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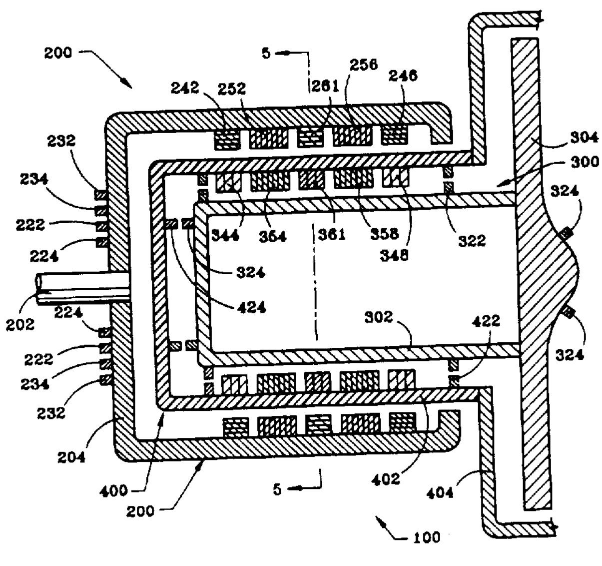

(57) Abstract

A driven rotor (300), connected to the prime mover shaft (202), with mounted horizontal stop rings (324), vertical stop rings (322), permanent magnet for floating rotor position (354, 358), and permanent rotor drive magnet is driven by a driver magnet mounted with strain gauge (242, 246) and permanent magnet (344, 348), electromagnet for driven rotor position and drive (252, 256), strain gauges signal transmission rings (222, 224) and electromagnet current transmission rings (252, 256, 261). The driver rotor (200), by using the signal generated by the strain gauges, varies the current to the electromagnets controlling magnetic field forces to float the driven rotor. When the unit is shut down, the driven rotor rests on the vertical stop rings uncoupled. The diamagnetic rotor casing (400) is in between the driven rotor and the driver rotor and is part of the envelope separating the fluid handled from the environment.

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ELECTROMAGNETIC-COUPLED/LEVITATED APPARATUS AND METHOD FOR ROTATING EQUIPMENT

FIELD OF THE INVENTION

The present invention relates generally to drives for rotating equipment. Specifically, the present invention relates to a driver for rotating equipment that is electromagnetically coupled and levitated.

BACKGROUND OF THE INVENTION

To solve the leakage problem encountered on centrifugal equipment, such as pumps compressors and fans, at the point where the rotating shaft penetrates the stationary casing, components such as packing and mechanical seals are used. However these components fail from time to time resulting in releases of handled fluid to the environment and sometimes damage to the equipment. To avoid this problem permanent magnetic drives that work inside the handled fluid envelope were developed. Also canned pumps where the induction motor rotor is inside the handled fluid envelope was developed. These two solutions have the problem that the internal shaft and bearings are in contact with the pumped fluid which also has to serve as the lubricating medium. This creates internal shaft/bearing maintenance problems. Additional drawbacks of the canned pump approach are: the possible effect that motor rotor induced currents can have on the pumped fluid, an the prime mover must be an induction motor.

The development of magnetic bearings used in combination with canned pumps has obviated the leakage and internal bearing maintenance problems in centrifugal pumps, however the drawbacks of the effects of motor rotor induced currents and limitation to the use of an induction motor as a prime mover remains.

The magnetic bearings mentioned above, consist of stationary electromagnets that induce magnets on the equipment rotor shaft, and by controlling current to the electromagnet, produce equipment rotor levitation. They are also used with prime movers external to the equipment casing such as large centrifugal pumps, centrifugal compressors and centrifugal fans, mechanical seals are required for these cases.

To eliminate such problems, canned pumps were developed. Canned pumps have the induction motor rotor inside the handled fluid envelope. Such solutions have the problem that the internal shaft and bearings are in contact with the pumped fluid. Also, the pumped fluid serves as the lubricating medium. This creates internal shaft/bearing maintenance problems. Additional drawbacks of the canned pump approach include, without limitation, the effect that motor rotor induced currents can have on the pumped fluid and the prime mover must be an induction motor.

