluid is arranged to flow from the second fluid communication port 30 back to the first fluid communication port 28 via the fluid circulation channel 32 externally. The fluid flow is made possible or at least assisted by pumping effect of rotating balancing part 20 in the housing 18. The balancing part 20 and/or the housing can be configured such pumping effect of the barrier fluid can be obtained. There may be a separate pump (not shown) arranged to the fluid circulation channel 32 should the pumping effect caused by the balancing part be too low.

[0037] The fluid circulation channel 32 is advantageously provided with a heat exchanger 34 so as to extract excessive heat from the mechanical slide ring sealings 12.1, 12.2 and the balancing part 20. The fluid circulation channel 32 is connected to a source of pressurized barrier fluid such that the intermediate space 26 is maintained at suitable pressure in respect to the maximum pressure obtainable from the multi-stage pump 100. It has been found out that by connecting the fluid circulation channel 32, or the intermediate space via a separate channel (not shown), to a suitable stage of the pump 100, the pressure in the intermediate space can be maintained at desired level. Thus, the assembly 10 is provided with a feed channel 36 which fluidly connects a stage of the pump 100 to the intermediate space 26, in the embodiment of the figure 4 indirectly via the fluid circulation channel 32. In other words, the feed channel 36 is connected to the multi-stage pump's fluid space between its fluid inlet 102 and outlet 104. The desired pressure level in the intermediate space 26 is 30-70% of the maximum pressure of the pump 100 or more advantageous substantially 50% of the maximum pressure of the pump 100. Still, if the pressure level in the intermediate space 26 is maintained between 30-70 % of the maximum pressure of the pump 100, partial beneficial effects of pressurizing the intermediate space are obtained, in terms of improving the operational life of the mechanical sealings.

[0038] The intermediate space 26 is connected to the multi-stage pump 100 to a stage between the first stage 14.1 and the last stage 14.n. When the pump has an uneven number of stages the feed channel 36 is preferably connected to the middle one of the stages. When the pump has an even number of stages the feed channel 36 is may be connected to either one of the two middle-stages. Should there be a need for obtaining more accu-

rate pressure level in the intermediate space 26, the feed channel 36 may be connected to a predetermined radial location in the housing at a pump stage.

[0039] This way the presence of pressurized barrier fluid decreases the pressure difference over the first mechanical slide ring sealing 12.1 practically automatically in response to the operational point of the pump 100.

[0040] Figure 5 depicts schematically an assembly 10 for compensating axial forces in a rotating flow machine 100 according to another embodiment of the invention. The assembly 10 in the figure 5 is substantially similar to that shown in the figure 1 and particularly the figure 4, however, provided with certain still further optional refinements. It also operates in substantially same way as the embodiments of the figure 1 and 4. Thus, the description of the features of the figure 4 is applicable also to the figure 5.

[0041] In addition to the features described in collection with the figure 4, in the assembly 10 according to the embodiment of the figure 5 the housing 18 of the balancing part comprises inside the first support sleeve 181 a cylindrical inner surface 40. Respectively the balancing part comprises a cylindrical outer surface 42. The cylindrical inner surface of the housing 18 and the cylindrical outer surface of the balancing part 20 together form radially supporting slide bearing between the balancing part and the housing. The cylindrical inner surface 40 has a first axial length, and the cylindrical outer surface 42 has a second axial length and the first axial length substantially equals to the second axial length.

[0042] More particularly, in the embodiment shown in the figure 5 the slide bearing surfaces are comprised of removable sleeves 44, 46 arranged to the housing 18 and the balancing part 20, respectively. Also, it is preferable that the slide bearing surfaces are comprised of removable sleeves having their axial length equal to the first and the second axial length. The removable sleeves are preferably made of silicon carbide (SiC) or other suitable material for slide bearing. The axial ends of the sleeve in the balancing part 20 serves as sealing surface of the first and the second mechanical slide ring sealing 12.1, 12.2. Circumstances for the radial bearing are very stable, which improves its reliability.

[0043] Figure 6 depicts schematically an assembly 10 for compensating axial forces in a rotating flow machine 100 according to another embodiment of the invention. The assembly 10 in the figure 6 is substantially similar to that shown in the figure 1 and particularly the figure 4, however, provided with certain further optional refinements. It also operates in substantially same way as the embodiments of the figure 1 and 4. Thus, the description of the features of the figure 4 is applicable also to the figure 5.

