

Differential pressure controlled motor and pump barrier fluids pressure regulation system**TECHNICAL FIELD OF THE INVENTION**

5 The present invention relates generally to subsea equipment involved in the transport of process fluids generated in subsea hydrocarbon production. 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
15 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
20 corresponding measures in the motor/pump module to prevent process fluid and particulate matter from immigration from the pump interior into a motor housing via bearings and seals in the motor/pump module.

Screw rotor pumps are often used for the purpose of pumping a multiphase fluid in
25 subsea production. The screw rotor pump is a positive displacement type of pump having two screws 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
30 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 is hydraulically separated from the pump 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
35 seal arrangements at both ends of the pump.

For purposes of lubrication and cooling, as well as for preventing intrusion of sea water and pumped medium into the structures of a subsea motor and pump

module, hydraulic fluid needs to be supplied to the motor/pump module. In this connection, barrier fluid and lubrication fluid are basically different definitions of the same type of fluid applied to protect the internals of the motor/pump module.

- 5 Accordingly, a motor housing that protects the motor from the ambient sea and from the medium in the pump is to be maintained at a pressure above the internal pressure of the pump, this way acting also 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
10 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.
- 15 Likewise, hydraulic fluid is typically supplied also to the pump for lubrication of its internal structure, such as pump rotor bearings, seals and timing gears. The pressure in the lubrication fluid circuit of the pump is to be maintained above the pressure of the medium that is displaced through the pump, in order to prevent intrusion of process fluid and particles into pump bearings, seals and timing gears.
- 20 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
25 shaft with no separate coupling to connect the two in a driving relationship. 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
30 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, motor barrier fluid and pump barrier fluid is supplied via the
35 umbilical, and leakage compensation and pressure control is managed through directional control valves located at the topside facility. 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 fluid systems increase correspondingly. As a consequence, there is a rising need for a motor and pump barrier fluids pressure regulation system that operates with instant response to a change in pressures in the motor and pump module and which provides increased reliability in operation.

5

SUMMARY OF THE INVENTION

The present invention thus aims at providing a motor and pump barrier 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.

10

The present invention specifically aims to provide a motor and pump barrier fluids pressure regulation system in a subsea motor and pump module, the 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 motor and pump barrier fluids pressure regulation system wherein a preset pressure differential between a motor barrier fluid circuit and a pump barrier fluid circuit is automatically maintained at all times.

15

As used in this context, the motor barrier fluid circuit shall be understood to include the fluid volumes in the motor housing cavity and its associated components and flow lines which are involved for controlling the fluid pressure in the motor housing cavity. Correspondingly, the pump barrier fluid circuit shall be understood at least to include the fluid volumes in the connection chamber cavity and its associated components and flow lines which are involved for controlling the fluid pressure in the connection chamber cavity. In a more general meaning, the pump barrier fluid circuit may also include fluid volumes in other cavities or passages in the pump.

25

The object of the present invention is achieved through the provision of a motor and a pump barrier fluids pressure regulation system for a subsea motor and pump module as defined in the accompanying claims.

30

Briefly, a pressure regulation system for the management of motor and pump barrier fluids in a subsea motor/pump application comprises:

35

- a barrier fluid circuit providing fluid flow communication from a hydraulic fluid supply to a first cavity in the motor and pump module,

- a pressure controlled flow control valve controlling the supply of hydraulic fluid to the barrier fluid circuit,
- a second cavity arranged to receive hydraulic fluid from the hydraulic fluid supply via the first cavity, and
- 5 • a pilot pressure circuit comprising means for detecting and returning to the pressure controlled flow control valve a differential pressure over a flow restriction connecting the first and second cavities.

10 An automatic pressure control system is in this way provided locally at the subsea motor and pump module, and characterized by a fast response and high reliability.

The system may be multiplied to maintain, independently, constant differential pressures between fluids in:

- 15 • a motor housing cavity (first cavity) and a cavity/passage (second cavity) in a pump structure;
- a motor housing cavity (first cavity) and a cavity (second cavity) in a connection chamber;
- a cavity (first cavity) in a connection chamber and a cavity/passage (second
- 20 cavity) in the pump structure; or
- a cavity/passage (first cavity) in the pump structure and the cavity (second cavity) in the pump through which the pumped medium is displaced in operation.

