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(54) **VESSEL WITH HEAVE COMPENSATION SYSTEM**

(57) A vessel comprising a hull (5) and a heave compensation system for a load that is suspended from the hull (5), wherein the heave compensation system comprises a winch (31) with a drum (36) on the hull (5) and a hoisting cable around the drum (36) for hoisting and suspending the load, a first hydraulic motor (33) and a second hydraulic motor (34) that are operatively connected to the drum (36) to rotate synchronously with the drum (36), and a hydraulic drive system with a hydraulic circuit to control the hydraulic fluid to the hydraulic motors (33), wherein the hydraulic drive system is able to switch between a hoisting mode and a heave compensation mode wherein in the hoisting mode the hydraulic motors (33) work parallel, and wherein in the heave compensation mode only the first hydraulic motor (33) is powered while the second hydraulic motor (34) is connected to a biased accumulator assembly.

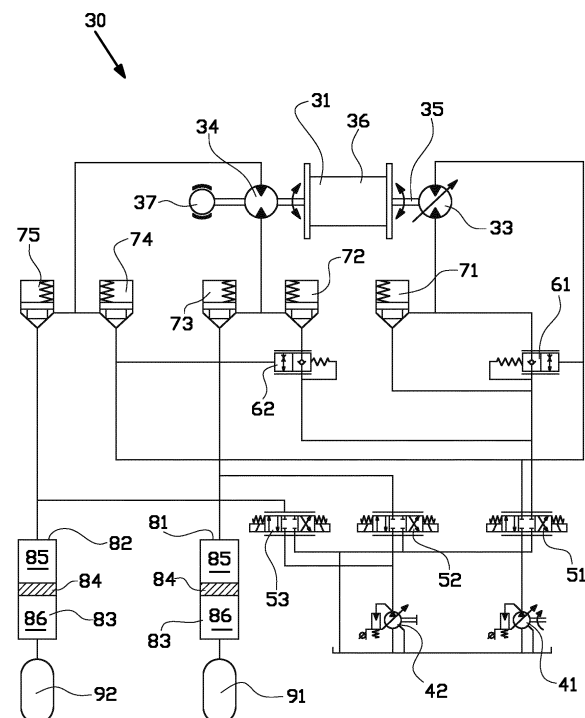


FIG. 2

Description

BACKGROUND

[0001] The invention relates to a vessel comprising a hull and a heave compensation system for a load that is suspended from the hull.

[0002] Vessels may be provided with a heave compensation system to keep a suspended load at a constant height while the hull is subject to heave. A known heave compensation system comprises a winch with a drum and a hoisting cable around the drum for hoisting and suspending the load. The heave, roll and pitch motions of the hull are detected and continuously compensated by corresponding counter-rotation of the drum. The rotation of the drum may be powered by a hydraulic motor. The drum may be subject to a high static torque, especially when the load is hoisted out of the water. Therefore a strong hydraulic motor is needed, having a relatively high hydraulic fluid displacement per rotation to deliver that torque. It would require a high fluid flow to drive that motor during heave compensation. In a submerged condition the weight of the load is reduced, resulting in a much lower torque requirement of the drum and consequently much lower fluid displacement per rotation of the motor. Attempts have been made to compensate this, for example by using reduction boxes with multiple gears or by using over-dimensioned or high performance hydraulic power packs, which are both not preferred.

[0003] It is an object of the present invention to provide a vessel with a heave compensation system having a winch that can deliver a high static torque in combination with a quick dynamic response during heave compensation.

[0004] It is an object of the present invention to provide a vessel with a heave compensation system having a winch that is rotated by a hydraulic driving system with an efficient use of the hydraulic driving components.

SUMMARY OF THE INVENTION

[0005] According to a first aspect the invention provides a vessel comprising a hull and a heave compensation system for a load that is suspended from the hull, wherein the heave compensation system comprises a winch with a drum on the hull and a hoisting cable around the drum for hoisting and suspending the load, a first hydraulic motor and a second hydraulic motor that are operatively connected to the drum to rotate synchronously with the drum, wherein the hydraulic motors each have a first hydraulic fluid port and a second hydraulic fluid port to drive the hydraulic motors and the winch in the two opposite rotation directions depending on the port into which the hydraulic fluid is fed, and a hydraulic drive system with a hydraulic circuit to control the hydraulic fluid through the first ports and second ports of the hydraulic motors, wherein the hydraulic drive system comprises a powered hydraulic fluid source to provide hy-

draulic fluid under pressure, a first hydraulic accumulator assembly to store and bias hydraulic fluid, a first valve assembly in a hydraulic fluid connection between the hydraulic fluid source and the ports of the hydraulic motors, a second valve assembly in a hydraulic fluid connection between the first valve assembly and the first port of the second hydraulic motor, and a third valve assembly in a hydraulic fluid connection between the first accumulator assembly and the first port of the second hydraulic motor, wherein the hydraulic drive system is able to switch between a hoisting mode and a heave compensation mode by means of the second valve assembly and the third valve assembly, wherein in the hoisting mode the hydraulic fluid from the first valve assembly is fed parallel into both first ports of the hydraulic motors or parallel into both second ports of the hydraulic motors to drive the rotation of the winch in one of the opposite rotation directions, and wherein in the heave compensation mode the hydraulic fluid from the first valve assembly is fed into the first port of the first hydraulic motor or into the second port of the hydraulic motor to drive the rotation of the winch in one of the rotation directions, and the first hydraulic accumulator assembly biases the hydraulic fluid to the first port of the second hydraulic motor.

[0006] The vessel is provided with a heave compensation system having a winch with a drum that is operatively connected to two hydraulic motors. In the hoisting mode the full load may be hoisted above the water. In this mode the two hydraulic motors are employed in parallel, whereby a high static torque is delivered to carry the load. At the given capacity of the hydraulic fluid source the delivery of this high torque is detrimental to the rotation speed of the winch. This low rotation speed allows a good control over the hoisting process. When the load is brought under water to be kept at a constant height, the hydraulic drive system is switched over to the heave compensation mode by alternating the opposite settings of the second valve assembly and the third valve assembly. In the heave compensation mode the second hydraulic motor is not powered anymore by the first valve assembly but it is connected to the biased first hydraulic accumulator assembly. Depending on the rotation direction the second hydraulic motor alternately acts as a hydraulic motor or as a hydraulic pump. The second hydraulic motor delivers substantially the entire static torque while the much lower dynamic torque is delivered by the first hydraulic motor. At the same given capacity of the hydraulic fluid source the first hydraulic motor is then able to quickly respond with a rotation speed that is much higher than in the hoist mode. In the system according to the invention the two hydraulic motors are in both modes both employed, which is efficient.

[0007] In an embodiment the first hydraulic motor is a variable displacement hydraulic motor that can change between a high fluid displacement mode, in which a first torque is delivered using a first amount of hydraulic fluid per rotation, and a low fluid displacement mode in which a lower second torque is delivered using a lower second

amount of hydraulic fluid per rotation, wherein in the hoisting mode the first hydraulic motor is in the high displacement mode and wherein in the heave compensation mode the first hydraulic motor is in the low displacement mode. By setting the first hydraulic motor into the low displacement mode the rotation speed is increased for the given capacity of the hydraulic fluid source. This enhances the dynamic response of the winch. In the hoisting mode the first hydraulic motor is set in the high displacement mode to deliver the maximal static torque.