[0044] Figure 7 depicts schematically an assembly 10 for compensating axial forces in a rotating flow machine 100 according to an embodiment of the invention. The assembly is substantially similar to that shown in the figure 1, however, provided with certain optional modifica-

tions. It also operates in substantially same way as the embodiments of the figure 1 and 4. Thus, the description of the features of the figures 1 and 4 are applicable also to the figure 7, and vice versa. In addition to the features described in collection with the figure 1 and/or in the figure 4, in the assembly 10 according to the embodiment of the figure 7 the balancing part 20 is formed of multiple separate members 20', 20". The first balancing part 20' comprises a pair of mechanical slide ring sealings 12.1, 12.2 as is shown in the figure 1 at both ends of the balancing part 20. The second balancing part 20" comprises here one mechanical slide ring sealing 12.3. There is the intermediate space 26 arranged between each two successive mechanical slide ring sealings 12.1, 12.2, 12.3. There is a first fluid communication port 28 and a second fluid communication port 30 arranged to the housing 18, which fluid communication ports open into the first intermediate space 26. And further, there is a third fluid communication port 28' and a fourth fluid communication port 30' arranged to the housing 18, which fluid communication ports open into the first intermediate space 26 between the second and third mechanical slide ring sealings 12.2, 12.3. It is also conceivable that the number of successive mechanical slide ring sealings is even more, wherein each intermediate space between two successive slide ring sealings comprising the communication ports for pressurizing the intermediate space as disclosed in the figure 1 and/or figure 4. Pressure in the successive intermediate spaces between successive slide ring sealings is gradually decreasing from the space nearest to the pump 100 to the space opposite side to the pump 100.

[0045] While the invention has been described herein by way of examples in connection with what are, at present, considered to be the most preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but is intended to cover various combinations or modifications of its features, and several other applications included within the scope of the invention, as defined in the appended claims. The details mentioned in connection with any embodiment above may be used in connection with another embodiment when such combination is technically feasible.

Numbered list of embodiments

[0046]

1. An assembly for compensating axial forces in a rotating flow machine comprising

- a housing,
- a shaft arranged rotatably to the housing,
- a rotationally symmetrical balancing part arranged to and coaxially with the shaft in the housing,
- the balancing part having a first axial end and a

second axial end,

- a first mechanical slide ring sealing arranged between the balancing part and the housing at the first axial end,
- a second mechanical slide ring sealing arranged between the balancing part and the housing at the second axial end,
- the first and the second mechanical slide ring sealings are arranged so as to seal an intermediate space, extending axially between the mechanical slide ring sealings, the intermediate space being bordered by the slide ring sealings, the balancing part and the housing, and
- a first fluid communication port opening into the intermediate space,
- the first fluid communication port being connected to a source of pressurized barrier fluid.

2. An assembly for compensating axial forces in a rotating flow machine according to embodiment 1, characterized in that the assembly comprises a second communication port opening into the intermediate space, and that the assembly comprises a fluid circulation channel connecting the first fluid communication port and the second communication port with each other.

3. An assembly for compensating axial forces in a rotating flow machine according to embodiment 2, characterized in that the fluid circulation channel is connected to a source of pressurized fluid.

4. An assembly for compensating axial forces in a rotating flow machine according to embodiment 1, characterized in that the first fluid communication port is connected to an external source of pressurized barrier fluid.

5. An assembly for compensating axial forces in a rotating flow machine according to embodiment 1 or 4, characterized in that the assembly comprises a second communication port opening into the intermediate space and the second fluid communication port is connected to a fluid discharge system.

6. An assembly for compensating axial forces in a rotating flow machine according to embodiment 2 or 3, characterized in that the circulation channel is fluidly connected to the rotating flow machine's working fluid space between its inlet and outlet.

7. An assembly for compensating axial forces in a rotating flow machine according to embodiment 1, characterized in that the housing of the balancing part comprises a cylindrical inner surface, and the balancing part comprises a cylindrical outer surface, the cylindrical inner surface of the housing and the cylindrical outer surface of the balancing part form

radial slide bearing between the balancing part and the housing.

8. An assembly for compensating axial forces in a rotating flow machine according to embodiment 7, characterized in that the slide bearing surfaces are comprised of removable sleeves arranged to the housing and the balancing part. 5

9. An assembly for compensating axial forces in a rotating flow machine according to embodiment 7, characterized in that the housing of the balancing part comprises a cylindrical inner surface having a first axial length, and the balancing part comprises a cylindrical outer surface having a second axial length, wherein the first axial length equals to the second axial length. 10 15

10. An assembly for compensating axial forces in a rotating flow machine according to embodiment 7, characterized in the slide bearing surfaces are comprised of removable sleeves having their axial length equal to the first and the second axial length. 20

11. An assembly for compensating axial forces in a rotating flow machine according to embodiment 1, characterized in that the first mechanical slide ring sealing comprises: a first stationary sealing ring supported to the housing in axially movable manner, a spring element causing axial force to the first stationary sealing ring urging the first stationary sealing ring towards the balancing part. 25 30