Generally, the development of magnetic bearings used in combination with can pumps has obviated the leakage and internal bearing maintenance problems in centrifugal pumps. However, the drawbacks of the effects of motor-rotor induced currents and the limitation associated with the use of an induction motor as a prime mover remains.

The magnetic bearings, known in the art and discussed above, consist of stationary electromagnets that induce magnets on the equipment rotor shaft. By controlling the current to the electromagnet, levitation of the equipment rotor is possible. Such devices are also used with prime movers external to the equipment casing, such as, for example, large centrifugal pumps, centrifugal compressors and centrifugal fans. In these devices, mechanical seals are required.

Sensing devices are also known. For, example strain gauges are known. Strain gauges have been used to measure stress, pressure and torque. Further, rotating transmission rings and fixed pick-up devices have been used for years for the conveyance of control and power electric currents between fixed and rotating parts in electric generators and motors.

It is, therefore, a feature of the present invention to provide an electromagnetic coupled/levitated drive for rotating equipment.

Another feature of the present invention is to provide, as part of a driven rotor, an active component of the driven equipment such as a pump or compressor impeller.

Another feature of the present invention is to provide an electromagnetic coupled/levitated drive suitable for use with different types of prime movers such as electric motors, combustion engines and gas or steam turbines.

Yet another feature of the invention is to provide, for centrifugal pumps, centrifugal compressors and centrifugal fans, a true sealed unit that makes it impossible the escape of polluting fluids to the environment.

Another feature of the present invention is to provide, for centrifugal pumps, centrifugal compressors and centrifugal fans, the possibility to use different types of prime movers and without inducing currents in the pumped fluid,

Another feature of the present invention is to provide, for centrifugal pumps, centrifugal compressors and centrifugal fans, a levitating rotor which eliminates the possibility of internal bearing failure, diminishes equipment down time and reduces maintenance.

Yet another feature of the invention is to provide, for centrifugal pumps, centrifugal compressors and centrifugal fans, a reduction of equipment vibration.

Still another feature of the present invention is to provide, for a tube pump that practices the present invention.

Yet still another feature of the present invention is to provide, for the tube pump, reduced NPSH requirement.

Another feature of the present invention is to provide, for the tube pump, the ability to handle large pieces of solids with the liquid fluid.

Another feature of the present invention is to provide, for the tube pump, ease of installation on an existing line.

Another feature of the present invention is to provide, for the tube pump, no change in flow direction for single stage applications.

Another feature of the present invention is to provide an electromagnetic coupled/levitated component of centrifugal prime mover, such as a turbine, when the motive fluid temperature is within the temperature limits required for magnet/electromagnet operation.

Additional features and advantages of the invention will be set forth in part in the description which follows, and in part will become apparent from the description, or may be learned by practice of the invention. The features and advantages of the invention may be realized by means of the combinations and steps particularly pointed out in the appended claims.

SUMMARY OF THE INVENTION

To achieve the foregoing objects, features, and advantages and in accordance with the purpose of the invention as embodied and broadly described herein is an electromagnetic-coupled/levitated apparatus and method for rotating equipment.

The electromagnetic-coupled/levitated apparatus for rotating equipment comprises a driver assembly in communication with a prime mover. The prime mover provides power to the driver assembly. The driver assembly includes at least one magnet for creating a magnetic field, and a distance sensor for communicating with an optional exciter. The distance sensor controls the strength of the magnetic field associated with the magnet of the driver assembly. An activated assembly is in magnetic communication with the driver assembly such that the driver assembly provides power to the activated assembly, and the driver assembly and the activated assembly are in electromagnetic coupled relationship with respect to movement. The activated assembly comprises at least one magnet for creating a magnetic field, and at least one exciter for communicating with the distance sensor of the driver assembly for identifying the positional relationship of the driver assembly with respect to the actuated assembly. The exciter and the sensor generate a signal for controlling the magnetic fields associated with the magnets in the assemblies for providing a levitating coupled relationship between the driver assembly and the activated assembly. Further, a containment assembly is provided for separating the driver assembly and the activated assembly such that any material associated with the activated assembly is isolated therein and any material associated with the driver assembly is isolated therein.