[0008] In an embodiment the first hydraulic motor is a dual displacement hydraulic motor that can switch between the high displacement mode and the low displacement mode.

[0009] In an embodiment the first hydraulic motor is a radial piston hydraulic motor in which the number of active radial pistons is adjustable.

[0010] In an embodiment the second hydraulic motor is a radial piston hydraulic motor.

[0011] Radial piston hydraulic motors are able to deliver a high torque without internal reduction gears. This makes the motors compact and reliable.

[0012] In an embodiment the second hydraulic motor delivers the same first torque using the same first amount of hydraulic fluid per rotation as the first hydraulic motor in its high fluid displacement mode, whereby the motors are in balance when the high static torque in the hoisting mode is delivered.

[0013] In an embodiment the hydraulic drive system comprises a fourth valve assembly between the hydraulic fluid source and the first hydraulic accumulator assembly to fill, refill or bias the first hydraulic accumulator assembly. In the hoisting mode the first hydraulic accumulator may be prepared for the heave compensation by bringing the hydraulic fluid to the desired pressure by means of the fourth valve assembly. The system can then quickly switch over to the heave compensation mode.

[0014] In an embodiment the hydraulic drive system comprises a second hydraulic accumulator assembly to store and bias hydraulic fluid, a fifth valve assembly in a hydraulic fluid connection between the first valve assembly and the second port of the second hydraulic motor, and a sixth valve assembly between the second hydraulic accumulator assembly and the second port of the second hydraulic motor, wherein the second hydraulic accumulator assembly biases the hydraulic fluid to the second port of the second hydraulic motor. The second hydraulic accumulator assembly ensures that the second hydraulic motor is continuously provided with sufficient hydraulic fluid when it is imposed to act as a hydraulic pump.

[0015] In an embodiment thereof the hydraulic drive system comprises a seventh valve assembly between the hydraulic fluid source and the second hydraulic accumulator assembly to fill, refill and bias the second hydraulic accumulator assembly. The seventh valve assembly can be used for the same purposes as the fourth valve assembly.

[0016] In an embodiment the pressure of the hydraulic

fluid in the biased first hydraulic accumulator assembly is higher than the pressure of the hydraulic fluid in the biased second hydraulic accumulator assembly, whereby the static torque is delivered by the pressure difference.

[0017] In an embodiment the first hydraulic accumulator assembly, and the second accumulator assembly when present, is a free piston accumulator comprising a cylinder with a port for passage of the hydraulic fluid and a piston that is slidable through the cylinder to bias the hydraulic fluid to the port.

[0018] In an embodiment the free piston accumulator comprises a biased or pressurized volume of gas that is separated from the hydraulic fluid by the piston. The gas may be nitrogen. The amount of gas and thereby the provided bias may be adjusted to the load.

[0019] In an embodiment the hydraulic drive system comprises a displacement sensor to determine the position of the piston in its sliding direction. With this the piston can be set halfway the cylinder to allow strokes in both directions during heave compensation. The setting may be performed by means of the fourth valve assembly and seventh valve assembly when present.

[0020] In an embodiment the first valve assembly comprises a bidirectional, proportional valve to control the winch during hoisting above the water, or above a working platform of the vessel.

[0021] In an embodiment the heave compensation system comprises a brake for the drum to be activated during switching between the hoisting mode and the heave compensation mode.

[0022] In an embodiment the hydraulic drive system comprises a controller that is operatively connected with the first valve assembly to control the first valve assembly in response to heave, roll and pitch parameters of the hull with respect to a reference height for the load.

[0023] In an embodiment the vessel is configured as a water injection dredging vessel, wherein the load is a jet bar that is provided with a series of water jet nozzles, wherein the jet bar is under water suspended from the hull.

[0024] According to a second aspect, the invention provides a method for suspending a load from a vessel, wherein the vessel comprises a hull and a heave compensation system for the load that is suspended from the hull of the vessel, wherein the heave compensation system comprises a winch with a drum on the hull and a hoisting cable around the drum for hoisting and suspending the load, a first hydraulic motor and a second hydraulic motor that are operatively connected to the drum to rotate synchronously with the drum, and a hydraulic drive system with a hydraulic circuit to control the hydraulic fluid through the hydraulic motors, wherein the hydraulic drive system comprises a powered hydraulic fluid source to provide hydraulic fluid under pressure and a first hydraulic accumulator assembly to store and bias hydraulic fluid, wherein the method comprises switching the hydraulic drive between a hoisting mode and a heave com-

pensation mode during hoisting the load, wherein in the hoisting mode the hydraulic fluid from the hydraulic fluid source is fed parallel through both the first hydraulic motor and the second hydraulic motor to drive the rotation of the winch in one of the opposite rotation directions, and wherein in the heave compensation mode the hydraulic fluid from the hydraulic fluid source is fed through the first hydraulic motor while the first hydraulic accumulator assembly is in fluid connection with the second hydraulic motor and delivers hydraulic fluid to or receives hydraulic fluid from the second hydraulic motor depending on the rotation direction of the first hydraulic motor.

[0025] In an embodiment thereof the hydraulic drive system is in the hoisting mode when the load is above the water line and wherein the hydraulic drive is switched between the hoisting mode and the heave compensation mode when the load is submerged in the water.

[0026] The various aspects and features described and shown in the specification can be applied, individually, wherever possible. These individual aspects, in particular the aspects and features described in the attached dependent claims, can be made subject of divisional patent applications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The invention will be elucidated on the basis of an exemplary embodiment shown in the attached drawings, in which:

Figures 1A and 2B a dredging vessel with a heave compensation system according to the invention;
Figure 2 the hydraulics of the heave compensation system of the vessel according to figures 1A and 1B;
Figures 3A and 3B the active components of the hydraulics when the heave compensation system is in the hoisting mode; and
Figures 4A and 4B the active components of the hydraulics when the heave compensation system is in the heave compensation mode.

DETAILED DESCRIPTION OF THE INVENTION

[0028] Figures 1A and 1B show a dredging vessel 1 that is configured for water injection dredging of a sea bed 10. Water injection dredging is applied to sea beds having a fluidisable top layer or sediment. The method is applied to make trenches for under water infrastructures in the sea bed 10 or for maintenance dredging of the sea bed 10 at shipping areas. The fluidized top layer may be transported by a natural, predictable water flow, such as a tidal flow or a river flow.

[0029] The dredging vessel 1 comprises a floating hull 5 with a bow 6, a stern 7, and a working platform 8 and propulsion 9 at the backside. On the platform 8 two supports 15 are provided. The supports 15 are provided with guide pulleys 22 and they also form the rotary bearings of an A-frame 16. The A-frame 16 is provided with hoisting

pulleys 20 at the starboard side and the port side. The A-frame 16 can pivot in direction A with respect to the working platform 8 to move the hoisting pulleys 20 between a position above the platform 8 and a position behind the stern 13. Two hoisting cables 21 run via the hoisting pulleys 20 and the guide pulleys 22 to two hydraulically powered winches 31 on the platform 8.

[0030] The hoisting cables 21 carry a horizontally extending jet bar 25 that is provided with a series of jet nozzles 26 that are directed in downward and backward direction B. The jet bar 25 is fed with pressurized water while suspended on the hoisting cables 21. During injection dredging the dredging vessel 1 moves at a constant speed in its forward shipping direction C. In order to obtain a constant depth of the sea bed 10 by the injection dredging, the jet bar 25 needs to pass at a constant height with respect to the water line. During the dredging the hull 5 is suspended is subjected to heave, making pitching and rolling movements. This is actively compensated by controlling the rotary motion of each of the two winches 31 by means of a hydraulic heave compensation system 30 according to the invention.