12. An assembly for compensating axial forces in a rotating flow machine according to embodiment 1, characterized in that the second slide ring sealing comprises: a second stationary sealing ring supported to the housing in axially movable manner, a spring element causing axial force to the second stationary sealing ring urging the second stationary sealing ring towards the balancing part. 35 40

13. An assembly for compensating axial forces in a rotating flow machine according to embodiment 11, characterized in that the balancing part is provided with a first rotating seal ring configured to co-operate with the first stationary sealing ring. 45

14. An assembly for compensating axial forces in a rotating flow machine according to embodiment 12, characterized in that the balancing part is provided with a second rotating seal ring configured to co-operate with the second stationary sealing ring. 50

15. An assembly for compensating axial forces in a rotating flow machine according to embodiments 13 and 14. 55

16. An assembly for compensating axial forces in a rotating flow machine according to embodiments 11 and 12, characterized in that the balancing part is provided with a ring member configured to co-operate with the first stationary sealing ring and the second stationary sealing ring.

17. An assembly for compensating axial forces in a rotating flow machine according to embodiment 2, characterized in that the fluid circulation channel is provided with a heat exchanger.

18. An assembly for compensating axial forces in a rotating flow machine according to anyone of the preceding embodiments, characterized in that the comprise more than two successive mechanical slide ring sealings arranged between the balancing part and the housing, and intermediate spaces between each two successive mechanical slide ring sealings a fluid communication port opening into each one of the intermediate space, the fluid communication port being connected to a source of pressurized barrier fluid.

19. A multi-stage centrifugal pump having a drive shaft and more than one impellers arranged to the drive shaft, comprising an assembly for compensating axial forces according to anyone of the preceding embodiments.

20. A multi-stage centrifugal pump according to embodiment 19, comprising an assembly for compensating axial forces according to embodiment 2 characterized in that the circulation line is connected to a stage of the pump between a first and a last stage of the pump.

21. A multi-stage centrifugal pump according to embodiment 20, characterized in that the circulation line is connected to the centrifugal pump at a location which provides 30-70% of the maximum pressure of the pump.

22. A multi-stage centrifugal pump according to embodiment 21, characterized in that pump has uneven number of stages and the circulation line is connected to a middle stage of the pump.

23. A multi-stage centrifugal pump according to embodiment 22, characterized in that pump has even number of stages and the circulation line is connected to one of the stages closest to middle of the stages of the pump.

24. A multi-stage centrifugal pump according to embodiment 19, characterized in that a pressure fluid source separate to the multi-stage centrifugal pump is connected to the first fluid communication port.

25. A multi-stage centrifugal pump according to embodiment 23, characterized in that the separate pressure fluid source is connected to the intermediate space via a pressure regulating valve.

Claims

1. An assembly (10) for compensating axial forces in a rotating flow machine (100) comprising

- a housing (18),
- a shaft (14) arranged rotatably to the housing (18),
- a rotationally symmetrical balancing part (20) arranged to and coaxially with the shaft (14) in the housing (18),
- the balancing part (20) having a first axial end (20.1) and a second axial end (20.2),
- a first mechanical slide ring sealing (12.1) arranged between the balancing part (20) and the housing (18) at the first axial end (20.1),
- a second mechanical slide ring sealing (12.2) arranged between the balancing part (20) and the housing (18) at the second axial end (12.2),
- the first and the second mechanical slide ring sealings (12.1, 12.2) are arranged so as to seal an intermediate space (26), extending axially between the mechanical slide ring sealings (12.1, 12.2), the intermediate space (26) being bordered by the slide ring sealings (12.1, 12.2), the balancing part (20) and the housing (18), and
- a first fluid communication port (28) opening into the intermediate space (26),
- the first fluid communication port (26) being connected to a source of pressurized barrier fluid (29).

2. An assembly for compensating axial forces in a rotating flow machine according to claim 1, **characterized in that** the assembly comprises a second communication port opening into the intermediate space, and that the assembly comprises a fluid circulation channel connecting the first fluid communication port and the second communication port with each other.

3. An assembly for compensating axial forces in a rotating flow machine according to claim 2, **characterized in that** the fluid circulation channel is connected to a source of pressurized fluid.

4. An assembly for compensating axial forces in a rotating flow machine according to claim 1, **characterized in that** the assembly comprises a second communication port opening into the intermediate space and the second fluid communication port is connected to a fluid discharge system.

5. An assembly for compensating axial forces in a rotating flow machine according to claim 2 or 3, **characterized in that** the circulation channel is fluidly connected to the rotating flow machine's working fluid space between its inlet and outlet.

