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(54) A MARINE PROPULSION SYSTEM

(57) The disclosure relates to a marine propulsion system for a marine vessel, comprising an engine, a propeller unit comprising one or more propellers, a transmission arranged between the engine and the propeller unit, a hydraulic clutch arrangement, the clutch arrangement is configured to control a power transfer between the engine and the propeller unit, and a control unit, wherein the clutch arrangement comprises a clutch plate and a clutch piston, the clutch piston is configured to be actuated by a first hydraulic area and/or a second hy-

draulic area, and wherein the first hydraulic area is pressurized by an electrically controlled proportional pressure valve and the second hydraulic area is pressurized by an electrically controlled on/off valve, the control unit is operatively connected with the electrically controlled proportional pressure valve and the electrically controlled on/off valve, and is configured to control the electrically controlled proportional pressure valve and the electrically controlled on/off valve.

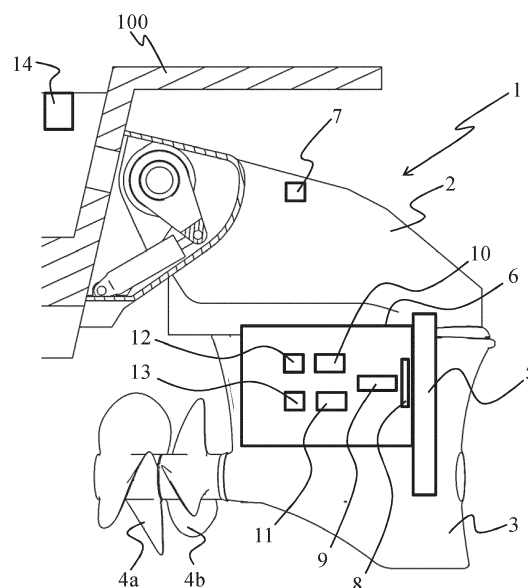


FIG. 1

Description

TECHNICAL FIELD

[0001] The disclosure relates generally to a propulsion system. In particular aspects, the disclosure relates to a marine propulsion system for a marine vessel. The disclosure can be applied to marine vessels, such as water crafts, motorboats, work boats, sport vessels, boats, ships, among other vessel types. Although the disclosure may be described with respect to a particular marine vessel, the disclosure is not restricted to any particular marine vessel.

BACKGROUND

[0002] Marine propulsion systems for a marine vessel often have an engine providing torque to one or more propellers driving the marine vessel with different speeds. In addition some kind of transmission and a clutch are arranged for transferring power between the engine and the propellers. The main design criteria of the clutch are to be able to transfer maximum driveline torque without slippage of the clutch.

[0003] However, most of the time driving the marine vessel it is not in full speed which may have the consequence that during lower speed the transferred torque is only a fraction of maximum clutch capability. This may be the consequence that the control of the transfer of torque at lower speeds is performing poorly.

SUMMARY

[0004] According to a first aspect of the disclosure, a marine propulsion system for a marine vessel, comprising

- an engine,
- a propeller unit comprising one or more propellers,
- a transmission arranged between the motor and the propeller unit,
- a hydraulic clutch arrangement, the clutch arrangement is configured to control a power transfer between the engine and the propeller unit,
- a control unit,

wherein the clutch arrangement comprises a clutch plate and a clutch piston, the clutch piston is configured to be actuated by a first hydraulic area and/or a second hydraulic area, and wherein the first hydraulic area is pressurized by an electrically controlled proportional pressure valve and the second hydraulic area is pressurized by an electrically controlled on/off valve, the control unit is operatively connected with the electrically controlled proportional pressure valve and the electrically controlled on/off valve, and is configured to control the electrically controlled proportional pressure valve and the electrically controlled on/off valve. The first aspect of

the disclosure may seek to provide improved control from low speed to full speed of the marine vessel and thereby to improve slip control performance. A technical benefit may include incorporating a first hydraulic area and a second hydraulic area which are configured to pressurize the clutch piston individually or together whereby the compressive forces on the clutch plate may be reduced which again increases resolution in the control pressure. Furthermore, by incorporating an electrically controlled proportional pressure valve for controlling the pressure in the first hydraulic area and an electrically controlled on/off valve for controlling the pressure in the second hydraulic area a higher level of redundancy is obtained. In case of failure to of the electrically controlled proportional valve, the electrically controlled on/off valves can provide gear engagement independently of the status of the proportional valve. Furthermore, a higher level of reliability resulting in possible fuel savings is obtained. The electrical control of the on/off valve makes it possible to engage transmission or gear based on a degree of clutch slippage. Hence, the speed difference over the clutch arrangement may be used to decide if the electrically controlled on/off valve shall be opened or closed.

[0005] Optionally in some examples, including in at least one preferred example, the control unit is configured to control the electrically controlled proportional pressure valve independently of the electrically controlled on/off valve, or the control unit is configured to control the electrically controlled on/off valve independently of the electrically controlled proportional pressure valve. A technical benefit may include that a higher degree of control is obtained for the propulsion system over a larger range of different speed of the marine vessel by, for instance only pressurizing the first hydraulic area during lower speed. Hereby, the compressive force on the clutch plate may be reduced which increases resolution in a control pressure. Improved resolution of control signal improves slip control performance for the propulsion system.

[0006] Optionally in some examples, including in at least one preferred example, further comprising an input unit for adjusting a speed of the marine vessel in a forward direction and/or in a reverse direction. A technical benefit may include that an operator may provide different input for maneuvering the marine vessel.

[0007] Optionally in some examples, including in at least one preferred example, the control unit is operatively connected with the input unit. A technical benefit may include that the control unit controls the propulsion system in accordance to the input so that no slippage of the clutch is experience independent of which speed is provided.

[0008] Optionally in some examples, including in at least one preferred example, the first hydraulic area is substantially equal in size to the second hydraulic area, the first hydraulic area being smaller than the second hydraulic area, or the first hydraulic area being larger than the second hydraulic area. A technical benefit may in-

clude that the clutch arrangement may be further optimized for providing a higher degree of control of the clutch arrangement and thereby the propulsion system.

[0009] Optionally in some examples, including in at least one preferred example, the control unit comprises a current controller, the current controller is configured to closed-loop current control the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve. A technical benefit may include that the control of the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve is increased.

[0010] Optionally in some examples, including in at least one preferred example, further comprising one or more pressure sensor(s) being configured to measure an actuation pressure of the clutch arrangement. A technical benefit may include that the actuation pressure of the piston may be detected and measured.

[0011] Optionally in some examples, including in at least one preferred example, the control unit comprises an actuation pressure controller. A technical benefit may include that the control of the actuation pressure to the piston is increased.

[0012] Optionally in some examples, including in at least one preferred example, the one or more pressure sensors are operatively connected with the actuation pressure controller. A technical benefit may include that the control of the actuation pressure to the piston is increased.

[0013] Optionally in some examples, including in at least one preferred example, the pressure sensor(s) is/are configured to measure forward and/or reverse actuation pressure, the measured actuation pressure is used as feedback to the actuation pressure controller. A technical benefit may include that the control of the actuation pressure to the clutch piston is increased.

[0014] Optionally in some examples, including in at least one preferred example, the actuation pressure controller is configured to control the actuation pressure of the clutch arrangement by a closed-loop control. A technical benefit may include that the control of the actuation pressure to the piston is increased.

[0015] Optionally in some examples, including in at least one preferred example, the control unit further comprises a propeller speed controller. A technical benefit may include that control of the propeller speed is increased.

[0016] Optionally in some examples, including in at least one preferred example, further comprises an engine controller configured to control an engine speed so as to avoid region with slip-stick near full clutch engagement. A technical benefit may include that the engine is controlled in view of slip-stick of the clutch.

[0017] According to a second aspect of the disclosure, a marine vessel comprising a marine propulsion system as describe above. The second aspect of the disclosure may seek to provide improved control from low speed to full speed of the marine vessel and thereby to improve

slip control performance and thereby a higher degree of utilization of the marine propulsion system during all speed of the marine vessel. In addition, by the higher degree of utilization the propulsion system may use less consumption during the different speed and thereby being more sustainable.

