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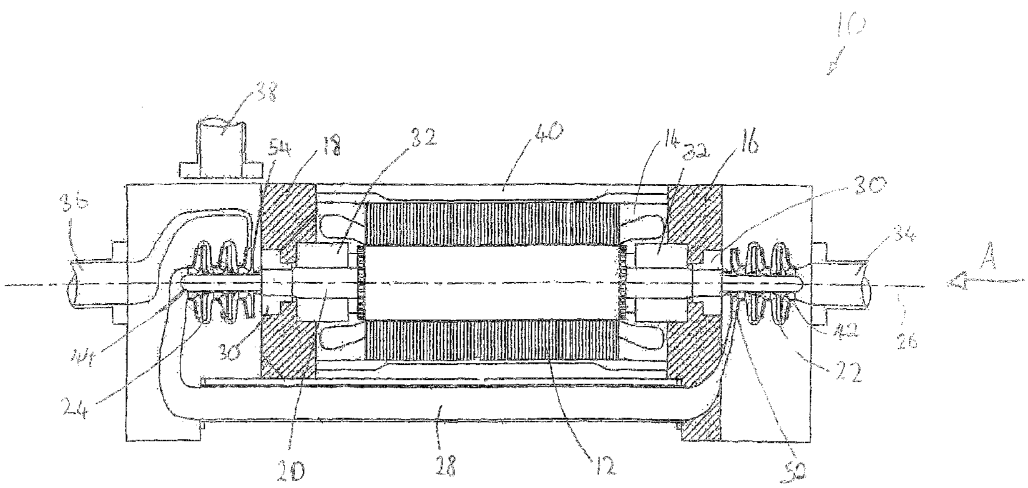
(54) **Title:** ROTODYNAMIC FLUID MACHINE



(57) Abstract: A rotodynamic fluid machine comprising a motor arranged for directly driving a shaft, a pressurised motor housing having end walls through which the shaft passes via dry gas seals to enclose the motor, means for maintaining the pressure within the motor housing which pressure is different from the pressure outside the motor housing, a first impeller directly connected to one end of the motor driven shaft, arranged to move process fluid from an inlet to an outlet in a first direction relative to the shaft axis, a second impeller directly connected to the opposite end of the shaft, arranged to move process fluid from a second inlet to a second outlet m an opposite direction to the first direction relative to the shaft axis such that suction is created at both ends of the shaft, and a process fluid conduit connecting the first outlet to the second inlet.

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ROTODYNAMIC FLUID MACHINE

The present invention relates to rotodynamic fluid machines and in particular to high power multistage units having a plurality of impeller stages. These are often used, for example, as high pressure pumps, particularly in the oil industry.

Multistage rotodynamic fluid machines can offer an increased output pressure over a single stage unit. However the provision of additional impeller stages necessarily increases the overall size of the unit.

Also, in known machines a coupling is required between the driving shaft extending from a motor and the driven shaft connected to one or more impeller stages, and this adds to the overall length of the machine. Furthermore couplings are a source of vibrational problems in rotating shafts and can greatly complicate a machine's rotor dynamics.

Traditional mechanical bearings become worn with use and require lubrication in order to ensure correct operation. The use of oil to lubricate rotating parts causes a decrease in efficiency and the oil may leak contaminating other parts.

Traditional high power multistage machines require high capacity thrust bearings and balancing discs to take up the resultant axial load created by the driving force of the impeller stages acting on the fluid. Seals are also required between the shafts and the housing to isolate the motor. Such parts also require lubrication and cause further losses in efficiency.

According to one aspect of the present invention there is provided a rotodynamic fluid machine comprising a motor arranged for directly driving a shaft, a pressurised motor housing having end walls through which the shaft passes via dry seals to enclose the motor, means for maintaining the pressure within the motor housing different from the pressure outside the motor housing, a first impeller directly connected to one end of the motor driven shaft, arranged to move process fluid from an inlet to an outlet in a first direction relative to the shaft axis, a second impeller directly connected to the opposite end of the shaft, arranged to move process fluid from a second inlet to a second outlet in an opposite direction to the first direction relative to the shaft axis such that suction is created at both ends of the shaft, and a process fluid conduit connecting the first outlet to the second inlet.

Preferably the pressure within the motor housing is different to the pressure of the process fluid in particular of the input process fluid, before it is pressurised or pumped up to discharge pressure. The pressure in the motor housing is preferably maintained high, i.e higher than the process fluid or other adjacent fluids so as to ensure no leakage of fluids into the motor, for example if a seal fails.

Another aspect of the invention provides a pump comprising a rotodynamic fluid machine of the first aspect.