6. An assembly for compensating axial forces in a rotating flow machine according to claim 1, **characterized in that** the housing of the balancing part comprises a cylindrical inner surface, and the balancing part comprises a cylindrical outer surface, the cylindrical inner surface of the housing and the cylindrical outer surface of the balancing part form radial slide bearing between the balancing part and the housing.

7. An assembly for compensating axial forces in a rotating flow machine according to claim 6, **characterized in that** the slide bearing surfaces are comprised of removable sleeves having their axial length equal to the first and the second axial length.

8. An assembly for compensating axial forces in a rotating flow machine according to claim 1, **characterized in that** the first mechanical slide ring sealing comprises: a first stationary sealing ring supported to the housing in axially movable manner, a spring element causing axial force to the first stationary sealing ring urging the first stationary sealing ring towards the balancing part, and that the second slide ring sealing comprises: a second stationary sealing ring supported to the housing in axially movable manner, a spring element causing axial force to the second stationary sealing ring urging the second stationary sealing ring towards the balancing part.

9. An assembly for compensating axial forces in a rotating flow machine according to claim 8, **characterized in that** the balancing part is provided with a ring member configured to co-operate with the first stationary sealing ring and the second stationary sealing ring.

10. A multi-stage centrifugal pump having a drive shaft and more than one impellers arranged to the drive shaft, comprising an assembly for compensating axial forces according to anyone of the preceding claims.

11. A multi-stage centrifugal pump according to claim 10, comprising an assembly for compensating axial forces according to claim 2 **characterized in that** the circulation line is connected to a stage of the pump between a first and a last stage of the pump.

12. A multi-stage centrifugal pump according to claim 10, **characterized in that** the circulation line is connected to the centrifugal pump at a location which provides 30-70% of the maximum pressure of the pump.