Preferrably, the distance sensor is a strain gauge having a permanent magnet associated therewith, and the exciter is a permanent magnet for interacting with the strain gauge magnet in a like pole configuration. In a preferred embodiment, the magnets associated with the driver assembly are electro-magnets and the magnets associated with the activated assembly are induced in ferro-magnetic elements.

In another embodiment of the present invention, a method of electromagneticly coupling levitating rotating equipment is provided. The method for levitating and coupling rotating equipment comprises the steps of engaging a prime mover with a driver assembly, generating a magnetic field from the driver assembly, spacially engaging within the magnetic field an activated assembly responsive to the magnetic field such that the activated assembly is in one-to-one positional relationship with the driver assembly, separating the driver assembly and the activated assembly such that any material associated with the activated assembly is isolated therein and any material associated with the driver assembly is isolated therein, and maintaing the driver assembly and the activated assembly in levitatingly coupled relationship such that the power from the prime mover is transfered to the activated assembly for powering the rotating equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings which are incorporated in and constitute a part of the specification, illustrate a preferred embodiment of the invention and together with the general description of the invention given above and the detailed description of the preferred embodiment given below, serve to explain the principles of the invention.

FIG. 1 is a schematic illustration of the present invention.

FIG. 2 is a more detailed schematic illustration of FIG. 1 showing the relationship of the parts with respect to contact with the rotating equipment.

FIG. 3 is a more detailed illustration of the present invention showing a preferred embodiment of the present invention.

FIG. 4 is an elevation view of a preferred embodiment of the electromagnetic-coupled/levitated drive invention of the present application.

FIG. 5 is a cross-sectional view taken along section lines 5-5 in FIG. 4.

FIG. 6 is a cross-sectional view of another embodiment of the present invention as applied to a fan apparatus.

FIG. 7 is a cross section of FIG. 6 taken along the section line 7-7 illustrating the dual containment assembly as practiced with the present invention.

FIG. 8 is an elevation view of a cross section of a tube pump as practiced using the present invention.

FIG. 9 is a cross-sectional of the tube pump apparatus illustrated in FIG. 8 as taken along the section lines 9-9.

FIG. 10 is a flow chart illustrating one embodiment of the method of the present invention.

The above general description and the following detailed description are merely illustrative of the generic invention, and additional modes, advantages, and particulars of this invention will be readily suggested to those skilled in the art without departing from the spirit and scope of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to the present preferred embodiments of the invention as described in the accompanying drawings.

Generic Embodiments

FIG. 1 is a general schematic view illustrating the relationship between the prime mover and the rotating equipment as practiced with the electromagnetic-coupled/levitated drive of the present invention. The drive provides a sealed, environmentally safe means for applying a prime mover to any rotating equipment.

FIG. 2 is a more detailed schematic illustration of FIG. 1 showing the relationship of the parts with respect to contact with the rotating equipment. FIG. 2 illustrates an embodiment of the present invention as distinguished between the containment of the material associated with the rotating equipment and the isolation of the prime mover. FIG. 2 illustrates that a prime mover 1 can move the rotating equipment 2 via the driver 10. The driver 10 has a "wet" side and a "dry" side. The wet side is the side associated with the rotating equipment 2. The wet side is comprised of an exciter 32 and a ferro-magnetic element 42 which operate to drive the rotating equipment 2. The prime mover is associated with a distance sensor 12 and an electro-magnet 22. The distance sensor 12 is in operative communication with the exciter 32 such that a signal can be generated by the distance sensor 12 to keep the drive of the present invention in levitation during operation. The distance sensor 12 is associated with a signal processor 14. The signal processor 14 communicates with a controller 16 which modulates current to the electro-magnet 22 and maintains levitation for the efficient use of the drive of the present invention. Similarly, the electro-magnet 22 is in operative association with the ferro-magnetic element 42. The combination of the electro-magnet 22 and the ferro-magnetic element 42 provides both levitation and torque. The relationship of the electro-magnet 22 and the ferro-magnetic element 42 can be altered, to maintain the effective operation of the drive of the present invention by the controller 16. Although the signal processor 14 and the controller 16 are illustrated as communicating with both the distance sensor 12 and the electro-magnet 22, it can be appreciated by those skilled in the art that separate processors and controllers, in unison, combination or any other embodiment, are readily adaptable for use in the present invention.