Preferably each of the first and second impellers are arranged to pump fluid generally towards the motor and the machine comprises a closed loop pressurised gas circulation system in fluid communication with a rotor part of the motor.

The rotodynamic fluid machine may comprise a magnetic bearing supporting the shaft in a motor housing.

According to a preferred embodiment, the shaft is integral with a rotor part of the motor.

Advantageously the first impeller comprises a plurality of impeller stages and the second impeller comprises a plurality of impeller stages, and the first and second impellers may each comprise a diffuser unit.

The diameter of the shaft may be larger in the region of the motor and smaller in the region of the or each impeller.

The motor is preferably an electric motor.

A rotodynamic fluid machine according to the present invention is particularly advantageous because mounting impellers directly onto the motor shaft eliminates the need for a coupling between a motor shaft and an impeller shaft. Thus the shaft length and the total length of the machine can be reduced. Axial thrust is also decreased and so thrust bearings can be reduced in size due to the back to back arrangement of the first and second impellers.

The number of radial bearings may also be reduced since bearings need not be provided on either side of a coupling (i.e. one for each of the motor and impeller shafts). Without a coupling, there is no need for advanced in-field alignment procedures and the rotor dynamics of the machine are simplified with vibration levels reduced. Furthermore the use of balancing discs is not required.

The use of magnetic bearings and dry gas seals advantageously allows for a rotodynamic machine which does not require the use of lubricating oil or hydraulic fluid. Thus the parasitic power losses caused by oil shear and drag are avoided. Furthermore the problem of oil leakage is eliminated and the overall machine is simplified. Maintenance is reduced as well as the number of auxiliary systems.

The motor housing is sealed to enclose the motor to maintain the different pressures and this advantageously provides a clean and dry air internal environment for the motor. In combination with the back-to-back arrangement of this inventive machine, particularly when combined with magnetic bearings, this provides the possibility of a dry, oil-free machine.

The back-to-back arrangement ensures that the axial forces are controlled without using large balance pistons which have hitherto been required in known motors.

In known open motors, the process fluid is in and around the electric motor and this creates problems with motor contamination and bearing lubrication.

For a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the single figure 1, which is a representation of a rotodynamic fluid machine according the present invention.

The figure shows a rotodynamic fluid machine 10 with an electric motor 12 enclosed in a pressurised housing 14 with end walls 16 and 18. The arrangement can be mounted vertically or horizontally.

A shaft 20 is integrated with the rotor of the motor 12 and extends from each end of the motor through the end walls 16, 18. The diameter of shaft 20 decreases towards its free ends.

A first set of impellers 22 is mounted on one end of shaft 20 on one side of the motor 12 and a second set of impellers 24 is mounted on the opposite end of shaft 20 on the other side of the motor 12. The shaft 20 and the impellers 22, 24 are rotatable about a common axis 26.

The impellers 22, 24 are arranged in a back-to-back configuration such that the first impeller set 22 is oriented 180° compared to the second impeller set 24, and so that the first and second impellers move fluid in diametrically opposed directions relative to the axis 26 of the shaft 20. The direction of fluid flow as referred to here is the global overall flow: naturally the local direction of flow at the outlet from the impeller blades will be radial or radial/axial mixed flow compared to the shaft, but the overall flow from impeller inlet to impeller outlet will be axial. The impellers 22 and 24 also comprise diffuser units. The fluid is moved towards the motor 12 from each impeller 22, 24. This serves to balance the axial forces in the rotodynamic machine, decreasing axial thrust and allowing smaller thrust bearings to be used. The fluid flows into each impeller 22, 24 from the free ends of the shaft 20 and thus creates end suction which is advantageous. The fluid flows into the machine through a primary inlet conduit 34 in the direction of arrow A towards a free end of the shaft 20 and enters the first set of impellers 22 at first inlet 42. It exits the first set of impellers 22 at first outlet 52. A fluid conduit 28 provides a fluid connection between the first set of impellers 22, and the second set of impellers 24. This runs generally parallel to the motor 12 as a crossover line and connects the first outlet 52 to the inlet 44 of the second set of impellers 24 at the other free end of the shaft 20, and exits the second set of impellers 24 at second outlet 54.

A dry gas seal 30 of known construction is located on shaft 20 at each side of the motor 12 to isolate the fluid from the motor. The inner surfaces of each seal 30 are shaped to maintain a gas seal with the outer surface of the rotating shaft 20.

Magnetic bearings 32 are interposed on each side of the motor 12 between the respective end walls 16, 18 of the motor housing and the shaft 20.

