

A compensated barrier and lubrication fluids pressure regulation system for a subsea motor and pump module

TECHNICAL FIELD OF THE INVENTION

5 The present invention relates generally to subsea equipment involved in the transport of hydrocarbon production fluids from a production site at the sea floor to a sea surface or land based host facility. More specifically, the present invention is concerned with a system that is designed for management of barrier and lubrication fluid pressures in a subsea motor and pump module.

10 BACKGROUND AND PRIOR ART

A process fluid in subsea hydrocarbon production is typically a multiphase fluid comprising oil and gas and eventually solid matter, which is extracted from an underground reservoir. A motor/pump module is arranged on the sea floor and configured for transport of the process fluid from the reservoir to a surface or land based host facility. The motor/pump module is frequently subjected to substantial variations in pressure in the pumped medium, as well as substantial transitional loads during pump start and stop sequences, e.g. The medium pressure at the suction side of the pump may be in the order of hundreds of bar, requiring corresponding measures in the motor/pump module to prevent process fluid and particulate matter from immigration from the pump interior into a motor housing, and into bearings and seals of the motor/pump module.

For the purpose of pumping a multiphase fluid in subsea production, screw rotor pumps are advantageously used. The screw rotor pump is a positive displacement type of pump having two screw shafts that are driven in rotation with intermeshing gears, between which a specific volume of fluid is displaced in the axial direction of the screws from a suction side of the pump to be discharged on the pressure side of the pump. The screws are journaled in bearings in a pump housing, and are drive-connected to a motor arranged in a motor housing. In case of a twin rotor screw pump, intermeshing timing gears carried on the screw shafts provide synchronization of the rotary motion. The motor housing interior is hydraulically separated from the pump housing interior by a seal arrangement, where the drive shaft is journaled to extend for connection with the pump rotor shaft. The pump bearings are separated from the pump medium by seal arrangements at both ends of the pump.

A hydraulic fluid in the motor housing is controlled at a pressure above the internal pressure of the pump, acting as a barrier which prevents intrusion of process fluid and particles into the motor housing via the seal and bearing arrangement. In result of the pressure difference, a leak flow of hydraulic fluid along the drive shaft is unavoidable. The leakage rate is dependent on fluid properties, differential pressure, the transient operating conditions of the pump, and the tightness of the seal(s). The leakage is compensated by refilling the motor housing from an external supply of hydraulic fluid. Likewise, hydraulic fluid is used for lubrication of pump bearings and timing gears. The pressure in the pump lubrication fluid is to be maintained above the pressure of the pumped medium internally of the pump, in order to prevent intrusion of process fluid and particles into pump bearings, seals and timing gears. Leakage via the pump seals into the pumped medium is compensated by refilling from an external supply of hydraulic fluid.

The motor and pump can be drive-connected inside the motor housing, or outside the motor housing. For instance, the motor and pump can share one and the same shaft with no separate coupling that connects them in a driving relation. In other designs the pump shaft can be coupled to the motor shaft inside the motor housing. In still other designs, the motor and pump is drive-connected by means of a coupling located in a coupling chamber defined between the motor housing and the pump. However, in all alternatives it is desirable to maintain at all times a pressure difference over the interfaces, i.e. between the motor housing, the coupling chamber when present, and the pump lubrication system and the pumped medium, respectively.

Conventionally, a motor barrier fluid and a pump lubrication fluid are each supplied from a host facility, and leakage compensation as well as pressure control is managed from the host facility, usually via an umbilical. As subsea hydrocarbon production sites are increasingly installed and operated at increasing depths and step-out distances, the response times and control requirements in lubrication and cooling systems increase correspondingly. As a consequence, there is a rising need for a barrier fluid and lubrication system that operates with improved control requirements and which provides increased reliability in operation.

SUMMARY OF THE INVENTION

The present invention thus aims at providing a barrier and lubrication fluids pressure regulation system for a subsea motor and pump module which avoids the

problems of prior art systems, and specifically those problems which are associated with long step-out distances and great water depths.