[0018] According to a third aspect of the disclosure, method for controlling a marine propulsion system as described above, comprising

arranging a clutch arrangement comprising a clutch plate and a clutch piston, the clutch piston is configured to be actuated by a first hydraulic area and/or a second hydraulic area, pressurizing the first hydraulic area by an electrically controlled proportional pressure valve, pressurizing the second hydraulic area by an electrically controlled on/off valve, controlling the electrically controlled proportional pressure valve independently of the electrically controlled on/off valve or vice versa. The third aspect of the disclosure may seek to provide improved control from low speed to full speed of the marine vessel and thereby to improve slip control performance and thereby a higher degree of utilization of the marine propulsion system during all speed of the marine vessel. In addition, by the higher degree of utilization the propulsion system may use less consumption during the different speed and thereby being more sustainable.

[0019] The disclosed aspects, examples (including any preferred examples), and/or accompanying claims may be suitably combined with each other as would be apparent to anyone of ordinary skill in the art. Additional features and advantages are disclosed in the following description, claims, and drawings, and in part will be readily apparent therefrom to those skilled in the art or recognized by practicing the disclosure as described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Examples are described in more detail below with reference to the appended drawings.

FIG. 1 is an exemplary of a marine propulsion system according to an example.

FIG. 2 is an exemplary of a marine propulsion system according to another example.

FIG. 3 is an exemplary of a clutch arrangement according to an example.

FIG. 4 is an overview of a control unit according to an example.

FIG. 5 is an example of a marine vessel.

FIG. 6 is a schematic flowchart of an example of a method for controlling a propulsion system.

FIGS. 7-9 are schematic flow charts of the methods of controlling the different components of the propul-

sion system via the sub-controllers of the control unit.

DETAILED DESCRIPTION

[0021] The detailed description set forth below provides information and examples of the disclosed technology with sufficient detail to enable those skilled in the art to practice the disclosure.

[0022] Marine propulsion systems for a marine vessel with an engine providing torque to one or more propellers driving the marine vessel with different speeds, also have a transmission and a clutch for transferring power between the engine and the propellers. The main design criteria of the clutch are to be able to transfer maximum driveline torque without slippage of the clutch. Unintended clutch slippage is a faulty condition in which there is not enough friction in the clutch whereby the clutch may fail to adequately engage or disengage the transmission. The consequence may be that propulsion system in these circumstances not are transferring the intended torque to drive the marine vessel.

[0023] However, most of the time driving the marine vessel it is not in full speed which may have the consequence that during lower speed the transferred torque is only a fraction of maximum clutch capability. This may have the consequence that the control of the transfer of torque at lower speeds is performing poorly. However, a controlled slippage may be desirable during very low speed of the marine vessel.

[0024] According to the present disclosure, the clutch piston has been divided into a first hydraulic area and a second hydraulic area that may be pressurized individually. The first hydraulic area is pressurized via an electrically controlled proportional pressure valve. By having separated the hydraulic area into two smaller hydraulic areas and by being able to pressurize, for instance only the first hydraulic area, the compressive force on the clutch plate may be reduced which increases resolution in a control pressure. Improved resolution of control signal improves slip control performance for the propulsion system. In case of a low speed the first hydraulic area is utilized when slippage shall be controlled at low load.

[0025] The second hydraulic area may be pressurized independently of the first hydraulic area by opening an electrically controlled on/off valve. When the entire piston is pressurized by both the first hydraulic area and the second hydraulic area by opening both the electrically controlled proportional pressure valve and the electrically controlled on/off valve fully, the clutch can transfer full engine power without slippage.

[0026] Furthermore, by the electrically controlled on/off valve pressurizing the second hydraulic area it may be possible to engage the transmission based on a degree of clutch slippage. Hereby the speed difference over the clutch may be used to decide if the electrically controlled on/off valve shall be opened or closed. This is an advantage compared to other solutions.

[0027] By controlling the electrically controlled propor-

tional pressure valve and/or the electrically controlled on/off valve based on the clutch slippage, it is possible to limit the risk for premature transmission engagement causing a sudden load increase for the engine. Thereby it is also possible to limit the risk that the engine is stalling during gearshift and/or cause damage or wear to the transmission.

[0028] At the same time gear engagement is not affected by changing load conditions like wind, current, and/or changes in propeller size, which also provide an advantage compared to prior solutions.

[0029] FIG. 1 is an exemplary marine propulsion system 1 according to an example. The marine propulsion system 1 is configured to be comprised on a marine vessel 100. The marine propulsion system 1 comprises an engine 2. In the example of FIG. 1, the engine 2 is an internal combustion engine. The combustion engine may be any type of internal combustion engine driven by e.g. diesel, gasoline, natural gas, hydrogen or any other combustible fuel. The marine propulsion system may also comprise a parallel hybrid driveline, so that one engine 2 and one or more electric motor(s) are sharing the load. In addition, the engine 2 is provided outside the marine vessel 100 as an outboard engine 2. In addition, the engine is provided outside the marine vessel 100 as an outboard engine 2. In another example, the engine may be arranged on the marine vessel 100 as an inboard engine. Furthermore, the propulsion system 1 may comprise one engine or a plurality of engines.

[0030] The propulsion system 1 also comprises a propeller unit 3 comprising one or more propellers 4a, 4b. In the example the propeller unit 3 has a first propeller 4a and a second propeller 4b. In other examples, the propeller unit may comprise one propeller or a plurality of propellers. If two or more propellers are arranged they may be arranged as counter-rotating propellers for instance. The propulsion system 1 comprises a transmission 5 arranged between the engine 2 and the propeller unit 3 to ensure that the intended rotation is provided to the propeller unit 3. The transmission 5 may comprise one or more gear(s). In addition, a hydraulic clutch arrangement 6 is arranged. The clutch arrangement 6 is configured to control a power transfer between the engine 2 and the propeller unit 3. The propulsion system 1 also comprises a control unit 7. In the example, the control unit 7 is arranged in the relation to the engine 2, however, in other examples it may be arranged on-board the marine vessel 100 or in relation to other components of the propulsion system 1.

[0031] Furthermore, the clutch arrangement 6 comprises a clutch plate 8 and a clutch piston 9, the clutch piston 9 is configured to be actuated by a first hydraulic area 10 and/or a second hydraulic area 11. According to the disclosure, the first hydraulic area 10 is pressurized by an electrically controlled proportional pressure valve 12 and the second hydraulic area 11 is pressurized by an electrically controlled on/off valve 13, the control unit 7 is operatively connected with the electrically controlled

proportional pressure valve **12** and the electrically controlled on/off valve **13**, and is configured to control the electrically controlled proportional pressure valve **12** and the electrically controlled on/off valve **13**.

[0032] Dividing the hydraulic area into two smaller sections and selectively pressurizing only the first hydraulic area **10** can effectively reduce the compressive force on the clutch plate. This heightened precision in control pressure ultimately enhances the slip control performance for the propulsion system **1**. In low-speed scenarios where slip control is required at low loads, the first hydraulic area **10** may be utilized.

[0033] The independent pressurization of the second hydraulic area **11** can be achieved by activating an electrically controlled on/off valve **13**. Once the entire piston is simultaneously pressurized by both hydraulic areas **10**, **11**, the electrically controlled proportional pressure valve **12** and the electrically controlled on/off valve **13** may be fully opened to facilitate seamless transfer of full engine power via the clutch, without any slippage.

[0034] The propulsion system **1** further comprising an input unit **14** for adjusting a speed of the marine vessel **100** in a forward direction and/or in a reverse direction of the marine vessel. The control unit **7** is operatively connected with the input unit **14** so that the control unit **7** may control the propulsion system **1** in accordance with the input so that the desired thrust is always provided. The input unit **14** is in the example arranged on the marine vessel **100**.

[0035] In **FIG. 2**, an exemplary of a marine propulsion system **1** according to another example is shown. The propulsion system **1** has the engine **2**, the propeller unit **3** with one or more propellers. Furthermore, the transmission **5** is arranged between the engine **2** and the propeller unit **3** to ensure that the intended rotation is provided to the propeller unit **3**.

[0036] The hydraulic clutch arrangement **6** is configured to control the power transfer between the engine **2** and the propeller unit **3**. The clutch arrangement **6** comprises the clutch plate **8** and the clutch piston **9**, the clutch piston **9** is configured to be actuated by the first hydraulic area **10** and/or the second hydraulic area **11**. According to the disclosure, the first hydraulic area **10** is pressurized by the electrically controlled proportional pressure valve **12** and the second hydraulic area **11** is pressurized by the electrically controlled on/off valve **13**, and the control unit **7** is operatively connected with the electrically controlled proportional pressure valve **12** and the electrically controlled on/off valve **13**.