25 In other words, with respect to the first recited implementation, a flow control valve is used to supply fluid to the motor housing in order to maintain a constant differential pressure across a restriction, this way maintaining a constant over-pressure in the motor barrier circuit relative to the pump barrier circuit, and thus across the motor shaft seal. The flow rate through the flow control valve is controlled

30 by the differential pressure over a restriction. In result, the supply fluid flow rate is always identical to the leakage rate at the defined differential pressure, regardless of system pressure variations. If the seal leakage rate should increase due to wear, e.g., the valve will automatically increase the flow rate as required to maintain the differential pressure across the seal. When the pump pressure increases during

35 normal operations, the valve will automatically adjust the flow rate to maintain a constant differential pressure across the seal. When the pump pressure is reduced during normal operations, the valve will automatically adjust the flow rate as required to maintain a constant differential pressure across the seal.

One alternative and advantageous embodiment foresees, that pump barrier fluid is received from the motor barrier fluid circuit via a flow restriction of fixed orifice diameter arranged externally of the motor and pump module, and over which the differential pressure is detected and returned to the pressure controlled on/off valve that feeds hydraulic fluid into the motor and pump barrier fluid circuits in response to detected deviations from a predefined, desired pressure difference.

In some applications very accurate control of the fluid flow rate is required in a lower flow rate range, while high maximum flow rates will be required at certain operating conditions. Both requirements are met in an embodiment wherein two or more valves having different flow rate ranges are connected in parallel in the fluid supply to the motor barrier circuit. More precisely, this embodiment comprises a set of valves, including at least first and second valves, which are arranged in parallel to feed hydraulic fluid into the motor barrier fluid circuit, and which are each responsive to the differential pressure over the flow restriction, and further wherein said at least two pressure controlled flow control valves are individually responsive to separate ranges of the differential pressure over the flow restriction.

In a set of first and second pressure controlled flow control valves the first valve is preferably set to open for hydraulic fluid flow into the motor barrier fluid circuit in result of a differential pressure at or below a first predefined differential pressure at the flow restriction, and the second valve is preferably set to open for hydraulic fluid flow into the motor barrier fluid circuit in result of a differential pressure at or below a second predefined differential pressure lower than the first predefined differential pressure.

In many applications for subsea hydrocarbon production the first predefined differential pressure may be set to about 5 bar, and the second predefined differential pressure can be set to about 4.5 bar.

In the set of first and second pressure controlled flow control valves arranged in parallel to feed hydraulic fluid into the motor barrier fluid circuit, the first valve can be sized for lower flow rates and the second valve be sized for higher flow rates. For example, the first valve may be sized for flow rates ranging down to about 0.3 l/min, and the second valve may be sized for flow rates ranging up to about 100 l/min or above.

If required, an ON/OFF valve may be connected in series with the second pressure controlled flow control valve of higher flow rate in order to control eventual internal leakage in this valve.

- 5 For security, a pressure controlled safety relief valve may be arranged in parallel with the flow restriction to dump hydraulic fluid from the motor barrier fluid circuit into the pump.

10 The motor and pump barrier 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 twin-screw pump-rotor assembly arranged there
15 between and journalled 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 via a seal arrangement and is configured to displace a fluid medium from the pump inlet for discharge via the pump outlet.

SHORT DESCRIPTION OF THE DRAWINGS

- 20 Embodiments of the invention will be more closely described below with reference made to the drawings. In the drawings,

Fig. 1 is a diagram illustrating the motor and a pump barrier fluids pressure regulation system in a first embodiment, and

25

Fig. 2 is a corresponding diagram illustrating a second embodiment of the pressure regulations system.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

- 30 In the drawings, a subsea motor and pump module comprises a motor/pump assembly generally denoted 1 to which motor barrier fluid and pump barrier fluid is supplied from an external hydraulic fluid supply.