[0031] The hydraulic layout of the heave compensation system 30 is shown in figure 2. The system 30 comprises a first hydraulic motor 33, a second hydraulic motor 34 and a brake 37 that are connected in parallel to the drive shaft 35 of the winch 31, wherein the hydraulic motors 33, 34 are located on opposite sides of the drum 36. The hydraulic motors 33, 34 are radial piston hydraulic motors that are directly connected to the drive shaft 35, that is, without reducing gears in between. The hydraulic motors 33, 34 deliver a specific torque of more than 200 Nm/bar with a displacement of more than 10000 cm³ per rotation. The typical maximum operating pressure is 300 bar.

[0032] The first hydraulic motor 33 is a variable displacement hydraulic motor. This motor 33 can change between a high fluid displacement mode, in which a high torque is delivered using a large amount of hydraulic fluid per rotation, and a low fluid displacement mode in which a lower torque is delivered using a lower amount of hydraulic fluid per rotation. In the low fluid displacement mode the motor 33 delivers more rotations at the same hydraulic fluid displacement. The variable displacement is embodied by setting the number of active radial pistons. In particular, it is a dual displacement motor using two groups of radial pistons of which one is selectively powered. The second hydraulic motor 34 is a regular radial piston hydraulic motor having specifications that are equal to the specifications of the first hydraulic motor 33 in its high fluid displacement mode. The hydraulic motors 33, 34 can work reversely as a hydraulic fluid pump when a rotation is imposed.

[0033] The system 30 comprises a first hydraulic pump 41, a second hydraulic pump 42, a first bidirectional, proportional valve 51, a second bidirectional, proportional valve 52 and a third bidirectional, proportional valve 53, a first break valve 61 and a second break valve 61, a first on-off valve 71, a second on-off valve 72, a third on-off

valve 73, a fourth on-off valve 74 and a fifth on-off valve 75, and a first free piston accumulator 81 and a second free piston accumulator 82.

[0034] The break valves 61, 62 can change between a check mode in which hydraulic fluid can pass in only one direction as indicated, and a throttle mode in which the passage of hydraulic fluid is throttled in a controlled manner. The mode is changed by feeding hydraulic fluid to the respective activation port.

[0035] The free piston accumulators 81, 82 each comprise a cylinder 83 and a freely slidable piston 84 inside that separates the inner space in a fluid chamber 85 that is connected to the port of the free piston accumulator 81, 82, and a gas chamber 86 that is connected to a respective external gas chamber 91, 92. The gas chambers 86, 91, 92 are filled with nitrogen under pressure. The free piston accumulators 81, 82 are each provided with a position sensor to derive the position of the pistons 84 in the longitudinal direction of the cylinders 83.

[0036] The hydraulic pumps 41, 42 deliver hydraulic fluid at a constant pressure of about 300 bar. The first hydraulic pump 41 is connected to the first proportional valve 51. The second hydraulic pump 42 is connected to the second proportional valve 52 and the third proportional valve 53. As described hereafter, the first pump 41 forms part of a hydraulic circuit that powers the rotation of the winch 31, while the second pump 42 forms part of a hydraulic circuit to bias the winch 31.

[0037] The first port of the first proportional valve 51 is hydraulically connected to the first break valve 61 and to the activation port for the check mode thereof. The connection is continued to the first port of the first hydraulic motor 33, wherein the first break valve 61 can be bypassed via the first on-off valve 71. The first port of the first proportional valve 51 is also hydraulically connected to the second break valve 62 and to the activation port for the check mode thereof. The connection is continued via the second on-off valve 72 to the first port of the second hydraulic motor 34.

[0038] The second port of the first proportional valve 51 is hydraulically connected to the pilot port or throttle activation port of the first break valve 61 and to the second port of the first hydraulic motor 33. The second port of the first proportional valve is also hydraulically connected to the pilot port or throttle activation port of the second break valve 62 and via the fourth valve 74 to the second port of the second hydraulic motor 34.

[0039] The first port of the second proportional valve 52 is hydraulically connected to the port of the first free piston accumulator 81 and via the third on-off valve 73 to the first port of the second hydraulic motor 34. The first port of the third proportional valve 53 is hydraulically connected to the port of the second free piston accumulator 82 and via the fifth on-off valve 75 to the second port of the second hydraulic motor 34.

[0040] The system 30 furthermore comprises an electric controlling circuit that is not shown. The controlling circuit is operatively connected to the proportional valves

51-53, the on-off valves 71-75, the break 37 and the position sensors of the free piston accumulators 81, 82. The electric controlling circuit comprises position sensors, and/or displacement sensors and/or accelerometers to determine the heave, roll and pitch motions of the hull 5 to be compensated. The controlling circuit may also be provided with joysticks for manual control of at least the proportional valve 51.

[0041] The system 30 is configured to operate in two modes, which are the hoisting mode and the heave compensation mode. These modes are elucidated under reference to figures 3A-3D. The system 30 can switch between the modes, wherein the brake 37 may be activated during the switching to keep the winches 31 temporary on hold.

[0042] Figures 3A and 3B show the operation in the hoisting mode. In this mode the jet bar 25 is hoisted above the platform or the water by manual use of the joysticks. In this mode the winches 31 need to deliver and control a high static torque while the rotation speed is less critical. The high torque is delivered by the two hydraulic motors 33, 34 that work parallel. In the hoisting mode the first on-off valve 71, the third on-off valve 73 and the fifth on-off valve 75 are closed, and the second on-off valve 72 and fourth on-off valve 74 are open. The first hydraulic motor 33 is set in its high fluid displacement mode. In the hoisting mode the free piston accumulators 81, 82 do not form part of the active circuit.

[0043] During hoisting as shown in figure 3A, wherein the jet bar 25 moves upward, the hydraulic fluid from the first port of the first proportional valve 51 passes the break valves 61, 62 that are in the check mode for that direction, and enter the first ports of the hydraulic motors 33, 34. The hydraulic fluid from the second ports of the hydraulic motors 33, 34 returns to the second port of the first proportional valve 51.

[0044] During paying out as shown in figure 3B, wherein the jet bar 25 moves downward, the hydraulic fluid from the second port of the first proportional valve 51 activate the throttle mode of the break valves 61, 62 via the pilot ports and enter the second ports of the hydraulic motors 33, 34. The hydraulic fluid from the first ports of the hydraulic motors 33, 34 returns to the first port of the first proportional valve 51 via the break valves 61, 62 to be throttled. Basically, the hydraulic motors 33, 34 that are subject to the high static torque act as a pump, wherein the pressurized fluid is drained off in a controlled manner.

[0045] Figures 4A and 4B show the operation in the heave compensation mode. In this mode the jet bar 25 is fully submerged in the water, resulting in about half the static weight due to partial buoyancy. In this mode the winches 31 need to deliver and control much lower static torques than in the hoisting mode, while the rotation speed is much higher to quickly respond to the dynamic motions of the hull 5. The static torque is delivered and maintained by the second hydraulic motor 34 while the rotation of the winches 31 is activated by the first hydraulic motor 33.