[0037] The control unit **7** may be configured to control the electrically controlled proportional pressure valve **12** independently of the electrically controlled on/off valve **13**, or the control unit **7** is configured to control the electrically controlled on/off valve **13** independently of the electrically controlled proportional pressure valve **12**.

[0038] In the example in **FIG. 2**, the first hydraulic area **10** is substantially equal in size to the second hydraulic area **12**.

[0039] **FIG. 3** shows an example of the clutch arrangement **6**. The clutch arrangement **6** comprises the clutch plate **8**. In the example one clutch plate **8** is arranged. In other examples two or more clutch plates may be arranged in the clutch arrangement **6**. The clutch plate **8** is activated by the clutch piston **9**. According to the example, the clutch piston **9** is configured to be actuated by the first hydraulic area **10** and/or the second hydraulic area **11**. In the example of **FIG. 3**, the first hydraulic area **10** is smaller than the second hydraulic area **11**. In another example, the first hydraulic area may be larger than the second hydraulic area. The first hydraulic area **10** is pressurized by the electrically controlled proportional pressure valve **12** and the second hydraulic area **11** is pressurized by the electrically controlled on/off valve **13**, and the control unit **7** is operatively connected with the electrically controlled proportional pressure valve **12** and the electrically controlled on/off valve **13**. In the example, a pump **15** is delivering a hydraulic fluid to the first hydraulic area **10** via the electrically controlled proportional pressure valve **12**, and the second hydraulic area **11** via the electrically controlled on/off valve **13**, respectively. A hydraulic tank **16** is arranged in fluid communication with the pump **15**. In addition, the input unit **14** is operatively connected with the control unit **7**.

[0040] Furthermore, a pressure sensor **17** is configured to measure an actuation pressure of the clutch arrangement **6**. In the example, the pressure sensor **17** is arranged in connection with the clutch piston **9**. In other examples, the pressure sensor **17** may be arranged in connection with other components of the clutch arrangement **6** for measuring and/or detecting the actuation pressure of the clutch arrangement. Also, a plurality of pressure sensors may be arranged for measuring and/or detecting the actuation pressure at different positions and at different components of the clutch arrangement **6**.

[0041] Moreover, a shunt resistor **18** may be arranged in connection with the electrically controlled proportional pressure valve **12** and/or the electrically controlled on/off valve **13**, the shunt resistor **18** is configured to measure a control current with a mA accuracy. In the example shown in **FIG. 3** both the electrically controlled proportional pressure valve **12** and the electrically controlled on/off valve **13** have a shunt resistor **18**.

[0042] In **FIG. 4**, an overview of a control unit **7** according to an example is shown. In the example, the control unit **7** comprises different sub-controllers which may control different components of the propulsion system **1** independently or in common.

[0043] The control unit **7** may comprise a propeller speed controller **21**, the propeller speed controller **21** is configured to control the propeller speed on basis of the propeller speed references **200**. The input unit **14** is configured to receive an input signal indicative of a propeller speed and to issue a propeller speed reference **200** based on the input signal. The actual propeller speed is detected at point **210** and is compared with the propeller

speed references **200** in the propeller speed controller **21**. If a difference between the propeller speed reference **200** and the detected propeller speed at **210** is observed the propeller speed controller **21** will control the propeller speed accordingly so that the actual propeller speed at **210** will correspond to the propeller speed reference **200**. This may be provided with a closed-loop control. The propeller speed controller **21** comprises a feed-forward speed part **30**. Based on speed reference magnitude, the feed-forward speed part **30** roughly calculate the pressure needed to reach intended rpm, under nominal load conditions. The feed-back speed part of the propeller speed controller is intended to compensate for differences from nominal load conditions, due to current, fouling or dents on propeller(s), varying friction in transmission, etc.

[0044] The control unit **7** may also comprise an actuation pressure controller **20**, the actuation pressure controller **20** is configured to control the actuation pressure on basis of the pressure reference **201** and/or the measured actuation pressure. The one or more pressure sensors **17** are operatively connected with the actuation pressure controller **20**. The pressure sensor(s) **17** is/are configured to measure forward and/or reverse actuation pressure at point **211**, the measured actuation pressure **211** is used as feedback to the actuation pressure controller **20**. The actuation pressure controller **20** is configured to control the actuation pressure of the clutch arrangement **6** by a closed-loop control. The actual actuation pressure is detected at point **211** and is compared with the pressure reference **201** in the actuation propeller controller **20**. If a difference between the pressure reference **201** and the measured actuation pressure **211** is observed, the actuation pressure controller **20** will control the actuation pressure accordingly so that the actual actuation pressure at **211** will correspond to the pressure reference **201**. The actuation pressure controller **20** comprises a feed-forward pressure part **31**. Based on pressure reference magnitude, the feed-forward pressure part **31** may calculate the current that shall be applied to the electrically controlled proportional pressure valve **12** and/or the electrically controlled on/off valve **13**, to obtain the intended pressure. These calculations may be based on stated current to pressure characteristics of the electrically controlled proportional pressure valve **12** and the electrically controlled on/off valve **13**. The feed-back part of the actuation pressure controller is intended to compensate for differences from nominal valve characteristics due to variations in oil temperature, valve hysteresis, etc.

[0045] The control unit **7** may also comprise a current controller **19**, the current controller **19** is configured to closed-loop current control the electrically controlled proportional pressure valve **12** and/or the electrically controlled on/off valve **13** on basis of the current reference **202**. The shunt resistors **18** may be arranged in connection with the electrically controlled proportional pressure valve **12** and/or the electrically controlled on/off

valve **13**, the shunt resistor **18** is configured to measure a control current at point **212** with a mA accuracy. The current controller **19** is configured to closed-loop current control the electrically controlled proportional pressure valve **12** and/or the electrically controlled on/off valve **13** on basis of the measured control current **212** and/or the current reference **202**. The actual control current is detected at point **212** and is compared with the current reference **202** in the current controller **19**. If a difference between the current reference **202** and the measured control current **212** is observed the current controller **19** will control the current accordingly so that the actual current at **212** will correspond to the current reference **202**. As mentioned previously, the current controller **19** compensates for temperature variations in valve coils, and implements dithering to minimize hysteresis caused by stiction of a valve body.

[0046] The current controller **19** may have a control frequency of more than 500Hz, preferably more than 1kHz, more preferably more than 2kHz.

[0047] Moreover, the current controller **19** may be configured to implement dithering of current 200Hz/±10mA to minimize hysteresis of the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve.

[0048] The propulsion system **1** may further comprise an engine controller **40**, the engine controller **40** is configured to control an engine speed on basis of propeller speed reference **200**. The engine controller **40** is configured to increase engine speed near full clutch engagement so that the clutch engagement is kept below where slip-stick behavior of the clutch disc may occur. Furthermore, the engine controller **40** may be configured to reset engine speed to idle speed when the clutch is set for full engagement. The engine controller is a feed forward controller.

[0049] In addition, the engine controller **40** may be operatively connected with the input unit **14**. Also, the control unit **7** and the engine controller **40** may be operatively connected.

[0050] The current controller **19**, the actuation pressure controller **20**, the propeller speed controller **21** and/or the engine controller **40** may be operatively connected.

[0051] By combining the current controller **19**, the actuation pressure controller **20** and the propeller speed controller **21** in the control unit **7**, an increase of the robustness of slip control is provided. The controllers together provides a very robust propeller low-speed control, with built in ability to protect the engine from overload and unintended stalling.

[0052] For example, during gearshifts the propeller speed controller may not be utilized. In this particular case the desired pressure (controller input) is ramped from low to high level, to achieve smooth acceleration of the propeller into full engagement, when the electrically controlled on/off valve is engaged.

[0053] Furthermore, in a continuous "low propeller

speed control" mode, both the propeller speed controller **21**, the actuation pressure controller **20** and the current controller **19** are used for controlling the different components of the system **1**. Moreover, in a gear engagement mode, the actuation pressure controller **20** and the current controller **19** are used for controlling the different components of the system **1**, but the propeller speed controller **21** and engine speed controller **40** may be disregarded the control situation.

[0054] In **FIG. 5**, a marine vessel **100** is shown. The marine vessel **100** comprises the propulsion system **1** as described above. In the example shown in **FIG. 5**, the propeller unit **3** is configured to pull the marine vessel **100**. In another example the propeller unit may be configured to push the marine vessel. The engine **2** is an internal combustion engine arranged onboard the marine vessel **100**.