During operation, the electric motor 12 drives both sets of impellers 22 and 24 directly via the shaft 20. Process fluid enters in the direction of arrow A through the inlet 34 and is pumped along the fluid conduit 28 by the first set of impellers 22. The conduit 28 is shaped to alter the direction of the fluid flow such that the fluid flows in substantially the opposite direction to arrow A as it enters the second set of impellers 24, at the other free end of the shaft 20.

The fluid exits the second set of impellers 24 via second outlet 54 and exits the machine via an outlet conduit 36, which is shaped such that the fluid exits the machine 10 in the direction of arrow A. An alternative outlet conduit 38 is shown which is oriented substantially at right angles to the outlet conduit 36.

The work done on the fluid by the first set of impellers 22 causes a resultant tensile force in shaft 20 which acts in the opposite direction to the tensile force caused by the second impeller 24. Thus the overall resultant force within the system during normal operation is effectively cancelled and thus substantially reduced, ideally to zero.

The magnetic bearings 32 act as radial and thrust bearings, by imparting a magnetic force on the shaft 20 and maintaining an air gap between the shaft 20 and the bearings 32. Sensor feedback systems of known construction (but not shown) are used to maintain the gap spacing so that there is no contact between the shaft 20 and the bearings 32. Hence there is virtually no friction or wear between these parts and the need for lubricating oil or any hydraulic fluid is avoided.

The motor stator is externally cooled by liquid 40, disposed around the motor stator, within the motor housing.

The motor rotor is cooled by a closed loop pressurised gas circulation. During operation, the motor housing is maintained at a pressure greater than that of the surrounding environment. This provides compact cooling and, for a rotodynamic machine running at high speeds (typically from 4,000 up to 12,000 rpm), allows the overall dimensions of the pump to be further reduced.

The use of magnetic bearings and dry gas seals in combination with overpressure of the motor provides for an oil-free rotodynamic unit and motor with no leakage of lubricating oil or hydraulic fluid. This increases efficiency, typically in the region of 2 to 3%, compared to a machine with lubricated parts and normal bearings and seals. In some cases, process lubricated bearings, which also exclude external lubrication supply, can be applied.

The rotodynamic machine of the present invention may be provided with more impellers positioned on each side of the motor, for example two impellers may be provided on each side.

The present invention is applicable to rotodynamic machines such as, for example, axial or centrifugal pumps, particularly to high-power (>1 MW) pumps.

CLAIMS

1. A rotodynamic fluid machine comprising a motor arranged for directly driving a shaft, a pressurised motor housing having end walls through which the shaft passes via dry seals to enclose the motor, means for maintaining the pressure within the motor housing different from the pressure outside the motor housing, a first impeller directly connected to one end of the motor driven shaft, arranged to move process fluid from an inlet to an outlet in a first direction relative to the shaft axis, a second impeller directly connected to the opposite end of the shaft, arranged to move process fluid from a second inlet to a second outlet, in an opposite direction to the first direction relative to the shaft axis, such that suction is created at both ends of the shaft, and a process fluid conduit connecting the first outlet to the second inlet.

2. A rotodynamic fluid machine according to claim 1 in which the pressure within the motor housing is also maintained different from the pressure of the process fluid.

3. A rotodynamic fluid machine according to claim 1 or claim 2 wherein the pressure within the motor housing is maintained higher than the pressure outside the motor housing.

4. A rotodynamic fluid machine according to any one of

the preceding claims wherein the pressure within the motor housing is maintained higher than the pressure of the process fluid.

5. A rotodynamic fluid machine according to any one of the preceding claims wherein the dry seals are dry gas seals.

6. A rotodynamic machine according to any one of the preceding claims wherein each of the first and second impellers are arranged to pump process fluid generally towards the motor.

7. A rotodynamic machine according to any one of the preceding claims comprising a closed loop pressurised gas circulation system in fluid communication with a rotor part of the motor.

8. A rotodynamic machine according to any one of the preceding claims, further comprising a magnetic bearing supporting the shaft in the motor housing.

9. A rotodynamic machine according to any one of the preceding claims, wherein the shaft is integral with a rotor part of the motor.

10. A rotodynamic machine according to any one of the preceding claims, wherein the first impeller comprises a plurality of impeller stages and the second impeller comprises a plurality of impeller stages.

11. A rotodynamic machine according to any one of the preceding claims wherein the first and second impellers each

comprise a diffuser unit.

12. A rotodynamic machine according to any one of the preceding claims wherein the diameter of the shaft is larger in the region of the motor and smaller in the region of the or each impeller.