35 Since the invention is not limited to any specific type or model of motor/pump assembly, but indeed can be applied to various motor/pump configurations involved in the transport of a process fluid from subsea hydrocarbon production, and which are familiar to the skilled person, the internals of the motor/pump assembly 1 need not be discussed in detail. In general, the motor/pump assembly comprises 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 which enters the pump via a pump inlet 4 to be discharged via a pump outlet 5, as illustrated by an arrow F. The pump rotor is drive-connected to the motor in a connection chamber 6, the interior of which is hydraulically separated from the pressurized (typically oil-filled) motor housing by means of a seal arrangement 7 which seals against the outside of a rotary shaft by which the pump rotor is drive-connected to the motor. The pump rotor is further journaled in bearing arrangements in the pump housing 3. Internally of the pump, pump barrier fluid is typically circulated for lubrication of internal structures in the pump, such as bearings, seals, timing gears if appropriate, etc., providing also a barrier towards the medium which passes through the pump.

Motor barrier fluid and pump barrier fluid is supplied to the subsea motor and pump module from an external supply (topside offshore or onshore) of hydraulic fluid via hydraulic fluid supply line 8. All other components of the system are installed subsea. Motor barrier fluid is supplied to the motor housing via a flow control valve 9 which controls the flow of hydraulic fluid into a motor barrier fluid circuit 10 that opens into the motor housing.

Pump barrier fluid is received in the connection chamber 6 from the motor housing 2 which communicates with the connection chamber via the seal arrangement 7. This flow communication over the seal arrangement 7 is a leakage of hydraulic fluid through the seal, the seal arrangement 7 in this context representing a restriction of fixed orifice diameter, disregarding wear of seal surfaces over time.

30

In order to compensate for leak flow via the restriction 7, the flow control valve 9 is pressure controlled and operated in response to the difference in pressure between the motor barrier fluid on the upstream side of flow restriction 7 and the pump barrier fluid on the downstream side thereof, i.e. the pressure difference between the motor housing and the connection chamber. The differential pressure over the flow restriction 7 is continuously detected and returned to the flow control valve 9 by means of a pilot pressure circuit 11. In the drawings, the pilot pressure circuit 11 is illustrated by thin and/or broken lines.

35

In the alternative embodiment illustrated in fig. 2, pump barrier fluid is supplied to the pump/connection chamber 6 from the motor barrier fluid circuit 10 via pump barrier fluid circuit 12. A flow restriction 13 of fixed orifice diameter is arranged in the pump barrier fluid circuit externally of the motor/pump module and restricts the flow of hydraulic fluid from the motor barrier fluid circuit 10 into the pump barrier fluid circuit 12.

Accordingly, the valve 9 is a pilot controlled flow control valve which cooperates with an internal (7) or an external (13) restriction to maintain a constant pressure difference between the motor barrier and pump barrier fluid circuits by adjusting the flow through the flow control valve. The flow through the restriction is only a small flow going into the pump via pump barrier fluid circuit, whereas the main flow is supplied to the motor via the motor barrier circuit.

In ordinary practise and scale it is considered sufficient to cover flow rates in the order of 0-100 l/min of supplied hydraulic fluid. However, in order to manage a wider range of flow rates than a singular valve 9 can provide, at least one additional pressure controlled flow control valve 14 may optionally be arranged in parallel with the first flow control valve 9 to supply fluid into the motor barrier fluid circuit 10. The flow control valves 9 and 14 are each responsive to the pressure in the pilot pressure circuit 11. As previously discussed, the flow control valves 9 and 14 may be individually responsive to separate ranges of the differential pressure over the flow restriction, and they may also be sized for different flow rates. If required, a set of more than two flow control valves may be connected in parallel to supply hydraulic fluid into the motor barrier fluid circuit.

With further reference to the drawing, reference number 15 refers to a pressure relief valve arranged to permit motor barrier fluid into the pump barrier fluid circuit via a by-pass line 16 which opens into the pump barrier fluid circuit downstream of the flow restriction 7 or 13. The pressure relief valve 15 manages and controls higher differential pressure during start-up and resulting from thermal expansion of the liquid volumes in the motor and pump. The pressure relief valve 15 also operates as a safety valve in case of an unexpected rise of the fluid pressure to a too high level. A one-way valve 17 is preferably arranged to prevent back-flow from the pump into the motor barrier circuit 10. A pressurized accumulator 18 may be arranged in the supply fluid line to provide adequate supply fluid pressure to the pressure controlled flow control valve(s) 9, 14.