FIG. 3 is another schematic embodiment of the present invention illustrating a preferred embodiment of the distance sensor 12. As illustrated in FIG. 2, the distance sensor 12 is preferably made of a permanent magnet 12A and a strain gauge 12B. The strain gauge 12B is operatively associated with the permanent magnet 12A such that the relationship there between provides a uniquely sensitive protector with respect to a magnetic field generated between the respective permanent magnets 32, 12A.

Operation

The operation of all devices described herein is basically the same. From a shut down non-energized position, a driven rotor rests on vertical movement stops. The prime mover will not start until the driven rotor is coupled and the driver rotor is in a levitating condition. A start switch will allow current to flow via transmission rings or the like, to strain gauges, electromagnets for an optional thrust bearing and electromagnets mounted on the driver rotor. When power is established, the driven rotor will go from resting on the stops to a nonrotating coupled levitation condition. This is accomplished by controlling the current to the electromagnets and changing, as required, the strength of the magnetic fields associated with the ferromagnet/electromagnet couples. A control signal is generated by the permanent magnet for levitating the rotor control/strain gauge combination.

The strain gauge generates a control signal that is used to modulate current to the electro-magnets for levitation control. A permissive switch activates the prime mover. The electromagnet/ferromagnet couples are designed to provide the required torque to drive the apparatus for appropriate load/floatation combinations. The working of the components as described herein will maintain the driven rotor in a floating condition from nonrotation to full rpm load condition.

During shut down, the drive can be maintained in an energized floating nonrotating condition or nonenergized condition with the driven rotor resting on the stop rings.

Specific Examples of Embodiments

FIG. 4 is a cross-sectional elevation view of an electro-magnetic coupled/levitated drive 100 which can be used with a variety of rotating equipment, such as, for example, multi-stage centrifugal compressors and multi-stage centrifugal pumps. The illustration of FIG. 4 provides an example of the present invention which results in a sealless unit providing an environmentally and structurally safe energizing apparatus. Generally, the electro-magnetic coupled/levitated drive 100 comprises a driver assembly 200, a activated assembly 300 and a containment assembly 400. Leakage is prohibited based upon the containment assembly 400. The containment assembly 400 separates the driver assembly 200 from the activated assembly 300.

A preferred embodiment of the present invention, as illustrated in FIG. 4, provides an activated assembly that has buoyancy for enhancing the efficacy of the invention. The rotor 302 may, for example, be hollow so as to create buoyancy for the activated assembly 300 with respect to the driver assembly 200. Buoyancy provides an upward force as a result of the pumped fluid being more dense than the hollow rotor 302. The buoyancy enhances movement characteristics, reduces the required magnetic field strength during levitation and reduces friction when not levitating. It can be appreciated by those skilled in the art that buoyancy can be utilized in various and sundry ways for accomplishing the levitation and drive functions of the present invention.

Also preferred, as illustrated in FIG. 4, the present invention provides that the interacting movement-related components are arranged to provide a symmetrical configuration about the center of gravity of the components. For example, the electro-magnet/ferro-magnetic element pairs 252/354, 256/358 are positioned to straddle the center of gravity of the activated assembly 300.

The driver assembly 200 comprises a driver rotor 204 and a shaft 202 which is connected to a prime mover. As the prime mover turns the shaft 202, the shaft rotates the driver rotor 204. The device as illustrated in FIG. 4 provides a driver rotor 204 having a generally cylindrical configuration. The shaft 202 is aligned to be placed along the longitudinal central axis of the cylindrical driver rotor 204. The sides of the cylindrical driver rotor 204 are moved in a circular path around the shaft 202.