[0055] **FIG. 6** shows a schematic flow chart of the method of controlling a marine propulsion system **1** as described above.

[0056] In step **500**, a control unit is being provided and is operatively connected with the propeller unit, the transmission and the clutch arrangement. In step **501**, an input signal is received from the input unit. In step **502**, a propeller speed reference is issued based on the input signal in step **501**. In step **503**, the propulsion system is controlled on basis on the propeller speed references **200** during varying operations and/or speed of the marine propulsion system **1**.

[0057] **FIGS. 7-9** show schematic flow charts of the methods of controlling the different components of the propulsion system via the sub-controllers of the control unit **7**.

[0058] In **FIG. 7**, the schematic flow chart of the propeller speed controller is shown. In step **600** the propeller speed reference is provided. In step **601**, the actual propeller speed is detected or measured. In step **602**, the actual propeller speed is compared with the propeller speed reference. If the actual propeller speed is substantial equal to the propeller speed reference it is continued to step **603**. If the actual propeller speed is different from the propeller speed reference it is continued to step **604** wherein the propeller speed is either increased or decreased in view of the propeller speed reference. Based on speed reference magnitude, the feed-forward speed part roughly calculate pressure needed to reach intended rpm, under nominal load conditions. The feed-forward speed part in step **600** feeds the calculated pressure to step **700**. The feed-back part is intended to compensate for differences from nominal load conditions, due to current, fouling or dents on propeller(s), varying friction of transmission, etc.

[0059] In **FIG. 8**, the schematic flow chart of the actuation pressure controller is shown. In step **700**, the actuation pressure reference is provided, for instance as described above. In step **701**, the actual actuation pressure is detected or measured. In step **702**, the actual actuation pressure is compared with the actuation pressure refer-

ence. If the actual actuation pressure is substantial equal to the actuation pressure reference it is continued to step **703**. If the actual actuation pressure is different from the actuation pressure reference it is continued to step **704** wherein the actuation pressure is either increased or decreased in view of the actuation pressure reference. Based on pressure reference magnitude, the feed-forward pressure part calculate the current that shall be applied to the pressure valves to get the intended pressure. Calculation is based on stated current to pressure characteristics of valve. The feed-forward pressure part in step **700** feeds the calculated pressure to step **800**. The feed-back part is intended to compensate for differences from nominal valve characteristics due to variations in oil temperature, valve hysteresis, etc.

[0060] In **FIG. 9**, the schematic flow chart of the current controller is shown. In step **800**, the current reference is provided. In step **801**, the actual current is detected or measured. In step **802** the actual current is compared with the current reference. If the actual current is substantial equal to the current reference it is continued to step **803**. If the actual current is different from the current reference it is continued to step **804** wherein the current is either increased or decreased in view of the current reference. As mentioned previously, the current controller compensates for temperature variations in valve coils, and implements dithering to minimize hysteresis caused by stiction of a valve body.

[0061] According to an example, a method for controlling a marine propulsion system **1** of the disclosure may comprising

- arranging a clutch arrangement **6** comprising a clutch plate **8** and a clutch piston **9**, the clutch piston **9** is configured to be actuated by a first hydraulic area **10** and/or a second hydraulic area **11**,
- pressurizing the first hydraulic area **10** by an electrically controlled proportional pressure valve **12**,
- pressurizing the second hydraulic area **11** by an electrically controlled on/off valve **13**,
- controlling the electrically controlled proportional pressure valve **12** independently of the electrically controlled on/off valve **13** or vice versa.

[0062] Certain aspects and variants of the disclosure are set forth in the following examples numbered consecutive below.

[0063] Example 1: A marine propulsion system (**1**) for a marine vessel (**100**), comprising

- an engine (**2**),
- a propeller unit (**3**) comprising one or more propellers,
- a transmission (**5**) arranged between the motor and the propeller unit,
- a hydraulic clutch arrangement (**6**), the clutch arrangement is configured to control a power transfer between the engine and the propeller unit,

- a control unit (7),

wherein the clutch arrangement (6) comprises a clutch plate (8) and a clutch piston (9), the clutch piston is configured to be actuated by a first hydraulic area (10) and/or a second hydraulic area (11), and wherein the first hydraulic area is pressurized by an electrically controlled proportional pressure valve (12) and the second hydraulic area is pressurized by an electrically controlled on/off valve (13), the control unit is operatively connected with the electrically controlled proportional pressure valve and the electrically controlled on/off valve, and is configured to control the electrically controlled proportional pressure valve and the electrically controlled on/off valve.

[0064] Example 2: The marine propulsion system (1) of example 1, wherein the control unit (7) is configured to control the electrically controlled proportional pressure valve (12) independently of the electrically controlled on/off valve (13), or the control unit (7) is configured to control the electrically controlled on/off valve (13) independently of the electrically controlled proportional pressure valve (12).

[0065] Example 3: The marine propulsion system (1) of any of the preceding examples, further comprising an input unit (14) for adjusting a speed of the marine vessel in a forward direction and/or in a reverse direction.

[0066] Example 4: The marine propulsion system (1) of example 3, wherein the control unit (7) is operatively connected with the input unit (14).

[0067] Example 5: The marine propulsion system (1) of any of the preceding examples, wherein the first hydraulic area (10) is substantially equal in size to the second hydraulic area (11), the first hydraulic area being smaller than the second hydraulic area, or the first hydraulic area being larger than the second hydraulic area.

[0068] Example 6: The marine propulsion system (1) of any of the preceding examples, wherein the clutch arrangement (6) has a predetermined actuation pressure, the predetermined actuation pressure is a pressure reference.

[0069] Example 7: The marine propulsion system (1) of any of the preceding examples, wherein the control unit (7) comprises a current controller (19), the current controller is configured to closed-loop current control the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve.

[0070] Example 8: The marine propulsion system (1) of any of the preceding examples, wherein the electrically controlled proportional pressure valve (12) and/or the electrically controlled on/off valve (13) is/are controlled by a predetermined current, the predetermined current is a current reference.

[0071] Example 9: The marine propulsion system (1) of example 7, wherein the current controller has a control frequency of more than 500Hz, preferably more than

1kHz, more preferably more than 2kHz.

[0072] Example 10: The marine propulsion system (1) of any of the examples 7 to 9, wherein the current controller (19) is configured to implement dithering of current 200Hz/±10mA to minimize hysteresis of the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve.

[0073] Example 11: The marine propulsion system (1) of any of examples 7 to 10, wherein a shunt resistor (18) is arranged in connection with the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve, the shunt resistor is configured to measure a control current with a mA accuracy.

[0074] Example 12: The marine propulsion system (1) of any of the preceding examples, further comprising one or more pressure sensor(s) (17) being configured to measure an actuation pressure of the clutch arrangement.

[0075] Example 13: The marine propulsion system (1) of any of the preceding examples, wherein the control unit (7) comprises an actuation pressure controller (20), the actuation pressure controller is configured to control the actuation pressure on basis of the pressure reference.

[0076] Example 14: The marine propulsion system (1) of example 13, wherein the one or more pressure sensors (17) are operatively connected with the actuation pressure controller (20).

[0077] Example 15: The marine propulsion system (1) of any of the examples 12 to 14, wherein the pressure sensor(s) (17) is/are configured to measure forward and/or reverse actuation pressure, the measured actuation pressure is used as feedback to the actuation pressure controller (20).

[0078] Example 16: The marine propulsion system of any of the examples 13 to 15, wherein the actuation pressure controller (20) is configured to control the actuation pressure of the clutch arrangement (6) by a closed-loop control.

[0079] Example 17: The marine propulsion system (1) of any of the preceding examples, wherein the control unit (7) further comprises a propeller speed controller (21), the propeller speed controller is configured to control the propeller speed on basis of the propeller speed references (200).

[0080] Example 18: The marine propulsion system (1) of any of the preceding examples, further comprises an engine controller (40) configured to control an engine speed so as to avoid region with slip-stick near full clutch engagement.

[0081] Example 19: The marine propulsion system (1) of any of the preceding examples, wherein the clutch arrangement (6) comprises a forward clutch unit and a reverse clutch unit.

[0082] Example 20: The marine propulsion system (1) of any of the preceding examples, wherein the clutch arrangement comprises a plurality of clutch plates.