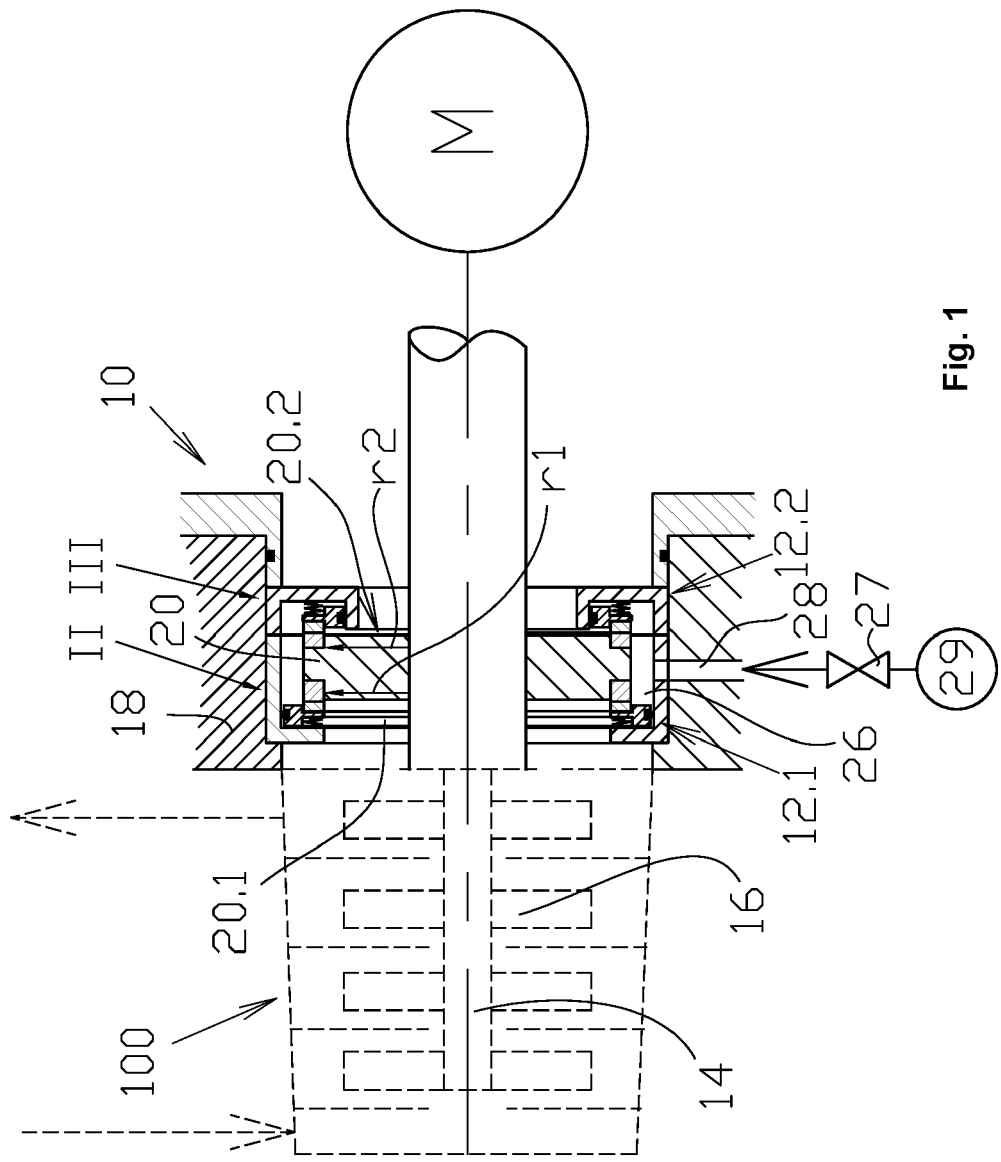


Fig. 1

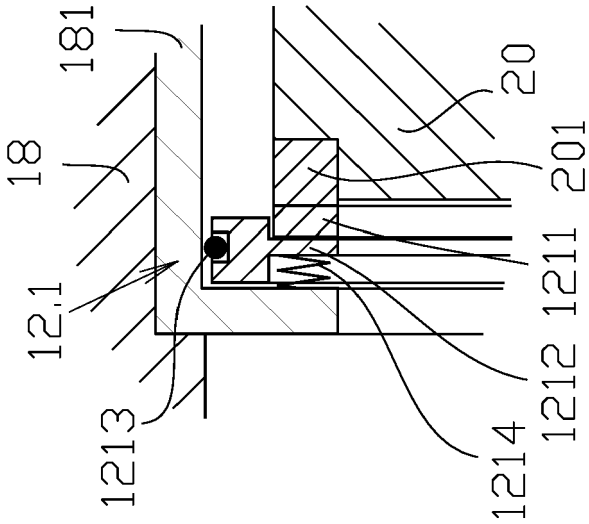


Fig. 2

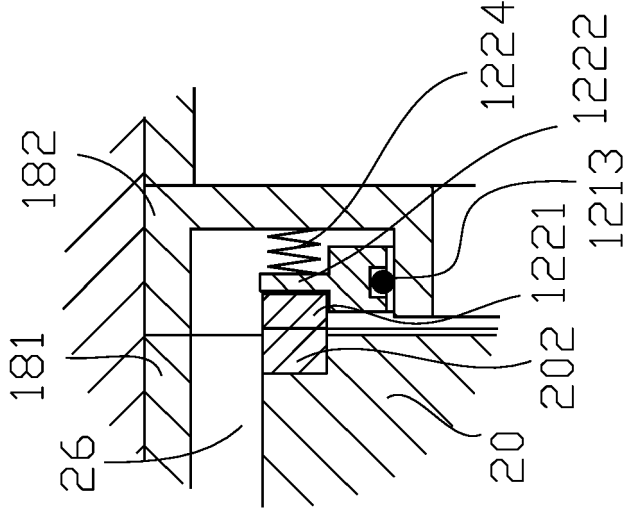


Fig. 3