[0046] When the system 30 is ready to switch from the hoisting mode to the heave compensation mode, the brake 37 is temporary activated while the average position of the pistons 84 in the cylinders 83 of the free piston accumulators 81, 82 are controlled around their mid positions by activation of the second proportional valve 52 and the third proportional valve 53, respectively. The bias pressure in the first free piston accumulator 81 is much higher than the bias pressure in the second free piston accumulator 82, wherein the pressure difference is about equal to the fluid pressure as applied at the last at the first port of the second hydraulic motor 34 during sub-

[0047] In the heave compensation mode the first on-off valve 71, the third on-off valve 73 and the fifth on-off valve 75 are open, and the second on-off valve 72 and fourth on-off valve 74 are closed. The first hydraulic motor 33 is set in its low fluid displacement mode. In the heave compensation mode the free piston accumulators 81, 82 form part of the active hydraulic circuit of the second hydraulic motor 34. The rotation of the winch 31 is activated by the first proportional valve 51, which is actively controlled by the electronic circuit in response to the heave parameters.

[0048] During downward compensation as shown in figure 4A, wherein the jet bar 25 moves upward with respect to the A-frame 16, the hydraulic fluid from the first port of the first proportional valve 51 bypasses the first break valve 61 via the first on-off valve 71 and enters the first port of the first hydraulic motor 33 only. The hydraulic fluid from the second port of the first hydraulic motor 33 returns to the second port of the first proportional valve 51. The biased hydraulic fluid from the first free piston accumulator 81 enters the first port of the second hydraulic motor 34 via the third on-off valve 73 to maintain the compensation of the static torque on the winch 31. The hydraulic fluid from the second port of the second hydraulic motor 34 is fed to the second free piston accumulator 82 via the fifth valve 75. The pistons 84 move accordingly in longitudinal directions D, E as indicated.

[0049] During upward compensation as shown in figure 4B, wherein the jet bar 25 moves downward with respect to the A-frame 16, the hydraulic fluid from the second port of the first proportional valve 51 enters the second port of the first hydraulic motor 33 only. The hydraulic fluid from the first port of the first hydraulic motor 33 returns to the second port of the first proportional valve 51 via the first on-off valve 71. The biased hydraulic fluid from the second free piston accumulator 82 enters the second port of the second hydraulic motor 34 via the fifth on-off valve 75 to ensure that the second hydraulic motor 34 remains filled with hydraulic fluid. The second hydraulic motor 34 acts as a pump. The hydraulic fluid from the first port of the second hydraulic motor 34 is fed to the first free piston accumulator 82 via the third valve 75 to maintain the compensation of the static torque on the winch 31. The pistons 84 move accordingly in longitudinal directions D, E as indicated.

[0050] In the heave compensation mode the pistons 84 move as indicated, wherein the pressure changes are limited due to the bias. That is, due to the bias the movement of the pistons 84 is not linear anymore to the pressure differences. Only the fraction of the static torque that is not compensated by the second hydraulic motor 34 due to the friction in the system and the stiffness of the gas volumes, the according pressure drop is taken by the first hydraulic motor 33. As only the first hydraulic motor 33 in its low displacement mode needs to be powered, it can respond very quickly with a rotation speed that is multiple times higher than the rotation speed in during hoisting. In this way a heave compensation system 30 is provided that can deliver high torques in its hoisting mode by powering both hydraulic motors 33, 34 in parallel, wherein the same two hydraulic motors 33, 34 are used in the heave compensation mode to carry the lower static torque on the one hand while being able to quickly respond on the other hand.

[0051] In the heave compensation mode the pistons 84 of the free piston accumulators 81, 82 are regularly brought back to their mid positions by activation of the second proportional valve 52 and the third proportional valve 53, respectively to compensate small hydraulic fluid losses inside the second hydraulic motor 34.

[0052] It is to be understood that the above description is included to illustrate the operation of the preferred embodiments and is not meant to limit the scope of the invention. From the above discussion, many variations will be apparent to one skilled in the art that would yet be encompassed by the scope of the present invention.

Claims

1. Vessel comprising a hull and a heave compensation system for a load that is suspended from the hull, wherein the heave compensation system comprises a winch with a drum on the hull and a hoisting cable around the drum for hoisting and suspending the load, a first hydraulic motor and a second hydraulic motor that are operatively connected to the drum to rotate synchronously with the drum, wherein the hydraulic motors each have a first hydraulic fluid port and a second hydraulic fluid port to drive the hydraulic motors and the winch in the two opposite rotation directions depending on the port into which the hydraulic fluid is fed, and a hydraulic drive system with a hydraulic circuit to control the hydraulic fluid through the first ports and second ports of the hydraulic motors, wherein the hydraulic drive system comprises a powered hydraulic fluid source to provide hydraulic fluid under pressure, a first hydraulic accumulator assembly to store and bias hydraulic fluid, a first valve assembly in a hydraulic fluid connection between the hydraulic fluid source and the ports of the hydraulic motors, a second valve assembly in a hydraulic fluid connection between the first

- valve assembly and the first port of the second hydraulic motor, and a third valve assembly in a hydraulic fluid connection between the first accumulator assembly and the first port of the second hydraulic motor, wherein the hydraulic drive system is able to switch between a hoisting mode and a heave compensation mode by means of the second valve assembly and the third valve assembly, wherein in the hoisting mode the hydraulic fluid from the first valve assembly is fed parallel into both first ports of the hydraulic motors or parallel into both second ports of the hydraulic motors to drive the rotation of the winch in one of the opposite rotation directions, and wherein in the heave compensation mode the hydraulic fluid from the first valve assembly is fed into the first port of the first hydraulic motor or into the second port of the hydraulic motor to drive the rotation of the winch in one of the rotation directions, and the first hydraulic accumulator assembly biases the hydraulic fluid to the first port of the second hydraulic motor.
2. Vessel according to claim 1, wherein the first hydraulic motor is a variable displacement hydraulic motor that can change between a high fluid displacement mode, in which a first torque is delivered using a first amount of hydraulic fluid per rotation, and a low fluid displacement mode in which a lower second torque is delivered using a lower second amount of hydraulic fluid per rotation, wherein in the hoisting mode the first hydraulic motor is in the high displacement mode and wherein in the heave compensation mode the first hydraulic motor is in the low displacement mode, wherein the first hydraulic motor is preferably a dual displacement hydraulic motor that can switch between the high displacement mode and the low displacement mode.
 3. Vessel according to claim 2, wherein the first hydraulic motor is a radial piston hydraulic motor in which the number of active radial pistons is adjustable.
 4. Vessel according to any one of the preceding claims, wherein the second hydraulic motor is a radial piston hydraulic motor.
 5. Vessel according to claims 2 and 4, wherein the second hydraulic motor delivers the same first torque using the same first amount of hydraulic fluid per rotation as the first hydraulic motor in its high fluid displacement mode.
 6. Vessel according to any one of the preceding claims, wherein the hydraulic drive system comprises a fourth valve assembly between the hydraulic fluid source and the first hydraulic accumulator assembly to fill, refill or bias the first hydraulic accumulator assembly.
 7. Vessel according to any one of the preceding claims, wherein the hydraulic drive system comprises a second hydraulic accumulator assembly to store and bias hydraulic fluid, a fifth valve assembly in a hydraulic fluid connection between the first valve assembly and the second port of the second hydraulic motor, and a sixth valve assembly between the second hydraulic accumulator assembly and the second port of the second hydraulic motor, wherein the second hydraulic accumulator assembly biases the hydraulic fluid to the second port of the second hydraulic motor, wherein the hydraulic drive system preferably comprises a seventh valve assembly between the hydraulic fluid source and the second hydraulic accumulator assembly to fill, refill or bias the second hydraulic accumulator assembly.
 8. Vessel according to claim 7, wherein the pressure of the hydraulic fluid in the biased first hydraulic accumulator assembly is higher than the pressure of the hydraulic fluid in the biased second hydraulic accumulator assembly.
 9. Vessel according to any one of the preceding claims, wherein the first hydraulic accumulator assembly, and the second accumulator assembly when present, is a free piston accumulator comprising a cylinder with a port for passage of the hydraulic fluid and a piston that is slidable through the cylinder to bias the hydraulic fluid to the port, wherein the free piston accumulator preferably comprises a biased or pressurized volume of gas that is separated from the hydraulic fluid by the piston, wherein the hydraulic drive system preferably comprises a displacement sensor to determine the position of the piston in its sliding direction.
 10. Vessel according to any one of the preceding claims, wherein the first valve assembly comprises a bidirectional, proportional valve.
 11. Vessel according to any one of the preceding claims, wherein the heave compensation system comprises a brake for the drum to be activated during switching between the hoisting mode and the heave compensation mode.
 12. Vessel according to any one of the preceding claims, wherein the hydraulic drive system comprises a controller that is operatively connected with the first valve assembly to control the first valve assembly in response to heave, roll and pitch parameters of the hull with respect to a reference height for the load.
 13. Vessel according to any one of the preceding claims, configured as a water injection dredging vessel, wherein the load is a jet bar that is provided with a series of water jet nozzles, wherein the jet bar is un-