13. A rotodynamic machine according to any one of the preceding claims wherein the motor is an electric motor.

14. A pump comprising a rotodynamic machine according to any one of the preceding claims.

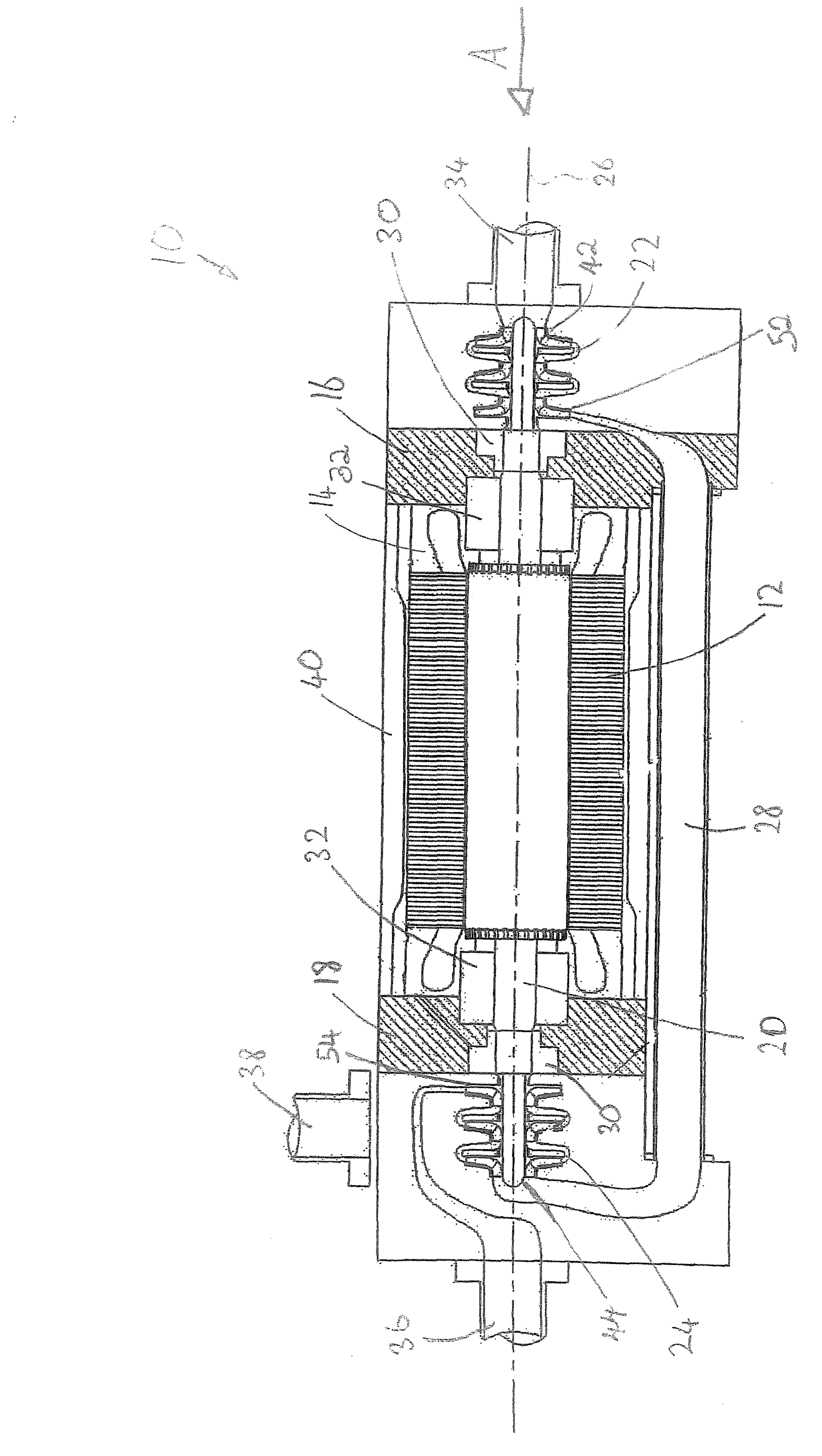

Fig 1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2005/054139

A. CLASSIFICATION OF SUBJECT MATTER
F04D1/06 F04D13/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 726 397 A (EBARA CORPORATION) 14 August 1996 (1996-08-14) the whole document	1-3,13, 14
X	EP 0 009 449 A (LE MATERIEL TELEPHONIQUE THOMSON-CSF; SOCIETE ELECTRO-HYDRAULIQUE SEH) 2 April 1980 (1980-04-02) the whole document	1-3,13, 14
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
8 December 2005	15/12/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Giorgini, G

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2005/054139

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2 339 186 A (NOBLE WILLIAM H) 11 January 1944 (1944-01-11) the whole document	1
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP2005/054139

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