[0083] Example 21: The marine propulsion system (1) of any of the preceding examples, further comprises an

additional engine or engines.

[0084] Example 22: The marine propulsion system (1) of any of the preceding examples, wherein the propeller unit (3) is configured to pull the marine vessel and/or is configured to push the marine vessel.

[0085] Example 23: A marine vessel (100) comprising a marine propulsion system (1) of any of the preceding examples.

[0086] Example 24: A method for controlling a marine propulsion system (1) of any of the examples 1 to 22, comprising

arranging a clutch arrangement (6) comprising a clutch plate and a clutch piston, the clutch piston is configured to be actuated by a first hydraulic area (10) and/or a second hydraulic area (11), pressurizing the first hydraulic area by an electrically controlled proportional pressure valve (12), pressurizing the second hydraulic area by an electrically controlled on/off valve (13), controlling the electrically controlled proportional pressure valve (12) independently of the electrically controlled on/off valve (13) or vice versa.

[0087] Example 25: The method of example 24, further comprising

providing a propeller speed controller (21), controlling the propeller speed on basis of the propeller speed references (200).

[0088] Example 26: The method of example 24 and/or 25, further comprising setting and/or calculating a predetermined actuation pressure, the predetermined actuation pressure is a pressure reference.

[0089] Example 27: The method of any of the examples 24 to 26, further comprising measuring an actuation pressure of the clutch arrangement.

[0090] Example 28: The method of example 27, further comprising

providing an actuation pressure controller (20), controlling the actuation pressure on basis of the reference pressure and/or the measured actuation pressure.

[0091] Example 29: The method of example 28, further comprising

measuring forward and/or reverse actuation pressure, applying the measured actuation pressure as feedback to the actuation pressure controller (20).

[0092] Example 30: The method of any of the examples 28 and/or 29, further comprising controlling the actuation pressure of the clutch arrangement by a closed-loop control.

[0093] Example 31: The method of any of the examples 24 to 30, further comprising pressurizing a hydraulic area by at least an electrically controlled valve, an electrically controlled proportional pressure valve and/or an electrically controlled on/off valve.

[0094] Example 32: The method of example 31, further comprising

determining and/or calculating a predetermined current, the predetermined current is a current reference, providing a current controller (19), controlling by a closed-loop current control the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve on basis of the current reference.

[0095] Example 33: The method of example 32, further comprising controlling with a control frequency of more than 500Hz, preferably more than 1kHz, more preferably more than 2kHz.

[0096] Example 34: The method of example 31 and/or 32, further comprising implementing dithering of current 200Hz/±10mA to minimize hysteresis of the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve.

[0097] Example 35: The method of any of the examples 31 to 34, further comprising providing a shunt resistor (18) in connection with the electrically controlled valve, the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve, measuring a control current with a mA accuracy by the shunt resistor.

[0098] Example 36: The method of example 35, further comprising controlling by a closed-loop current control the electrically controlled proportional pressure valve and/or the electrically controlled on/off valve on basis of the measured control current and/or the current reference.

[0099] Example 37: The method of any of the examples 24 to 36, further comprising providing an engine controller (40), controlling an engine speed on basis of an input of the operator.

[0100] Example 38: The method of example 37, further comprising increasing engine speed near full clutch engagement so that the clutch engagement is kept below where slip-stick behavior of the clutch disc may occur.

[0101] Example 39: The method of example 37 and/or 38, further comprising resetting engine speed to idle speed when the clutch is set for full engagement.

[0102] The terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly in-

dicates otherwise. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. It will be further understood that the terms "comprises," "comprising," "includes," and/or "including" when used herein specify the presence of stated features, integers, actions, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, actions, steps, operations, elements, components, and/or groups thereof.

[0103] It will be understood that, although the terms first, second, etc., may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element without departing from the scope of the present disclosure.

[0104] Relative terms such as "below" or "above" or "upper" or "lower" or "horizontal" or "vertical" may be used herein to describe a relationship of one element to another element as illustrated in the Figures. It will be understood that these terms and those discussed above are intended to encompass different orientations of the device in addition to the orientation depicted in the Figures. It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element, or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present.

[0105] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms used herein should be interpreted as having a meaning consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0106] It is to be understood that the present disclosure is not limited to the aspects described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the present disclosure and appended claims. In the drawings and specification, there have been disclosed aspects for purposes of illustration only and not for purposes of limitation, the scope of the disclosure being set forth in the following claims.

Claims

1. A marine propulsion system (1) for a marine vessel (100), comprising

- an engine (2),

- a propeller unit (3) comprising one or more propellers (4a, 4b),
 - a transmission (5) arranged between the engine (2) and the propeller unit (3),
 - a hydraulic clutch arrangement (6), the clutch arrangement is configured to control a power transfer between the engine and the propeller unit,
 - a control unit (7),
 wherein the clutch arrangement (6) comprises a clutch plate (8) and a clutch piston (9), the clutch piston (9) is configured to be actuated by a first hydraulic area (10) and/or a second hydraulic area (11), and
 wherein the first hydraulic area (10) is pressurized by an electrically controlled proportional pressure valve (12) and the second hydraulic area (11) is pressurized by an electrically controlled on/off valve (13), the control unit (7) is operatively connected with the electrically controlled proportional pressure valve (12) and the electrically controlled on/off valve (13), and is configured to control the electrically controlled proportional pressure valve (12) and the electrically controlled on/off valve (13).

2. The marine propulsion system (1) of claim 1, wherein the control unit (7) is configured to control the electrically controlled proportional pressure valve (12) independently of the electrically controlled on/off valve (13), or the control unit (7) is configured to control the electrically controlled on/off valve (13) independently of the electrically controlled proportional pressure valve (12).

3. The marine propulsion system (1) of any of the preceding claims, further comprising an input unit (14) for adjusting a speed of the marine vessel in a forward direction and/or in a reverse direction.

4. The marine propulsion system (1) of claim 3, wherein the control unit (7) is operatively connected with the input unit (14).

5. The marine propulsion system (1) of any of the preceding claims, wherein the first hydraulic area (10) is substantially equal in size to the second hydraulic area (11), the first hydraulic area (10) being smaller than the second hydraulic area (11), or the first hydraulic area (10) being larger than the second hydraulic area (12).

6. The marine propulsion system (1) of any of the preceding claims, wherein the control unit (7) comprises a current controller (19), the current controller is configured to closed-loop current control the electrically controlled proportional pressure valve (12) and/or the electrically controlled on/off valve (13).

7. The marine propulsion system (1) of any of the preceding claims, further comprising one or more pressure sensor(s) (17) being configured to measure an actuation pressure of the clutch arrangement (6). 5
8. The marine propulsion system (1) of any of the preceding claims, wherein the control unit (7) comprises an actuation pressure controller (20).
9. The marine propulsion system (1) of claim 7, wherein the one or more pressure sensors (17) are operatively connected with the actuation pressure controller (20). 10
10. The marine propulsion system (1) of any of the claims 7 to 9, wherein the pressure sensor(s) (17) is/are configured to measure forward and/or reverse actuation pressure, the measured actuation pressure is used as feedback to the actuation pressure controller (20). 15 20
11. The marine propulsion system (1) of any of the claims 7 to 10, wherein the actuation pressure controller (20) is configured to control the actuation pressure of the clutch arrangement (6) by a closed-loop control. 25
12. The marine propulsion system (1) of any of the preceding claims, further comprising a propeller speed controller (21). 30
13. The marine propulsion system (1) of any of the preceding claims, further comprising an engine controller (40) configured to control an engine speed so as to avoid region with slip-stick near full clutch engagement. 35
14. A marine vessel (100) comprising a marine propulsion system (1) of any of the preceding claims. 40
15. A method for controlling a marine propulsion system (1) of any of the claims 1 to 13, comprising
 - arranging a clutch arrangement (6) comprising a clutch plate (8) and a clutch piston (9), the clutch piston (9) is configured to be actuated by a first hydraulic area (10) and/or a second hydraulic area (11), 45
 - pressurizing the first hydraulic area (10) by an electrically controlled proportional pressure valve (12), 50
 - pressurizing the second hydraulic area (11) by an electrically controlled on/off valve (13), controlling the electrically controlled proportional pressure valve (12) independently of the electrically controlled on/off valve (13) or vice versa. 55