der water suspended from the hull.

14. Method for suspending a load from a vessel, wherein the vessel comprises a hull and a heave compensation system for the load that is suspended from the hull of the vessel, wherein the heave compensation system comprises a winch with a drum on the hull and a hoisting cable around the drum for hoisting and suspending the load, a first hydraulic motor and a second hydraulic motor that are operatively connected to the drum to rotate synchronously with the drum, and a hydraulic drive system with a hydraulic circuit to control the hydraulic fluid through the hydraulic motors, wherein the hydraulic drive system comprises a powered hydraulic fluid source to provide hydraulic fluid under pressure and a first hydraulic accumulator assembly to store and bias hydraulic fluid, wherein the method comprises switching the hydraulic drive between a hoisting mode and a heave compensation mode during hoisting the load, wherein in the hoisting mode the hydraulic fluid from the hydraulic fluid source is fed parallel through both the first hydraulic motor and the second hydraulic motor to drive the rotation of the winch in one of the opposite rotation directions, and wherein in the heave compensation mode the hydraulic fluid from the hydraulic fluid source is fed through the first hydraulic motor while the first hydraulic accumulator assembly is in fluid connection with the second hydraulic motor and delivers hydraulic fluid to or receives hydraulic fluid from the second hydraulic motor depending on the rotation direction of the first hydraulic motor.
15. Method according to claim 14, wherein the hydraulic drive system is in the hoisting mode when the load is above the water line and wherein the hydraulic drive is switched between the hoisting mode and the heave compensation mode when the load is submerged in the water.

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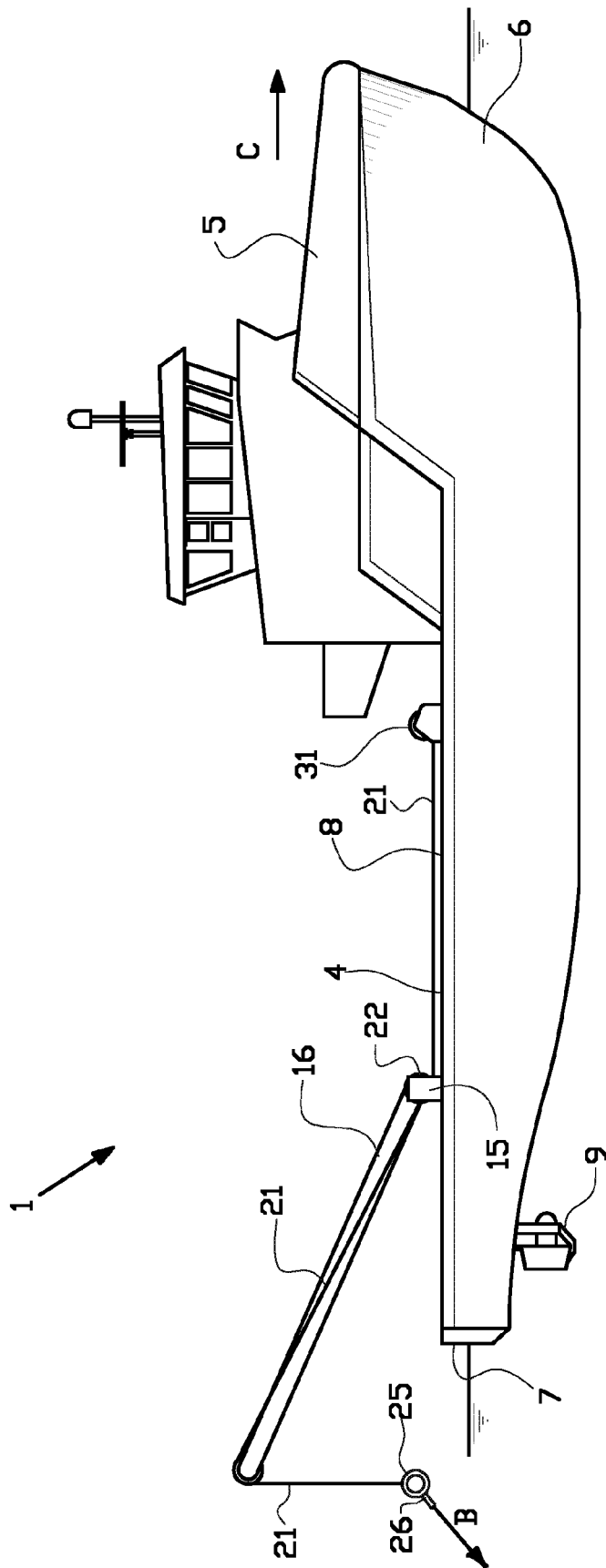