Also, the driver assembly 202 has, engaged with the inner wall of the sides of the cylindrically oriented driver rotor 204, a number of other components. The additional components are a distance sensor 242, an electro-magnet 252, a electro-magnet 261, and a second electro-magnet 256 and a second distance sensor 246. The electro-magnet 261 is part of an optional thrust bearing for preventing any axial misalignment between the driver assembly 200 and the activated assembly 300. A containment assembly 400 is provided so as to be inserted into an open end of the driver assembly 200. The containment assembly 400 comprises, at one end, a generally cylindrical configuration which coincides with, but is smaller than, the cylindrical configuration provided by the driver assembly 200. The containment assembly 400 is fixedly secured from movement. Also, the containment assembly 400 comprises a rotor casing 402 and a pump casing 404. The diamagnetic rotor casing 402 is made of material that is not effected by the magnetic fields associated with the present invention, and is termed for use herein as non-magnetic. The casings 402, 404 are in a fixed relationship to the central axis, i.e., the shaft 202 of the driver assembly 200. The containment assembly 400 also has a plurality of vertical stops 422, and horizontal stops 424 which can be added at various locations depending on application and engineering design. The containment assembly 400 has an exterior surface and an interior surface. The exterior surface of the containment assembly 400 associated with the diamagnetic rotor casing 402 provides a facing relationship with the interior of the driver assembly 200. The driver assembly 200 is provided such that it can rotate about the diamagnetic rotor casing 402 of the containment assembly 400.

An activated assembly 300 is in facing relationship to the interior surface of the containment assembly 400. The activated assembly 300 comprises a rotor 302 and an impeller 304. The rotor 302 has an interior surface and an exterior surface. The exterior surface of the propelled rotor 302 is in a facing relationshipwwith the interior surface of the diamagnetic rotor casing 402. Further, the exterior surface of the propelled rotor 302 of the activated assembly 300 has fixedly secured thereto a first exciter 344, a first ferro-magnetic element 354, a ferro-magnetic element 361, a second ferro-magnetic element 358 and a second exciter 348. The ferro-magnetic element 361, and the previously discussed electro-magnet bar 261, comprise the thrust bearing. Also, the exterior surface of the propelled rotor 302 has a plurality of vertical stops 322 and horizontal stops 324. The vertical and horizontal stops 322, 324 are in an engaging relationship with the vertical and horizontal stops 422, 424 associated with the inner portion of the diamagnetic rotor casing 402 of the containment assembly 400 when in a non-rotating, non-levitating mode. The exciters 344, 348 can be configured in various embodiments. For example, the exciters 344, 348 can be widened to enhance alignment with the strain gage. Also, the exciters 344, 348 can be in a ring-shaped configuration.

The impeller 304 of the activated assembly 300 is fixedly secured to the propelled rotor 302. Also, the impeller 304 has one or more horizontal stops 324 which interact with one or more horizontal stops 424 associated with the pump casing 404 of the containment assembly 400 when in a non-rotating, non-levitating mode.

As the driver assembly 200 rotates around the containment assembly 400, the activated assembly 300 is energized and levitated based upon the spacial relationship of the electro-magnets 252, 256 and the ferro-magnetic elements 354, 358. Thus, as the driver assembly 200 is activated with respect to the electro-magnets 252, 256, the activated assembly 300 provides a 1-to-1 moving relationship with the driver assembly 200.

To maintain an acutely aligned relationship for the activated assembly 300, the first and second distance sensors 242, 246 act in cooperation with the exciters 344, 348 fixedly secured to the outer surface of the rotor 302. The distance sensors provide information via the sensor transceivers 232, 234 to a controller (See, FIG. 2). Also, the transceivers 222, 224 provide the current to the electro-magnets 252, 256 and 261. The controller provides feed-back to the apparatus of the present invention. The magnetic intensity generated by the electro-magnets 252, 256 provides that the activated assembly 300 is maintained in a location sufficient for the present invention to provide coupling and levitation with respect to the driver assembly 200. The transceivers 232, 234, 222, 224 are also known in the art as collector rings.