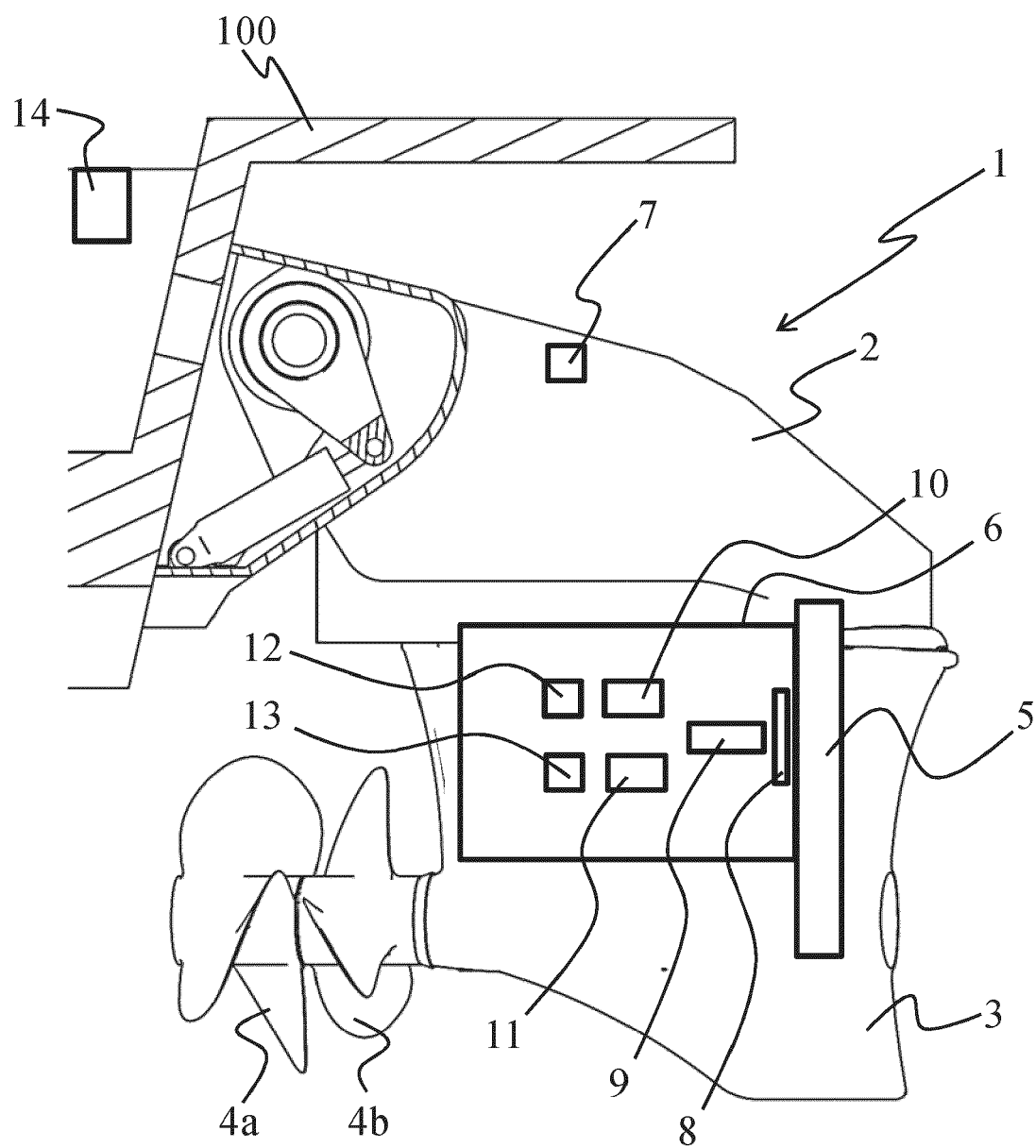
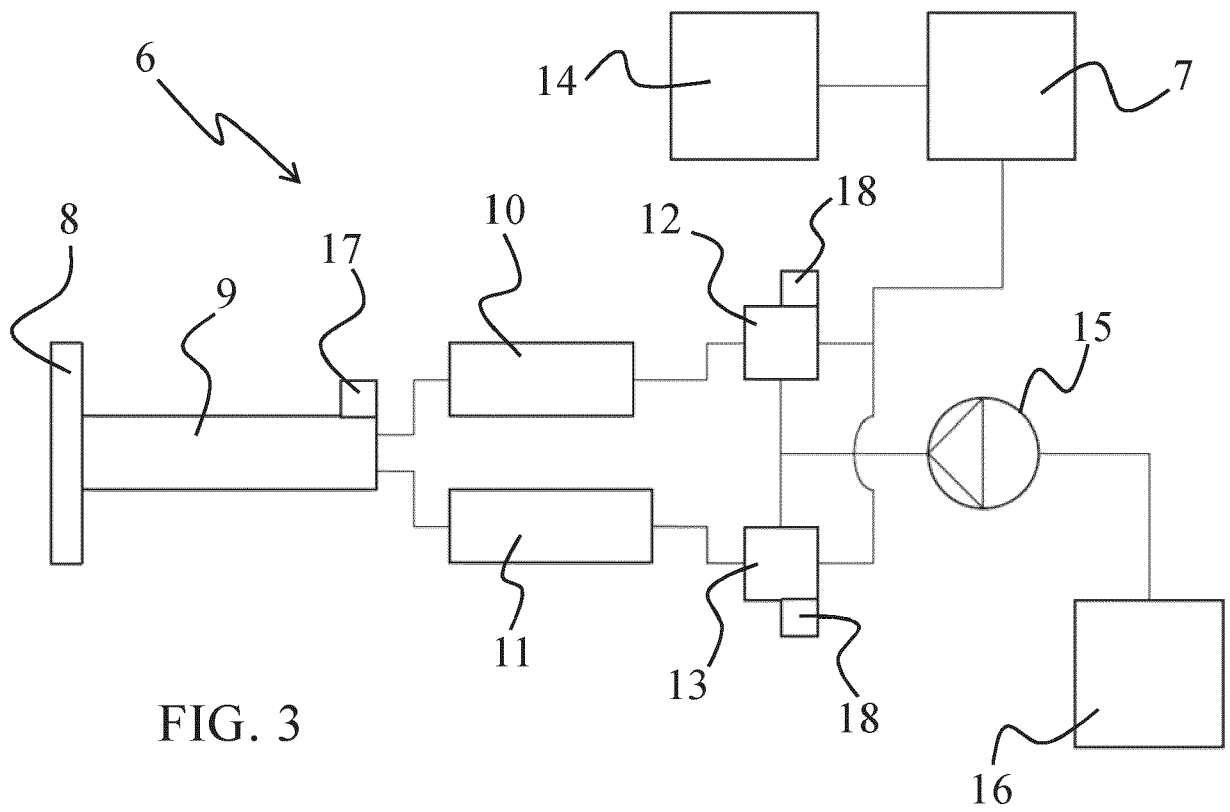
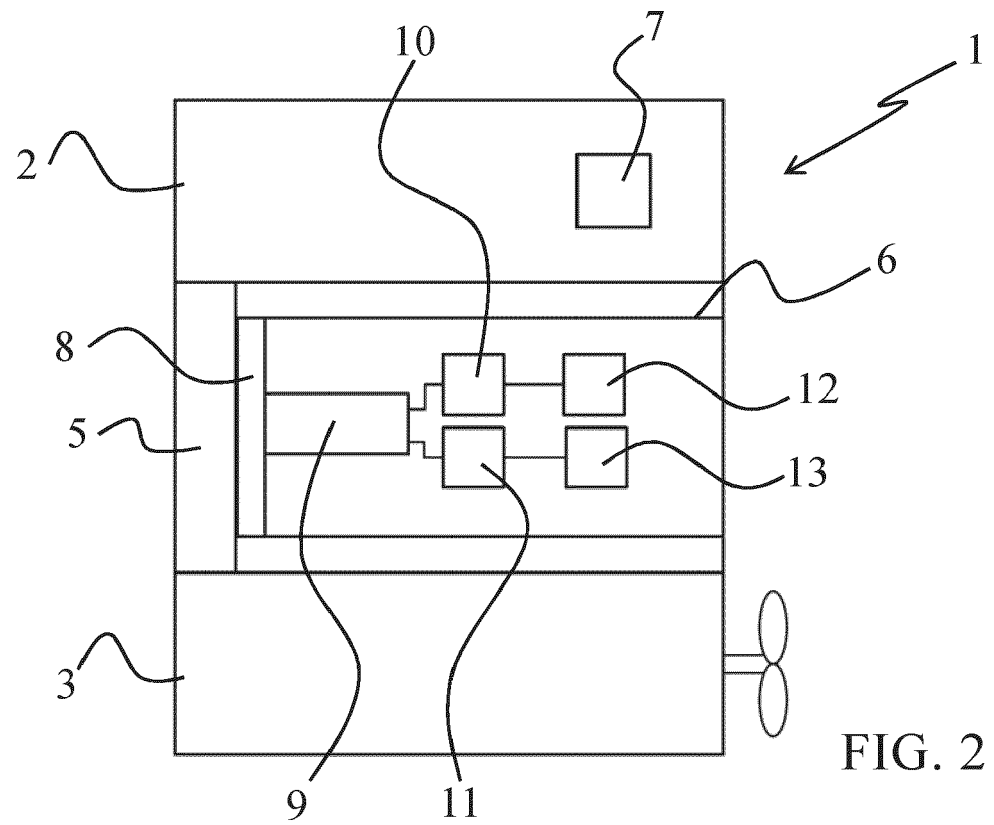