FIG 1A

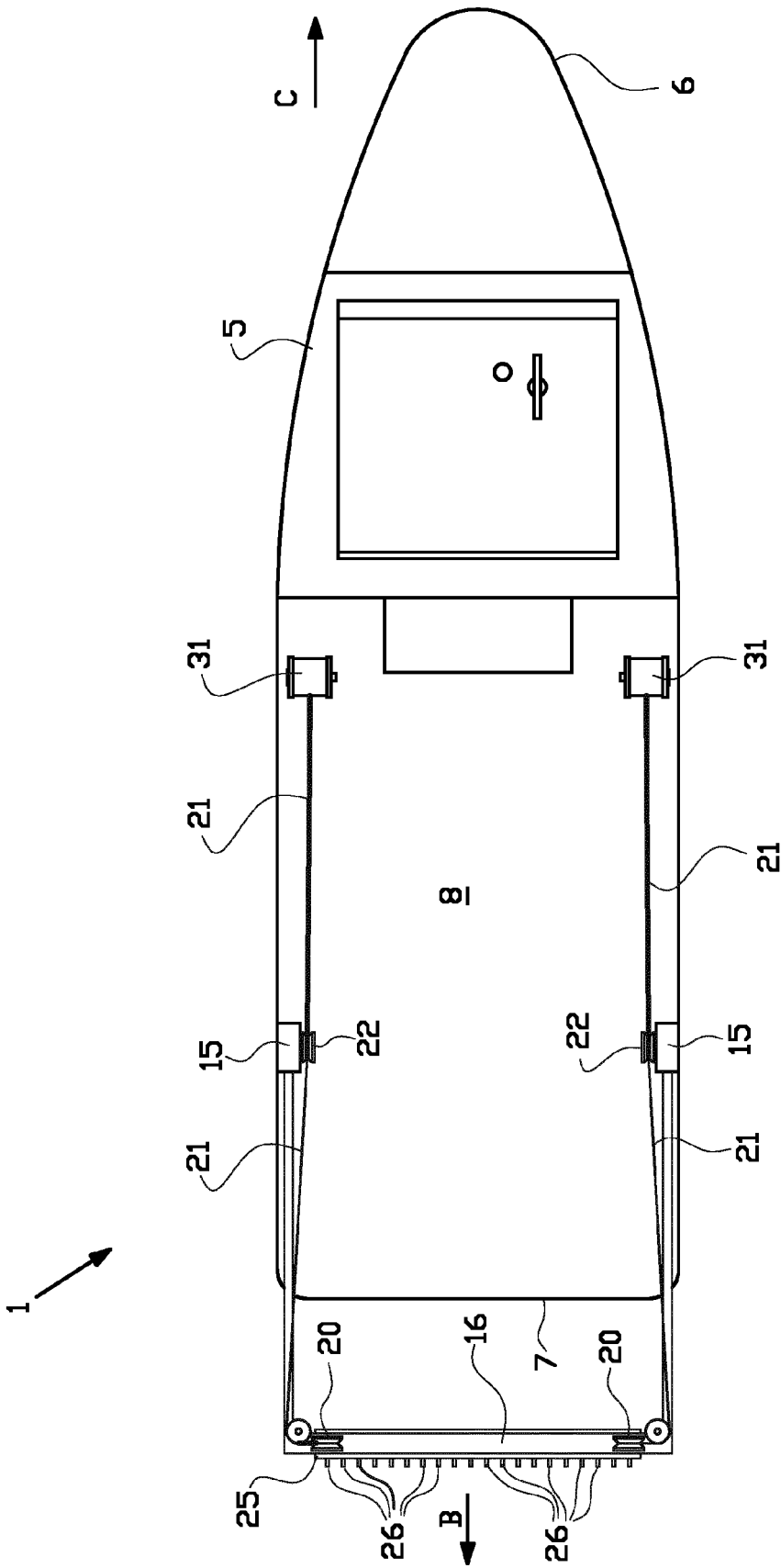


FIG 1B

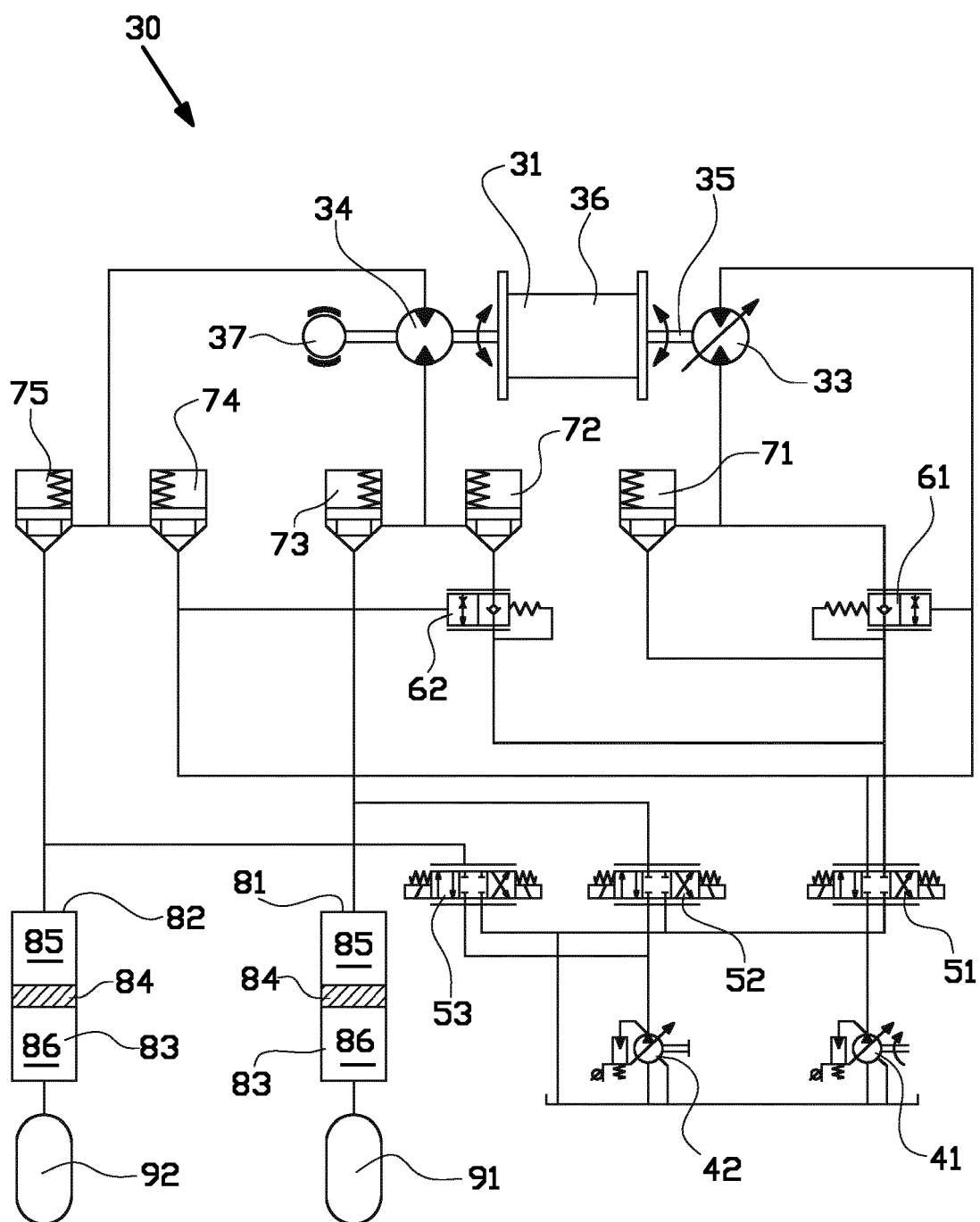


FIG. 2

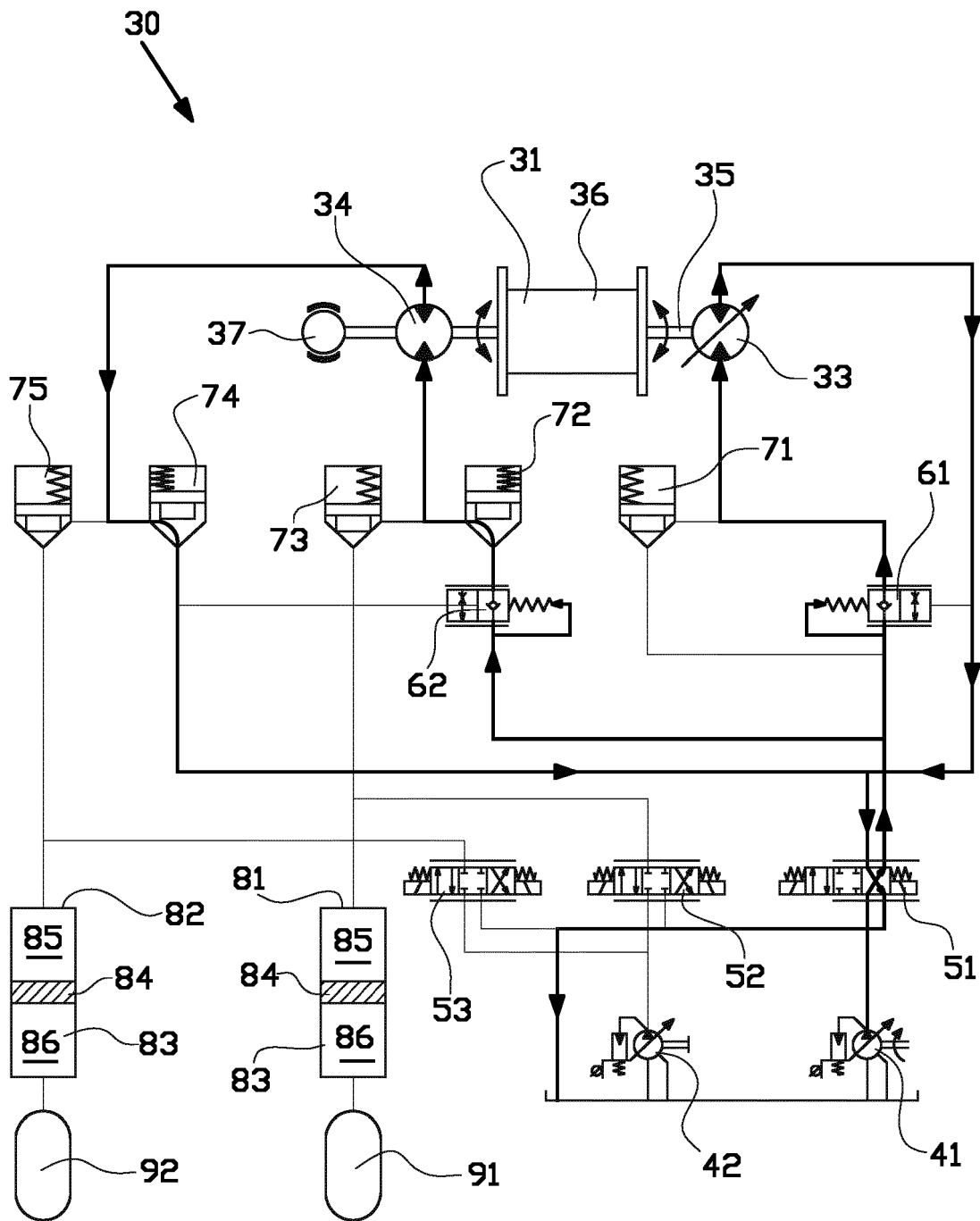


FIG. 3A

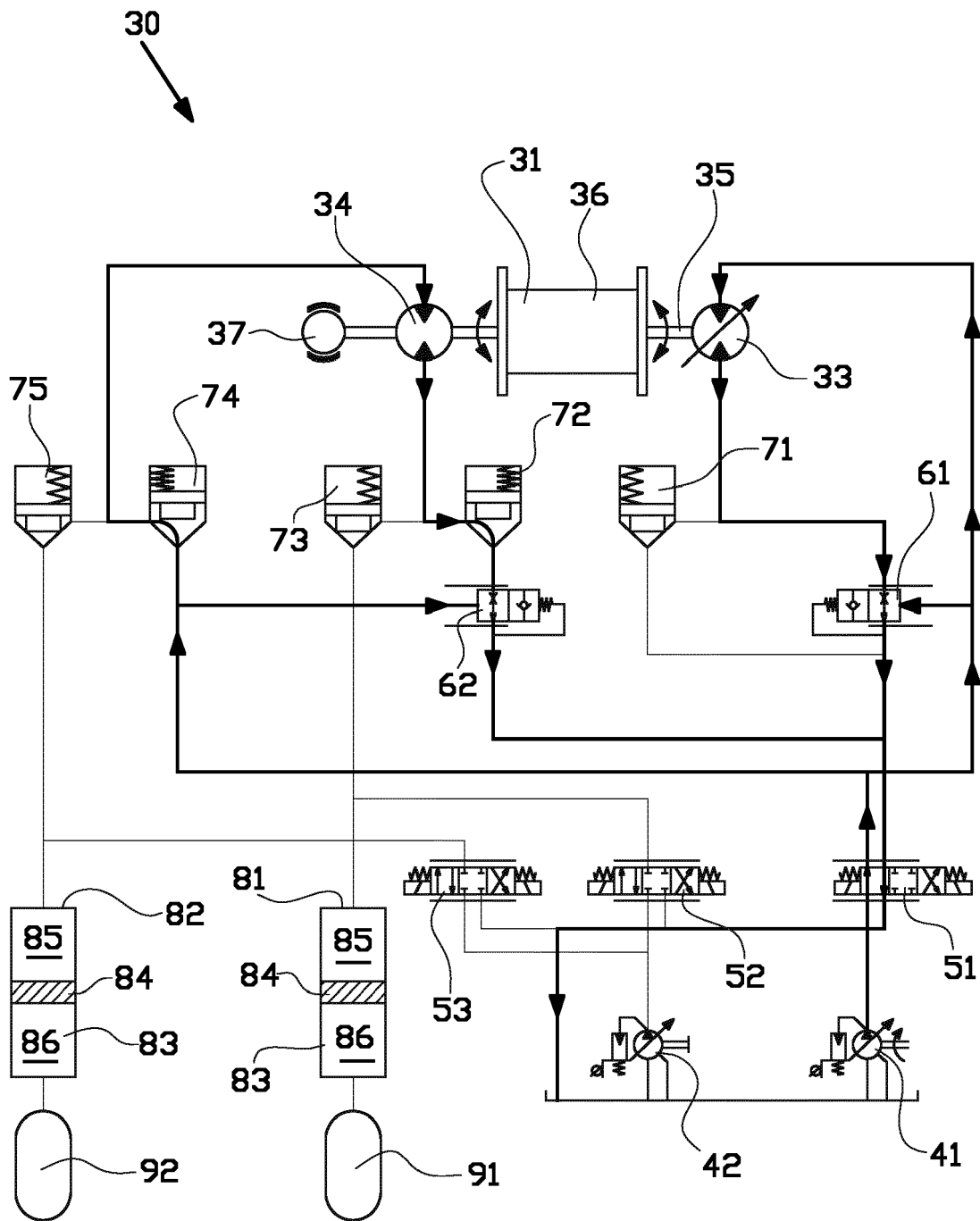