The present invention specifically aims at providing a barrier and lubrication fluids pressure regulation system for a subsea motor and pump module, the system having an inherent capability to adapt to pressure changes in the pumped medium. The present invention further aims at providing a barrier and lubrication fluids pressure regulations system having an inherent capability to compensate for loss of hydraulic fluid caused by leakage via seals and bearings in the motor and pump module. Still another object of the present invention is to provide a barrier and lubrication fluids pressure regulations system wherein a preset pressure differential between a barrier fluid circuit and a lubrication fluid circuit is automatically maintained at all times and balanced towards the pumped medium pressure.

The barrier and lubrication fluids pressure regulation system of the present invention may advantageously be applied to a subsea motor and pump module which comprises a pump motor disposed in a motor housing; a pump disposed in a pump-housing having a pump inlet at a suction side and a pump outlet at a discharge side of the pump, and a pump-rotor assembly arranged there between and journaled in bearings in the pump-housing. The pump-rotor assembly is drive-connected to the motor through a drive-shaft that reaches between the motor and pump housings via a seal arrangement, and is configured to displace a fluid medium from the pump inlet for discharge via the pump outlet.

Briefly, the object of the invention is achieved through a barrier and lubrication fluids pressure regulation system comprising a hydraulic fluid supply providing motor barrier fluid and pump lubrication fluid to a subsea motor and pump module; a barrier fluid circuit, in which the hydraulic fluid is pre-tensioned towards the motor by a pressure applied from a first separating pressure compensator; a lubrication fluid circuit, in which the hydraulic fluid is pre-tensioned towards the pump by a pressure applied from a second separating pressure compensator, wherein the second pressure compensator is responsive to the pumped medium pressure at a pump inlet and/or at a pump outlet (at a suction and/or discharge side of the pump) to apply the sum of that pressure and its inherent pre-tensioning pressure to the lubrication fluid circuit, and the first pressure compensator is responsive to the pressure in the lubrication fluid circuit

to apply the sum of that pressure and its inherent pre-tensioning pressure to the barrier fluid circuit.

5 A system according to the invention provides immediate response to any change in the pumped medium pressure, and is a simple and robust solution which continuously maintains a predetermined pressure difference between the barrier and lubrication fluid circuits, and which at all times keeps the circuit pressures in balance with the pressure of the pumped medium.

10 In a preferred embodiment, the barrier fluid circuit and the lubrication fluid circuit are separately connectable to a hydraulic fluid supply via controllable on/off valves, respectively, and the lubrication fluid circuit communicates with the hydraulic fluid supply via a loading compartment of the first pressure compensator.

15 This embodiment provides inherent compensation for loss of hydraulic fluid caused by leakage through seals that separate the barrier and lubrication fluid circuits in the motor and pump module, as well as a compensation for leak flows into the pumped medium.

20 The pumped medium pressure at the suction or discharge side of the pump is communicated to the loading compartment of the second pressure compensator via a pilot line. Preferably, the pumped medium pressure is communicated to the second pressure compensator over a separating diaphragm included in the pilot line.

25 This embodiment provides immediate response to pressure variations in the pumped medium, while avoiding intrusion of process fluids, sea water and particulate matter into the pump lubrication circuit.

30 Preferably, the pilot line communicates with the hydraulic fluid supply via an optional on/off valve which is controllable for feeding hydraulic fluid to the suction side or to the discharge side of the pump via the pilot line and through a one-way valve permitting back flow through the diaphragm.

35 This embodiment advantageously provides means for flushing the pilot line and diaphragm housing with hydraulic fluid for the purpose of removing hydrocarbons that may potentially intrude into the pilot line and form into solid matter, such as

hydrates or particles, which may obstruct an accurate communication of pumped medium pressure to the barrier and lubrication fluid circuits. Flushing may additionally have the purpose of resetting the position of the diaphragm to ensure proper communication.

- 5 In order to avoid interruption of operation caused by unexpected pressure build-up in the circuits, flow communication between the pump inlet or outlet and the barrier or lubrication fluid circuits, respectively, can be established via a pressure controlled safety relief valve opening into the pilot line.
- 10 For a number of applications it will be appropriate if the first and second pressure compensators are each set to deliver a differential pressure typically of about 5 bar (72.5 psig).