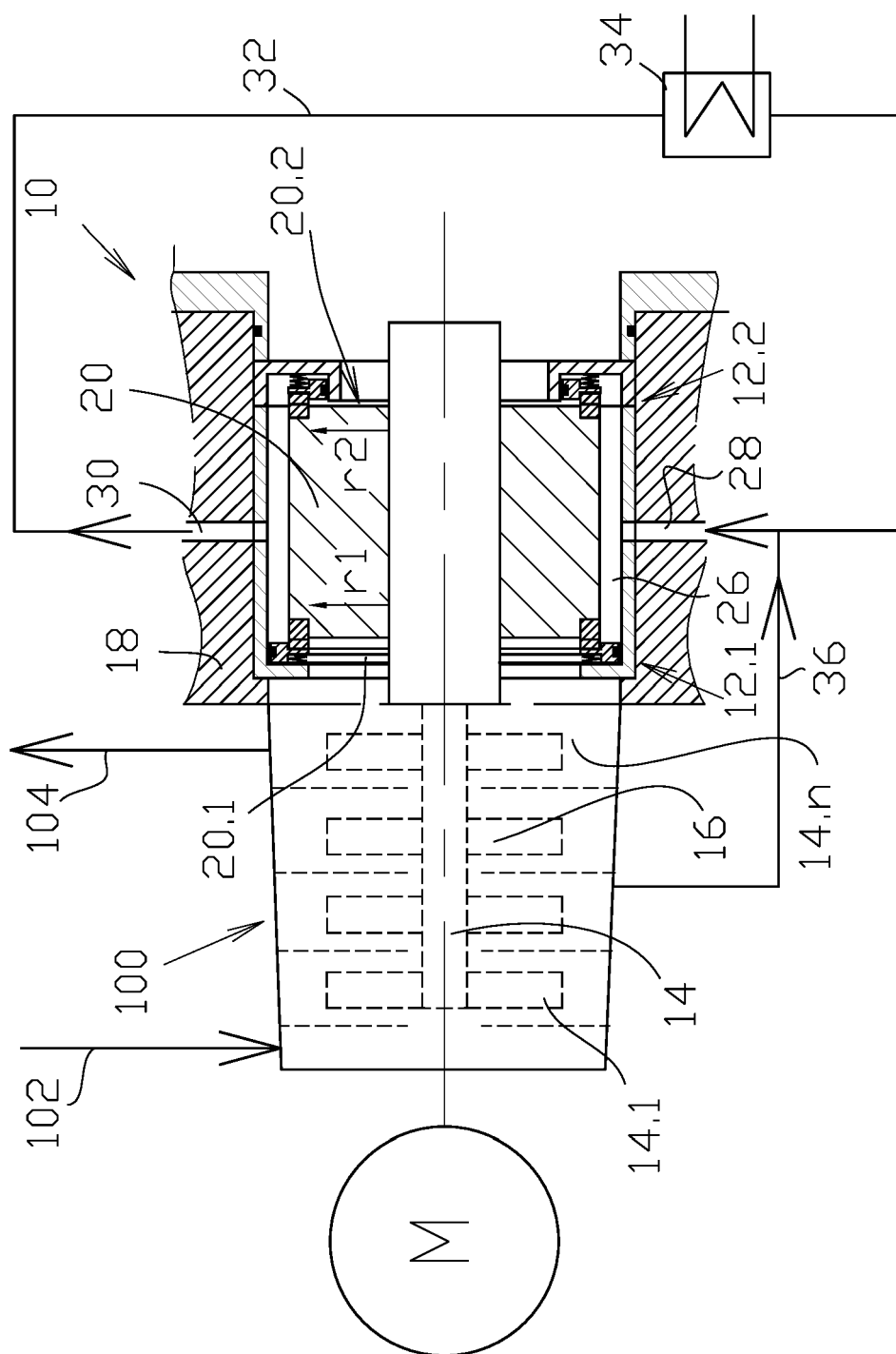


Fig. 4

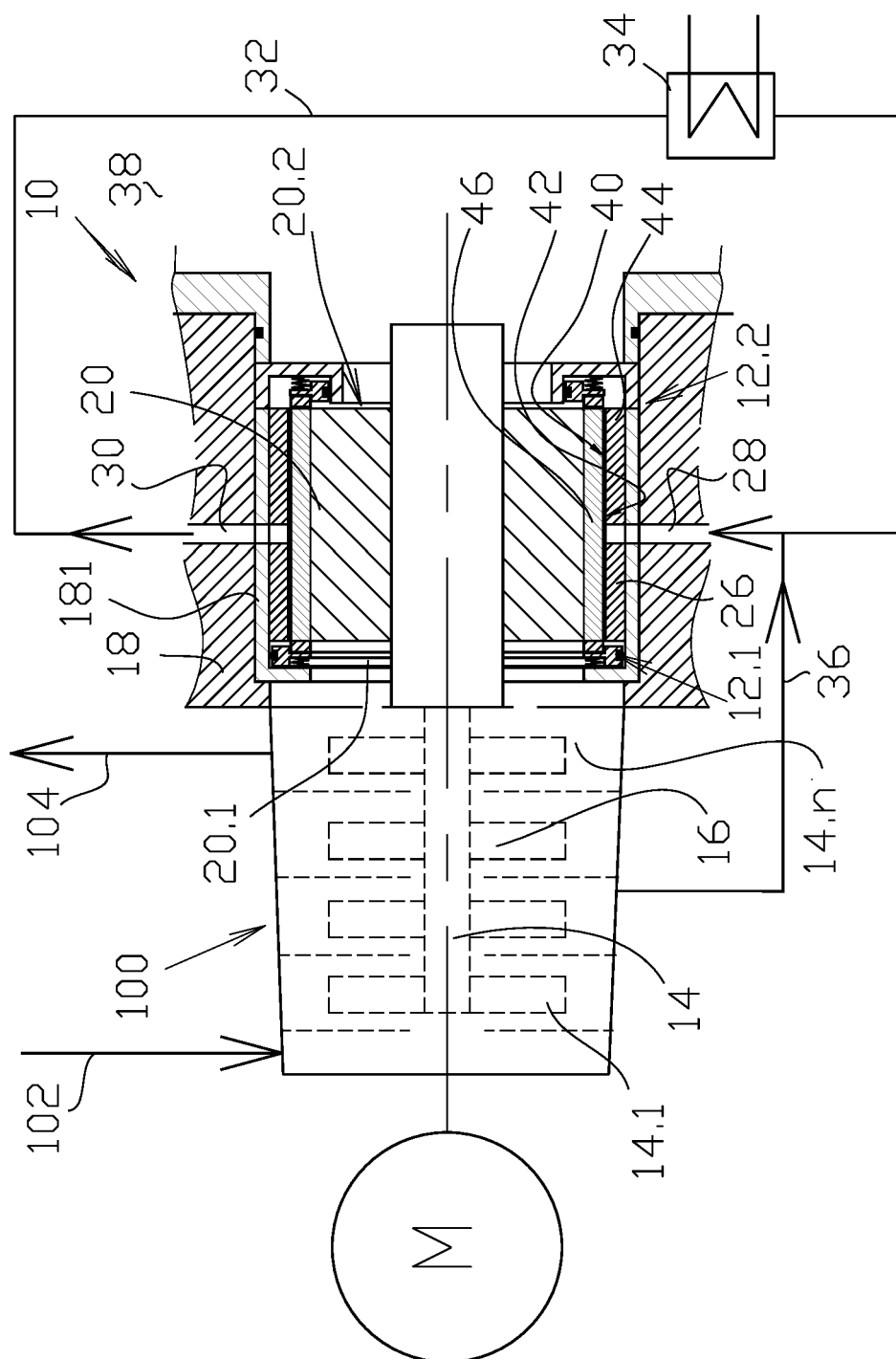


Fig. 5

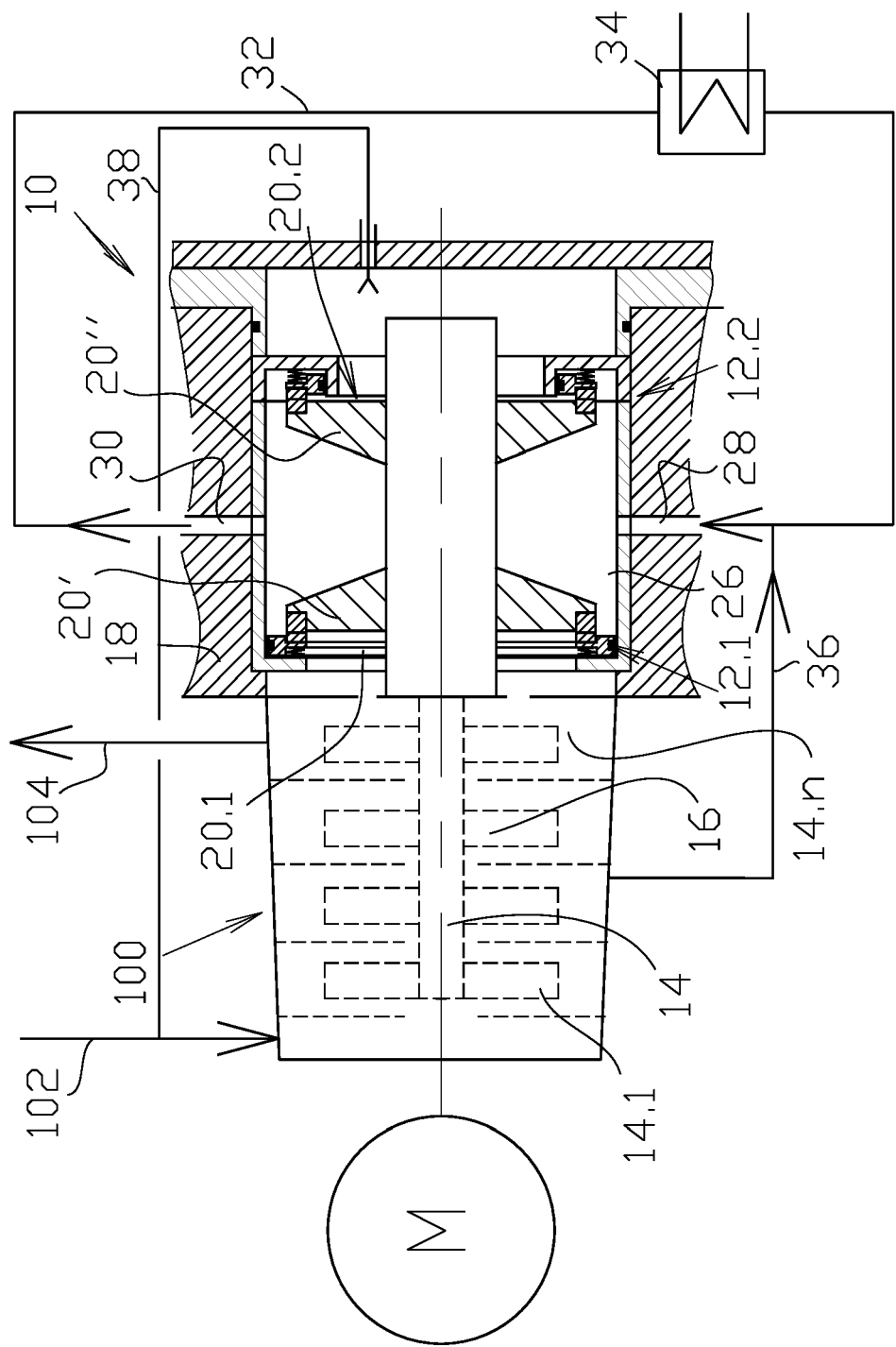


Fig. 6