FIG. 1



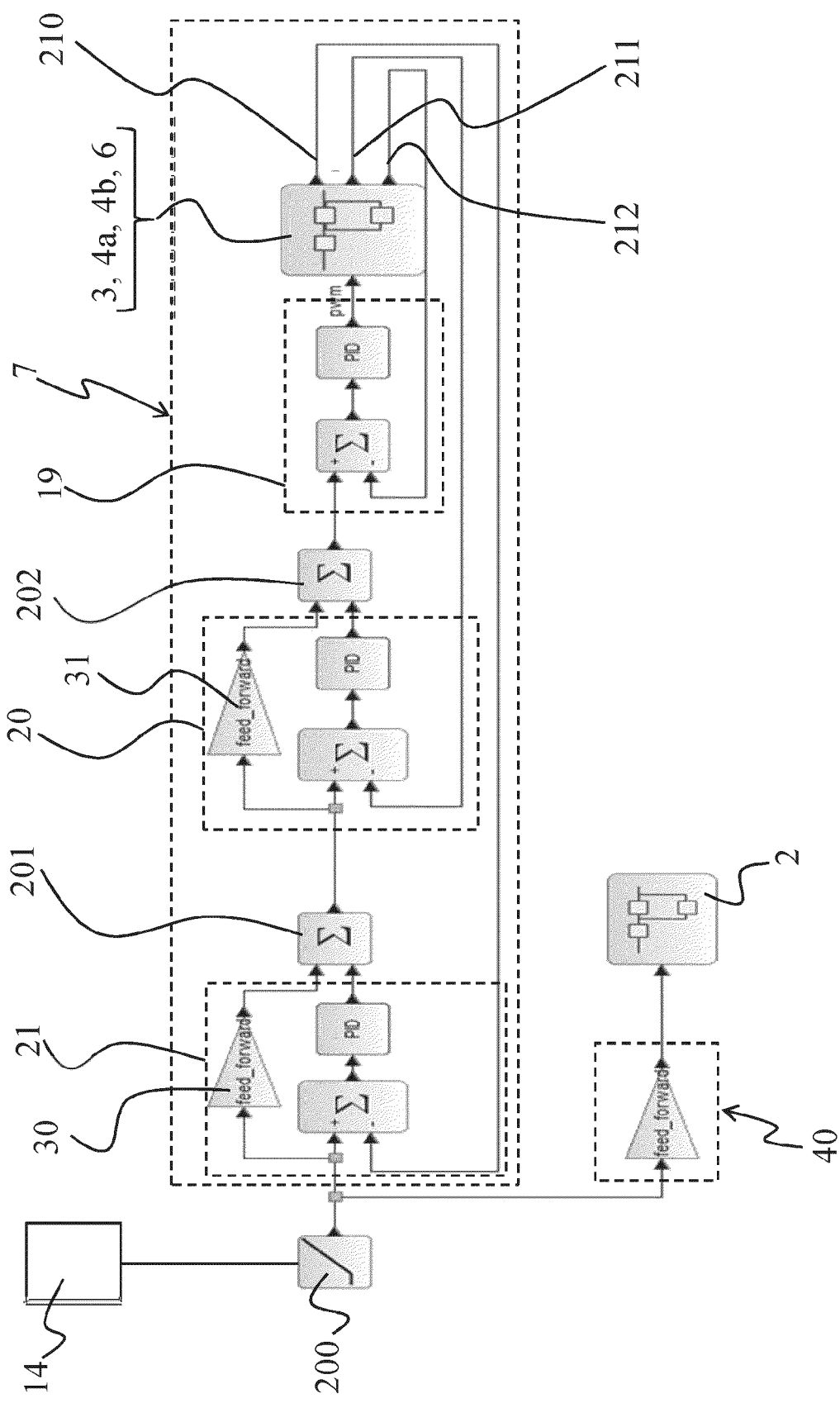


FIG. 4

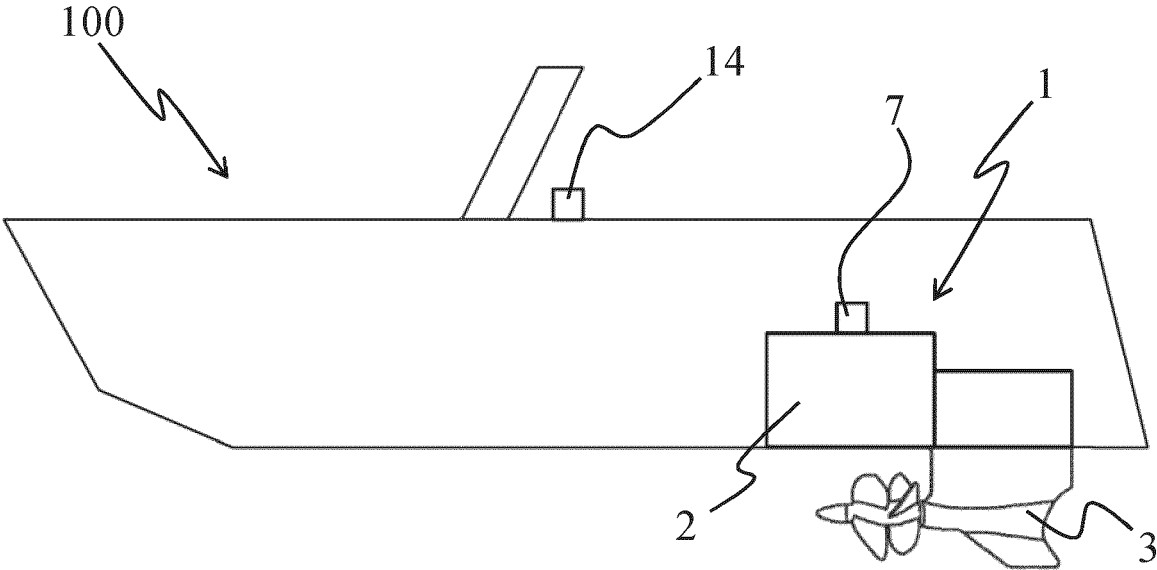


FIG. 5

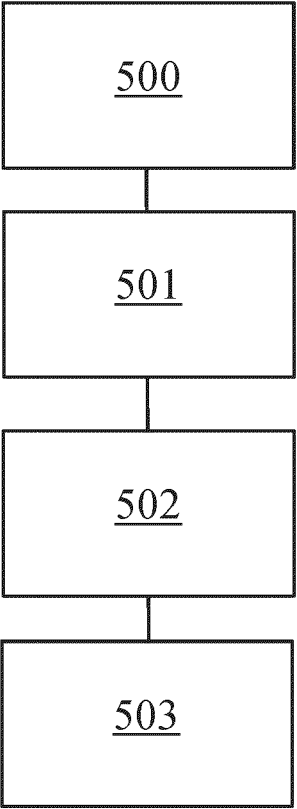


FIG. 6

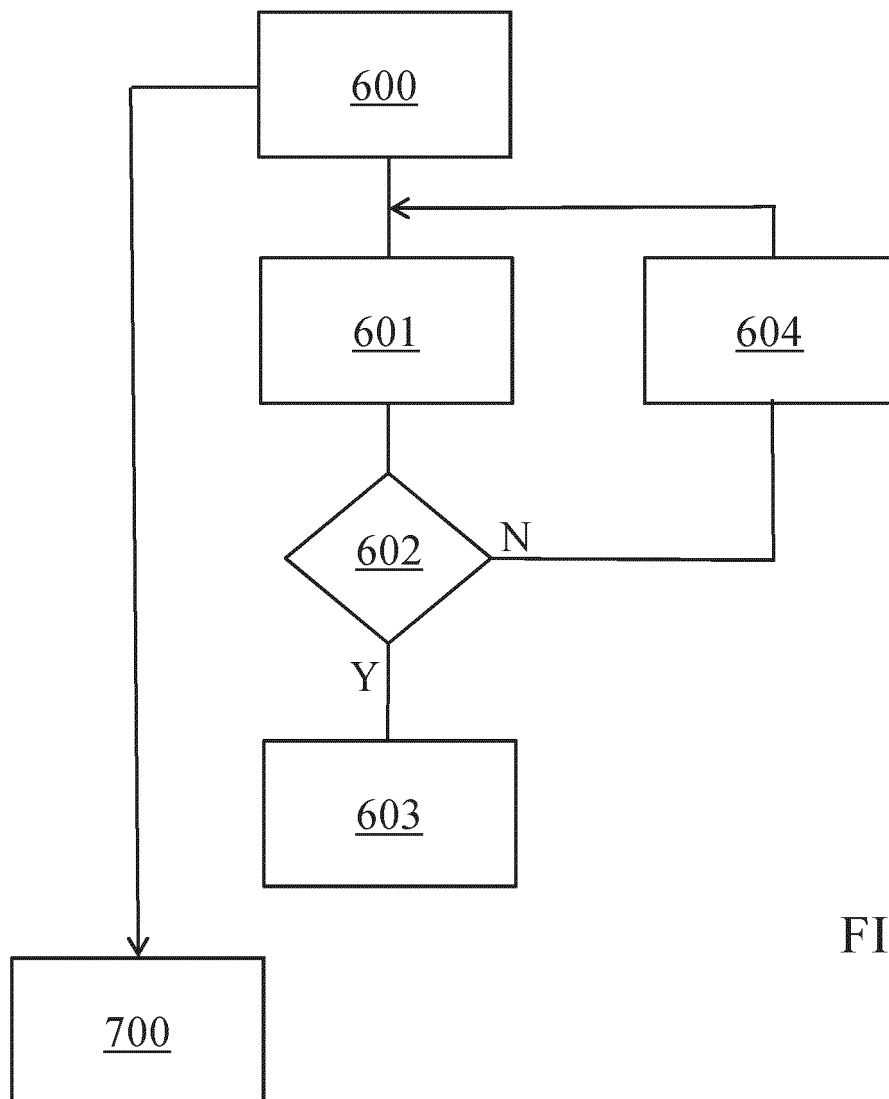


FIG. 7

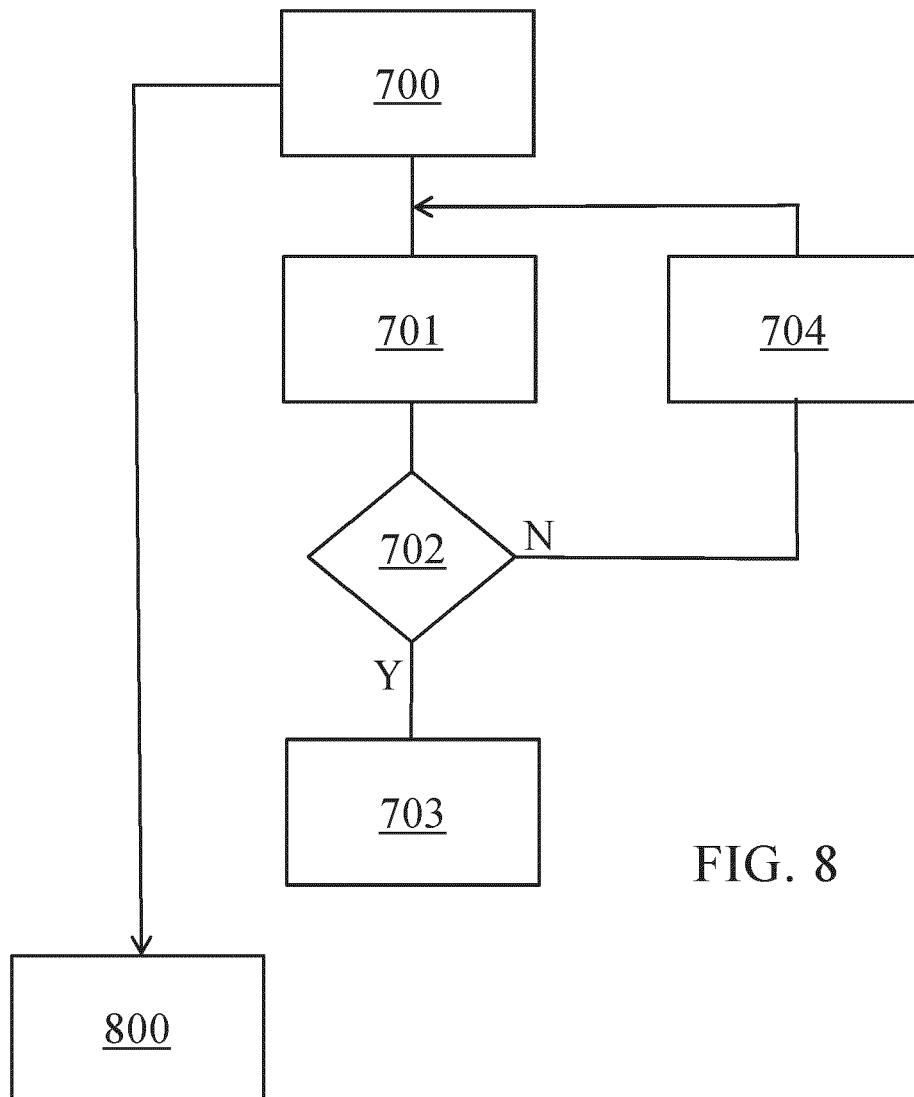


FIG. 8

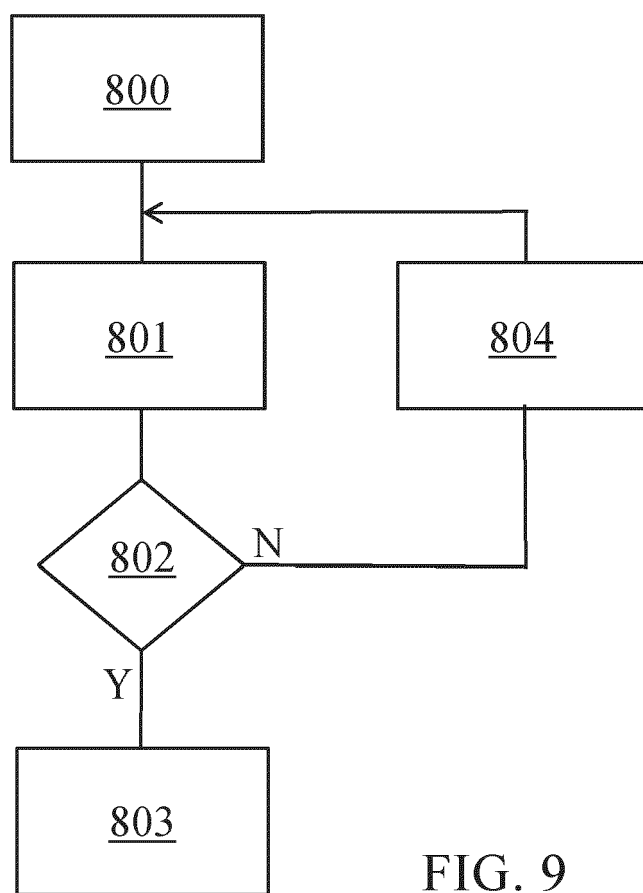


FIG. 9



EUROPEAN SEARCH REPORT

Application Number

EP 23 20 5494

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2010/121505 A1 (YAMAZAKI TAKAYOSHI [JP] ET AL) 13 May 2010 (2010-05-13) * the whole document *	1-15	INV. B63B79/10 B63B79/40 B63H23/30
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			TECHNICAL FIELDS SEARCHED (IPC)
			B63B B63H
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		5 April 2024	Freire Gomez, Jon
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