- The first and second pressure compensators may each be associated with a
- 15 sensing means which returns the compensator position to control logic. Depending on type of pressure compensator, a sensing means may be realized as a linear variable differential transformer (LVDT) responsive to the position of a compensator piston. The sensor reads the actual compensator position and communicates with a control logic that operates the on/off valves. The control logic is preferably
- 20 designed to maintain a pressure compensator in idling position by operating the on/off valve to refill the subject fluid circuit. The control logic is in this way effective for conversion of the compensator position into compensator pressure and thereby also into barrier fluid and pump lubrication pressures.

- 25 The barrier fluid circuit may comprise a cooler unit external to the motor housing.

- Without being limited to any specific type or model of motor and pump module, the barrier fluid and lubrication system of the invention is advantageously applied to a pump equipped with a twin-screw rotor, and the lubrication circuit arranged to
- 30 supply oil to pump bearings, as well as to timing gears that are installed in the pump for synchronizing the rotation of the rotors.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

- In the following, preferred embodiments of the invention will be described in more
- 35 detail with reference made to the accompanying, schematic drawing, Fig. 1.

In the drawing, reference number 1 refers to a subsea motor and pump module comprising a motor that is encased in a pressurized, water tight enclosure or motor

housing 2, as well as a pump rotor assembly encased in a pump housing 3. The motor driving the pump is typically an electric motor, although other drive units such as hydraulic motors or turbines may alternatively be employed.

- 5 The pump rotor is configured for displacement of a pumped medium, typically a multi-phase production fluid from a reservoir below the sea floor, which enters the pump housing via a pump inlet 4 on the suction side of the pump, to be discharged via a pump outlet 5 on the discharge side of the pump. The pump rotor is drive-connected to the motor, and the pump interior is hydraulically separated from the
- 10 pressurized (typically oil-filled) motor housing by means of a seal arrangement 6 which seals against the outside of a rotary shaft (indicated by reference number 7) by which the pump rotor is drive-connected to the motor. The pump bearings are separated from the pump medium by seal arrangements 8 and 9 at both ends of the pump. The pump rotor is journaled in bearing arrangements (not shown) in
- 15 the pump housing 3.

Since the invention is not limited to any specific type or model of motor and pump assembly, but indeed can be applied to various motor and pump configurations which are involved in the transport of a hydrocarbon production fluid and operated

20 by the skilled person, the internals of the motor and pump module 1 need not be discussed in detail.

Hydraulic fluid is supplied to the motor and pump module 1 via line 10 from a hydraulic fluid supply (indicated by reference 11), which may be located topside on

25 a surface platform, or on a land based host facility, e.g. All other components of the compensated barrier and lubrication fluids pressure regulation system are installed subsea.

The hydraulic fluid is supplied via flow control valves 12 and 13 which are

30 controllable and switched between on and off modes in response to a demand for refilling the system based on changes in fluid pressure in the barrier and lubrication fluid circuits.

More precisely, the on/off valve 12 serves for refilling of a motor barrier fluid circuit comprising lines 14, 15, and 17 in the drawing. Line 14 connects the motor barrier fluid circuit with the hydraulic fluid supply via the on/off valve 12. Line 15 opens

35 for hydraulic fluid into the motor housing interior, acting as a barrier at the interface between the motor and pump housings 2 and 3 and typically also

providing lubrication and cooling fluid for the motor. The barrier fluid circuit is indirectly connectable for flow communication with the pump inlet via line 16 which serves, as an additional safety function, for dumping hydraulic fluid from the barrier fluid circuit via a safety relief valve 18 in case of an unexpected rise of the fluid pressure to a too high level. The fluid pressure in the barrier fluid circuit is controlled by the fluid pressure in line 17, which opens into line 15 from a first pressure compensator 19 which applies a bias to the barrier fluid circuit as will be described more closely below. A cooler 20 may be incorporated in the barrier fluid circuit.