The illustrated embodiment meets the purpose of the invention, namely to maintain a constant differential pressure between two fluid-filled cavities which are hydraulically interconnected in the motor and pump module. Fluid is supplied at a controlled flow rate to the cavity having the highest pressure such that the

5 differential pressure is maintained constant independent of leakage rate between the cavities. The invention is also effective for compensation of flow rates caused by compression and thermal expansion of the fluids in the cavities.

Although the invention is disclosed with reference to a system for controlling barrier

10 fluid pressures over an interface between a motor housing and a connection chamber, it will be realized that a similar setup can be used for controlling barrier fluid pressures at other interfaces in a motor and pump module at subsea level, requiring fluid barriers for separation or for preventing intrusion from surrounding media. It will be realized that in addition to the interfaces listed in the summary, the

15 invention may be applied at any separating interface in the motor or pump, such as seals and bearings forming parts of a pump lubrication system, or seals and bearings forming parts of a motor lubrication or cooling system, e.g.

The invention is of course not in any way restricted to the embodiments described

20 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 motor and a pump barrier fluids pressure regulation system for a subsea motor and pump module (1), the pressure regulation system comprising:

- a barrier fluid circuit (10) providing fluid flow communication from a hydraulic fluid supply (8) to a first cavity in the motor and pump module,

5 - a pressure controlled flow control valve (9) controlling the supply of hydraulic fluid to the barrier fluid circuit (10);

- a second cavity arranged to receive hydraulic fluid from the hydraulic fluid supply via the first cavity, and

10 - a pilot pressure circuit (11) comprising means for detecting and returning to the pressure controlled flow control valve (9) a differential pressure over a flow restriction (7; 13) connecting the first and second cavities.

2. The regulation system of claim 1, wherein a pump barrier fluid circuit (12) is arranged to receive hydraulic fluid from a motor barrier fluid circuit (10) via a flow
15 restriction (13) of fixed orifice diameter arranged externally of the motor and pump module (1), and over which the differential pressure is detected and returned to the pressure controlled flow control valve (9) that feeds hydraulic fluid into the motor and pump barrier fluid circuits in response to deviations from a predefined, desired pressure difference.

20

3. The regulation system of claim 1 or 2, wherein said pressure controlled flow control valve (9) is one of a set of valves, including at least first and second valves (9, 14), which are arranged in parallel to feed hydraulic fluid into the motor barrier fluid circuit (10), and which are each responsive to the differential pressure over the
25 flow restriction (7; 13), and further wherein said at least two pressure controlled flow control valves are individually responsive to separate ranges of the differential pressure over the flow restriction.

4. The regulation system of claim 3, wherein in a set of first and second pressure
30 controlled flow control valves the first valve (9) is set to open for hydraulic fluid flow into the motor barrier fluid circuit (10) in result of a differential pressure at or below a first predefined differential pressure at the flow restriction (7; 13), and the second valve (14) is set to open for hydraulic fluid flow into the motor barrier fluid circuit (10) in result of a differential pressure at or below a second predefined differential
35 pressure lower than the first predefined differential pressure.

5. The regulation system of claim 4, wherein the first predefined differential pressure is about 5 bar, and the second predefined differential pressure is about 4.5 bar.
- 5 6. The regulation system of any of claims 2-5, wherein in a set of first and second pressure controlled flow control valves the first valve (9) is sized for lower flow rates and the second valve (14) is sized for higher flow rates.
7. The regulation system of claim 6, wherein the first valve (9) is sized for flow rates
10 ranging down to about 0.3 l/min, and the second valve (14) is sized for flow rates ranging up to about 100 l/min or above.
8. The regulation system of any of claims 3-7, wherein an ON/OFF valve is
15 higher flow rate.
9. The regulation system of any previous claim, wherein a pressure controlled pressure relief valve (15) is arranged in parallel with the flow restriction (7; 13) to dump hydraulic fluid from the motor barrier fluid circuit (10) into the pump.
- 20