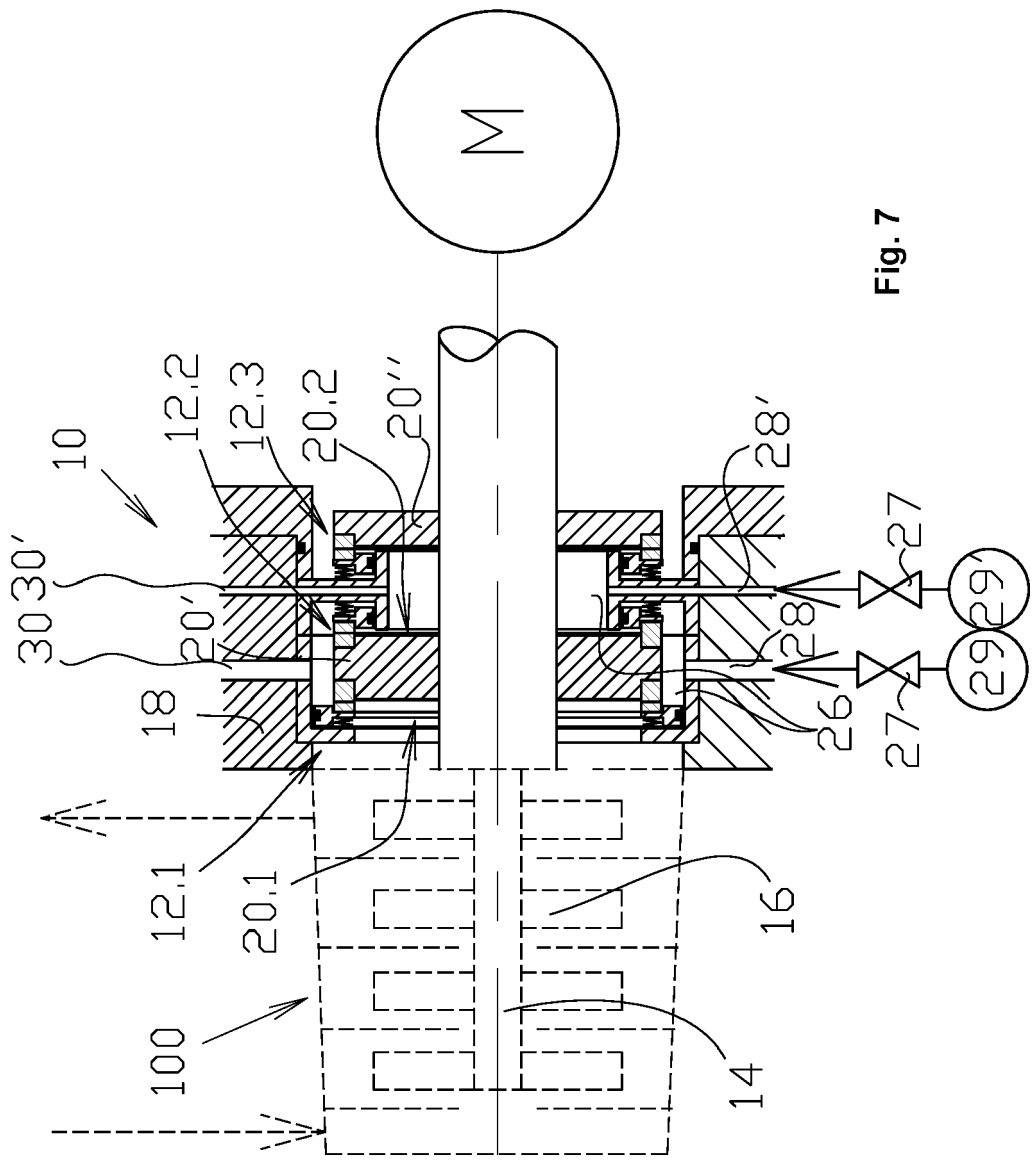


Fig. 7



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Application Number
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Place of search The Hague		Date of completion of the search 9 September 2021	Examiner Lovergine, A
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