Similarly, the on/off valve 13 serves for refilling of a pump lubrication fluid circuit comprising lines 21, 22 and 24. Line 21 connects the pump lubrication fluid circuit with the hydraulic fluid supply via the on/off valve 13. Line 22 opens for hydraulic fluid into the pump housing, providing for lubrication of pump rotor bearings and, if appropriate, lubrication of timing gears. More precisely, the on/off valve 13 feeds hydraulic fluid into the lubrication circuit via the loaded compartment of the first pressure compensator 19, adding the fluid pressure in the lubrication circuit to the inherent pre-tensioning pressure that is set in the pressure compensator 19 which applies the sum of these pressures to the barrier fluid circuit, via line 17. Line 23 is indirectly connectable with the pump inlet as will be described below, and serves as an additional safety function for dumping hydraulic fluid from the pump lubrication fluid circuit via a safety relief valve 25, in case of an unexpected rise of the fluid pressure to a too high level. The fluid pressure in the lubrication fluid circuit is controlled by the fluid pressure in line 24, which opens into line 22 from a second pressure compensator 26 which applies a bias to the lubrication fluid circuit.

In result, the fluid pressures in the barrier and lubrication fluid circuits are in this way mutually balanced to maintain a constant pressure difference between the two circuits at all actual fluid pressures in the lubrication fluid circuit. The pressure differential is determined by the bias of the first pressure compensator 19, which may be controllable. A pressure differential of typically about 5 bar (72.5 psig) is in most cases considered appropriate.

In addition, the fluid pressures in the barrier and pump lubrication fluid circuits are together balanced relative to the pressure of the pumped medium at the suction side of the pump. To this purpose, the medium pressure is communicated to the loaded compartment of the second pressure compensator 26, via line 27,

adding the pressure of the pumped medium to the inherent pre-tensioning pressure that is set in the pressure compensator 26 which applies the sum of these pressures to the pump lubrication circuit, via line 24.

5 In result, the fluid pressures in the barrier and lubrication fluid circuits are in this way together balanced with respect to the pressure in the pumped medium at the suction side of the pump. The pressure differential is determined by the bias of the second pressure compensator 26, which may be controllable. A pressure differential of typically about 5 bar (72.5 psig) is in most cases considered
10 appropriate.

The pumped medium pressure is communicated to the loaded compartment of the second pressure compensator 26 via a separating diaphragm 28 which is incorporated in the pilot line 27. The diaphragm effects isolation of the pumped
15 medium from the motor barrier and pump lubrication circuits.

For the purpose of cleaning the pilot line 27 and the diaphragm housing 29 from deposits of solids that may enter together with the pumped medium, a flushing circuit is provided in the barrier and lubrication fluids pressure regulation system.
20 Flushing may additionally serve the purpose to reset the position of the diaphragm to ensure proper communication. The flushing circuit comprises an on/off valve 30 incorporated in a line 31 connecting the hydraulic fluid supply with the loaded compartment of the second pressure compensator 26. A one way valve 32 arranged in the diaphragm 28 permits back flushing of hydraulic fluid to the pumped
25 medium inlet 4, via the second pressure compensator, the diaphragm and the pilot line.

The compensators will normally manage a rise of pressure in the barrier and lubrication fluid circuits. In order to manage a situation of excessive pressure in
30 any of the circuits, additional safety functions may be installed. In the drawing, these additional safety functions are represented by the lines 23 and 16 which are connected, directly and indirectly, respectively, to the pilot line 27 as illustrated. Reverse flow in lines 16 and 23 is prevented through one way valves incorporated downstream of the safety relief valves 18 and 25.

35 Likewise in order to manage a sudden critical situation, such as hydrocarbon detection external to the pump e.g., an isolation valve 33 is arranged to cut

pressure communication between the pumped medium and the barrier and lubrication fluid circuits.

In order to avoid gas accumulation in the pilot line 27 and/or in the diaphragm housing 29, which would cause misreading of the actual medium pressure due to compression or hydrate formation, a pipe loop 34 can be included in the pilot line to effect capture of a gas phase portion of a multi-phase production fluid.

Further, in order to avoid hydrate formation and solidification of gaseous and liquid components of a multi-phase production fluid in the pilot line 27, the pilot line is associated with a heating trace 35 effective for maintaining the fluid temperature in the pilot line above a solidification temperature for these fluid components.