FIG. 3B

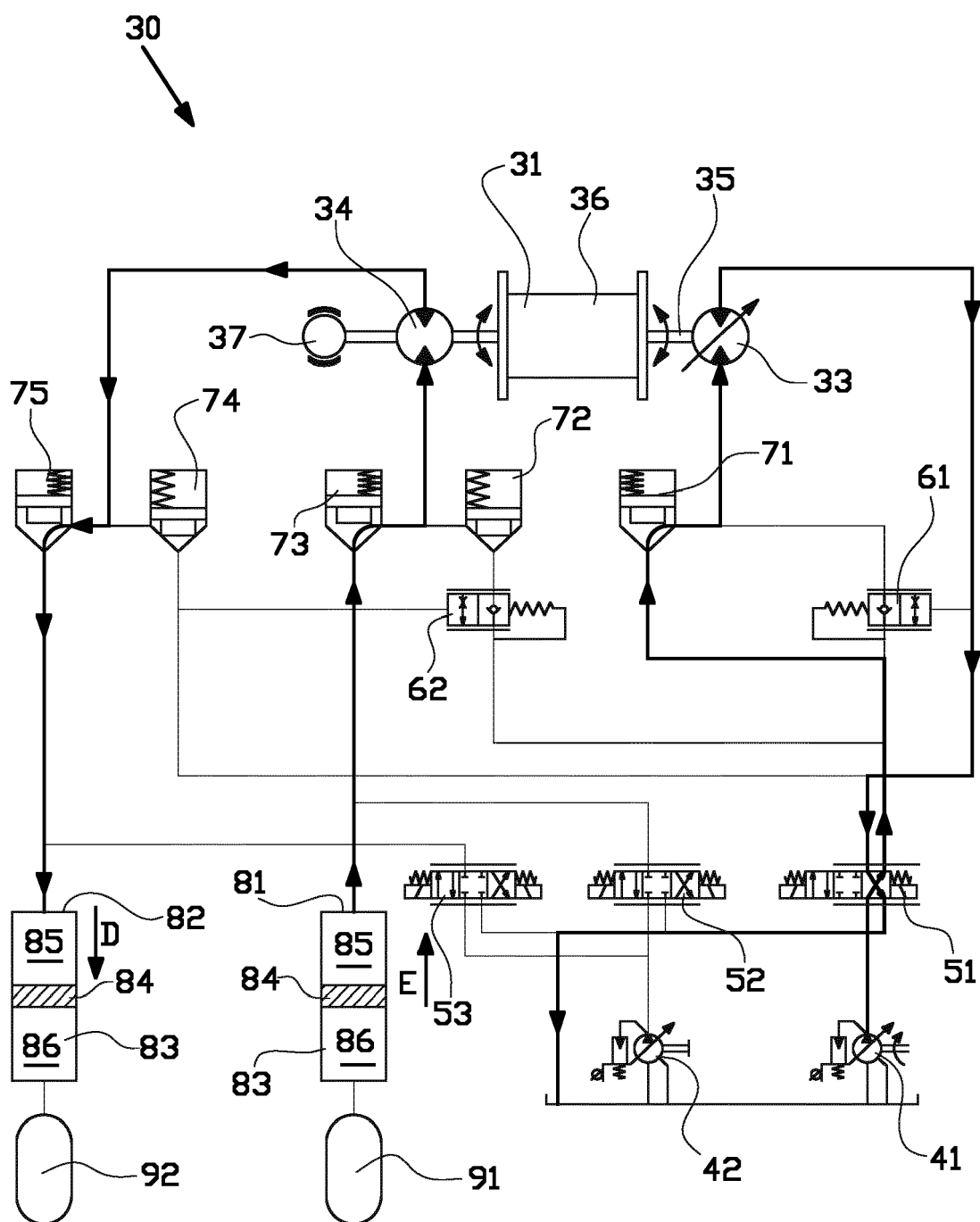


FIG. 4A

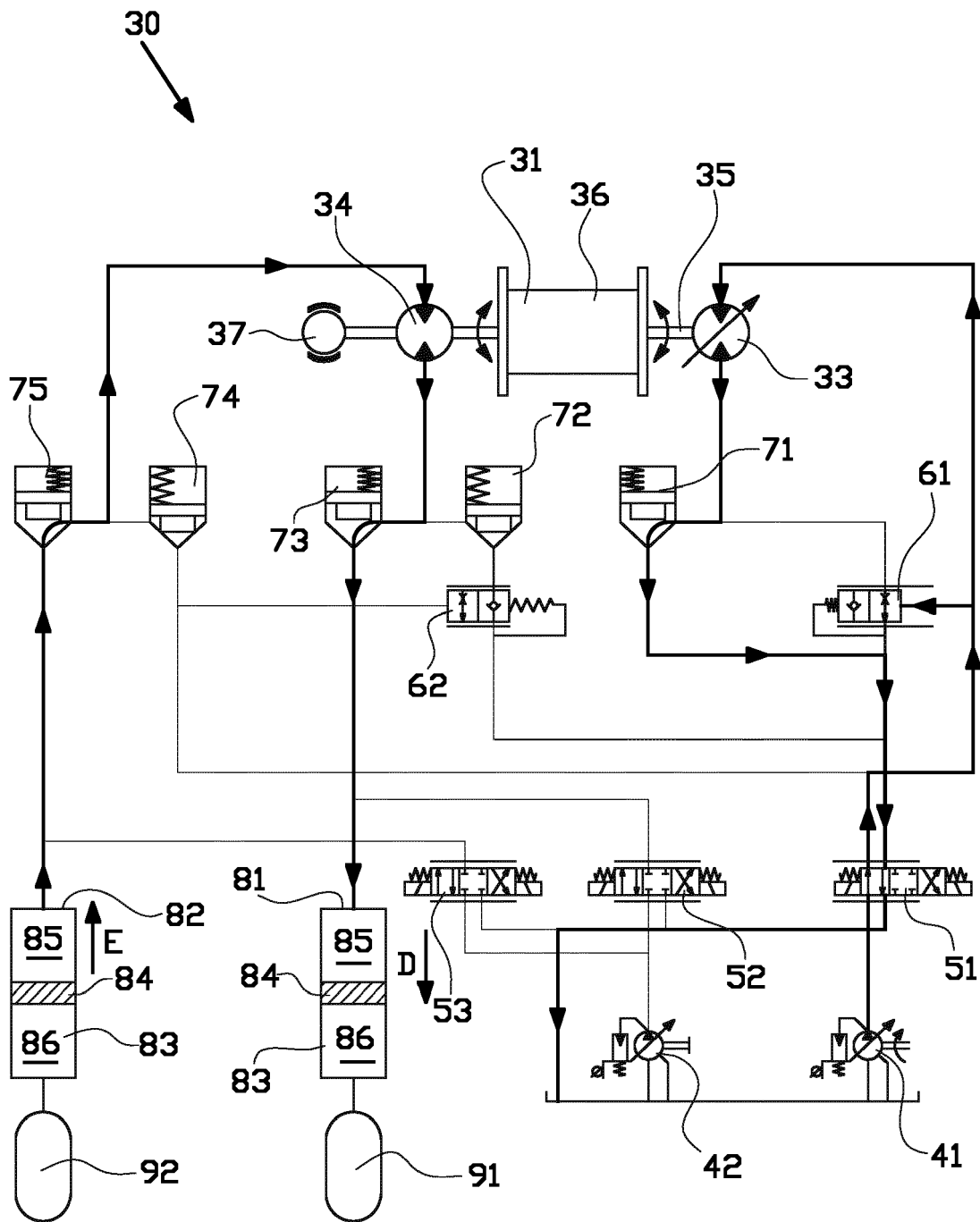


FIG. 4B



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Application Number
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Place of search The Hague		Date of completion of the search 29 March 2016	Examiner Verheul, Omiros
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