FIG. 5 is a cross section view taken along the section-line 5-5 in FIG. 4. FIG. 5 illustrates the enclosed relationship of the activated assembly 300 with respect to the containment assembly 400. Also, FIG. 5 illustrates the rotating relationship of the driver assembly 200 and the activated assembly 300. Further, FIG. 5 illustrates the aligned relationship of the electro-magnets 252 with the ferro-magnetic elements 354. As the driver assembly 200 rotates about the containment assembly 400, the activated assembly 300 follows, in unison, the driver assembly 200. Also noted for reference on FIG. 5 are the shaft 202 and the electro-magnets 261, 361.

FIG. 6 is a cross-sectional elevation view of an apparatus practicing the present invention for driving a fan rotor. The apparatus illustrated in FIG. 6 provides a diametrically opposite configuration as illustrated in FIG. 4. Particularly, the driver assembly 200 is interior of the containment assembly 400 and the activated assembly 300, where as in FIG. 4, the driver assembly 200 is exterior of both the containment assembly 400 and the activated assembly 300.

The fan rotor apparatus 106 of the present invention as illustrated in FIGS. 6 and 7 comprises a driver assembly 200, a activated assembly 300 and a containment assembly 400. The driver assembly 200 comprises a shaft 202, a coupling 205 and a driver rotor 204. The driver shaft 202 is rotated by a prime mover (not illustrated). The coupling 205 provides for easy disassembly of the driver rotor 204 from the shaft 202. The driver rotor 204 comprises an elongate member having a generally cylindrical relationship. The driver rotor 204 has an exterior surface upon which a plurality of distance sensors 242, 246, electro-magnets 252,

AMENDED CLAIMS

[received by the International Bureau on 29 May 1996 (29.05.96); original claims 1 and 20 replaced by new claims 21 and 22; original claims 2 and 8 amended; original claim 7 deleted (5 pages)]

21. (New) A sealed drive for use with a pumped fluid moved by a rotating device which fluid is prevented from escaping from the sealed drive, the drive comprising:

(a) a driver assembly in rotational communication with a prime mover, the prime mover provides rotational power to the driver assembly, the driver assembly comprising:

(1) a driver rotor responsive to the rotational power received from the prime mover such that the driver rotor rotates,

(2) at least one electro-magnet on the driver rotor such that the electro-magnet is rotating, the electro-magnet for creating a magnetic field,

(3) at least one sensor on the driver rotor, such that the sensor is rotating, the sensor for generating a control signal,

(4) at least one transceiver in operative association with the sensor for receiving the control signal from the sensor, and in operative association with the electro-magnet for modulating power to the electro-magnet and thereby controlling the strength of the associated magnetic field,

(b) an activated assembly comprising:

(1) an activated rotor responsive to the driver assembly such that the activated assembly rotates,

(2) at least one ferro-magnet on the activated rotor such that the ferro-magnet is rotating, the ferro-magnet for creating a magnetic field,

such that the sensor interacts with the activated rotor for generating the control signal, the control signal indicative of the relative position of the driver assembly with respect to the activated assembly for controlling the magnetic field associated with the electro-magnet for providing and maintaining a levitating coupled relationship between the driver assembly and the activated assembly due to the interaction of the magnetic fields generated by the electro-magnet of the driver assembly and the ferro-magnet of the activated assembly, and

(c) a containment assembly for separating the driver assembly and the activated assembly such that any pumped fluid associated with the activated assembly is isolated therein.

2. (Amended) A drive for rotating equipment as defined in claim 1 further comprising an exciter in operative association with the sensor for identifying the positional/distance relationship of the driver assembly with respect to the actuated assembly, such that the sensor controls the magnetic fields associated with the electromagnets [magnets in the assemblies] for providing a levitating coupled relationship between the driver assembly and the activated assembly.

3. A drive for rotating equipment as defined in claim 2 wherein the distance sensor is a strain gauge having a magnet associated therewith, and the exciter is a magnet for interacting with the gauge magnet.

4. A drive for rotating equipment as defined in claim 3 wherein the magnet associated with the strain gauge is a permanent magnet.

5. A drive for rotating equipment as defined in claim 3 wherein the magnet associated with the exciter is a permanent magnet.