The pressure compensator 19 and 26 may be any available type of dome loading pressure compensator for use at full sea depth, and designed for separating the pilot fluid from the hydraulic circuit to be controlled at the subject range of pressures. A compensator having an adjustable spring bias which is controllable to set a differential pressure in the order of about 5 bar is preferred. A pressure compensator suitable for the aimed purpose is equipped with a sensor that reads the compensator position and returns a signal to a control logic 36 that operates the valves 12 and 13 between on and off modes. In case of a compensator designed with a telescoping rod for visual indication of the compensator piston position, the sensor may be an LVDT-sensor. The control logic may be designed to maintain a compensator in an idling position by operating the subject on/off valve for refilling the subject fluid circuit, and in this way converting the compensator's piston position into compensator pressure and thereby also into motor barrier fluid or pump lubrication fluid pressure. The control logic may be located subsea, or remotely located to communicate with the barrier and lubrication fluids pressure regulation system electronically via an umbilical.

The invention is of course not in any way restricted to the embodiments described above. On the contrary, many possibilities to modifications thereof will be apparent to a person with ordinary skill in the art without departing from the basic idea of the invention such as defined in the appended claims.

CLAIMS

1. A compensated barrier and lubrication fluids pressure regulation system for a subsea motor and pump module comprising:

- a hydraulic fluid supply providing barrier fluid and lubrication fluids to the motor and pump module;

5 - a barrier fluid circuit (14, 15, 17), in which the hydraulic fluid is pre-tensioned towards the motor by a pressure applied from a first separating pressure compensator (19);

10 - a lubrication fluid circuit (21, 22, 24), in which the hydraulic fluid is pre-tensioned towards the pump by a pressure applied from a second separating pressure compensator (26),

wherein the second pressure compensator (26) is responsive to the pressure of the pumped medium at a suction or at a discharge side of the pump and applies the sum of that pressure and its inherent pre-tensioning pressure to the lubrication fluid circuit, and the first pressure compensator (19) is responsive to the pressure
15 in the lubrication fluid circuit and applies the sum of that pressure and its inherent pre-tensioning pressure to the barrier fluid circuit.

2. The system of claim 1, wherein the barrier fluid circuit and the lubrication fluid circuit are separately connectable to a hydraulic fluid supply (10) via controllable
20 on/off valves (12; 13), respectively, and the lubrication fluid circuit communicates with the hydraulic fluid supply via a loading compartment of the first pressure compensator (19).

3. The system of claim 2, wherein pumped medium pressure is communicated to
25 the loading compartment of the second pressure compensator (26) via a pilot line (27).

4. The system of claim 3, wherein pumped medium pressure is communicated to the second pressure compensator (26) over a separating diaphragm (28) included
30 in the pilot line (27).

5. The system of claim 4, wherein the pilot line (27) communicates with the hydraulic fluid supply via an on/off valve (30) which is controllable for feeding hydraulic fluid to the suction side or to the discharge side of the pump via the pilot
35 line (27) and a one-way valve permitting back flow through the diaphragm (28).

6. The system of any of claims 1-5, wherein flow communication between a pump suction or a discharge side and the barrier fluid circuit or the lubrication fluid circuit, respectively, can be established via a safety relief valve (25) opening into the pilot line (27).

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7. The system of any previous claim, wherein the first and second pressure compensators (19; 26) are each set to deliver a differential pressure typically of about 5 bar.

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8. The system of any previous claim, wherein the first and second pressure compensators (19; 26) are each associated with a sensing means which returns the compensator position to control logic.

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9. The system of claim 8, wherein the sensing means is an LVDT responsive to the position of a pressure compensator piston.

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10. The system of claim 8 or 9, wherein the control logic is designed to maintain a pressure compensator in an idling position by operating the on/off valve to refill the subject fluid circuit.

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11. The system of any previous claim, wherein the barrier fluid circuit comprises a cooler unit external to the motor housing.

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12. The system of any previous claim, wherein the motor and pump module (1) comprises a motor disposed in a motor housing, a pump disposed in a pump housing having a pump inlet at a suction side and a pump outlet at a discharge side of the pump, and a pump-rotor assembly arranged there between and journaled in bearings in the pump housing, the pump-rotor assembly is drive-connected to the motor via a drive-shaft that reaches between the motor and pump housings via a seal arrangement, wherein the pump-rotor assembly is configured to displace a fluid medium from an inlet to the pump for discharge via an outlet of the pump.

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13. The system of any previous claim, wherein the pump is a twin-rotor screw pump and the lubrication circuit is arranged to supply oil to timing gears effective for synchronizing the rotation of the rotors.