6. A drive for rotating equipment as defined in claim 3 wherein the magnets are arranged in a like-pole configuration.

7. A drive for rotating equipment as defined in claim 2 wherein the magnet associated with the driver assembly is electro-magnet.

8. (Amended) A drive for rotating equipment as defined in claim 2 wherein the ferromagnet [magnet] associated with the activated assembly is induced on a ferro-magnetic element by the electromagnet [magnet] associated with the driver assembly.

9. A drive for rotating equipment as defined in claim 1 wherein the driver assembly comprises a cylinderical member having an open end and a closed end with the closed end engaged with the prime mover, and the activated assembly comprises a rotor and an impeller such that the rotor is operatively engaged in the cylinderical member of the driver assembly.

10. A drive for rotating equipment as defined in claim 9 wherein the rotor of the driver assembly has buoyancy for enhancing movement characteristics, reducing the required magnetic field strength during levitation and reducing friction when not levitating.

11. A drive for rotating equipment as defined in claim 9 wherein the driver assembly is configured with the activated assembly to be symmetrical about the center of gravity thereof.

12. A drive for rotating equipment as defined in claim 1 wherein the driver assembly comprises a cylinderical member engaged with the prime mover, and the activated assembly comprises a device, the device is adapted for receiving the cylinderical member of the driver assembly such that the cylinderical member is operatively engaged in the device of the activated assembly.

13. A drive for rotating equipment as defined in claim 12 wherein the device comprises at least one cartridge for removeably engaging the activated assembly.

22. (New) A method for levitating and coupling a rotating device for use with a pumped fluid moved by the rotating device which fluid is prevented from escaping, comprising the steps of:

(a) rotating a driver assembly with a prime mover, the driver assembly having at least one rotating electro-magnet, at least one rotating sensor and at least one transceiver,

(b) separating the driver assembly from the pumped fluid by a containment assembly,

(c) creating a magnetic field using the rotating electro-magnet,

(d) generating a control signal from the rotating sensor,

(e) receiving the control signal from the rotating sensor via the transceiver,

(f) generating a modulation signal for transmission by the transceiver,

(g) modulating power to the rotating electro-magnet via the modulation signal from the transceiver thereby controlling the strength of the associated magnetic field,

(h) activating a ferro-magnet on an activated assembly such that the ferro-magnet is rotating,

(i) determining the relative position of the driver assembly with respect to the activated assembly by the interaction of the control signal of the rotating sensor with the activated assembly,

(j) controlling the magnetic field associated with the rotating electro-magnet for providing and maintaining a levitated and coupled relationship between the driver assembly and the activated assembly due to the interaction of the magnetic fields generated by the rotating electro-magnet of the driver assembly and the rotating ferro-magnet of the activated assembly,

(k) maintaining a one-to-one positional relationship between the driver assembly and the activated assembly due to the interaction of the magnetic fields generated by the rotating electro-magnet of the driver assembly and the rotating ferro-magnet of the activated assembly,

(l) separating the driver assembly and the activated assembly such that the pumped fluid from the rotating device is isolated between the containment assembly and the activated assembly, whereby maintaing the driver assembly and the activated assembly in coupled relationship and_maintaining the driver assembly and the activated assembly in levitating relationship is defined as activating, such that the prime mover drives the driver assembly, the driver assembly activates the activated assembly, and the activated assembly droves the rotating equipment.

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H02K 49/00, 1/22; H02P 15/00
US CL : 310/103, 266
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)

U.S. : 310/103, 266

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 practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US, A, 4,163,164 (PIETERS) 31 July 1979, col. 2, lines 58-68 and col.3, lines 1-3.	20 ------- 1-19
Y	US, A, 5,355,042 (LEWIS ET AL) 11 October 1994, col.2, lines 34-45.	1-19
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Y	US, A, 5,209,650 (LEMIEUX) 11 May 1993, col.3, lines 64-	17

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

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B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

APS
search terms: strain gauge, motor, magne?; vane, rotor, magne?, 1985-1993; isolate#, magnet##, impeller, sensor#