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Amended claims in accordance with Rule 137(2) EPC.

(54) METHOD FOR STARTING A COMBUSTION ENGINE IN A MARINE HYBRID DRIVE UNIT

(57) A method for starting a combustion engine (1) in a marine hybrid drive unit (100, 200), wherein the marine hybrid drive unit (100, 200) comprises the combustion engine (1) and an electric drive motor (2). The combustion engine (1) comprises an electric starter unit (8). The electric drive motor (2) is permanently connected to the driven shaft (4). A driven shaft (4) of the marine hybrid drive unit (100, 200) can be driven in a combustion engine mode solely by the combustion engine (1), in an electric propulsion mode solely by the electric drive motor (2) and

in a combined mode by the combustion engine (1) and the electric drive motor (2). The method comprises the steps:

- starting the electric motor (2) and
- starting the combustion engine (1) by the electric starter unit (8).

A marine hybrid drive unit (100, 200) comprising a control unit (101, 201), which is configured to execute said method.

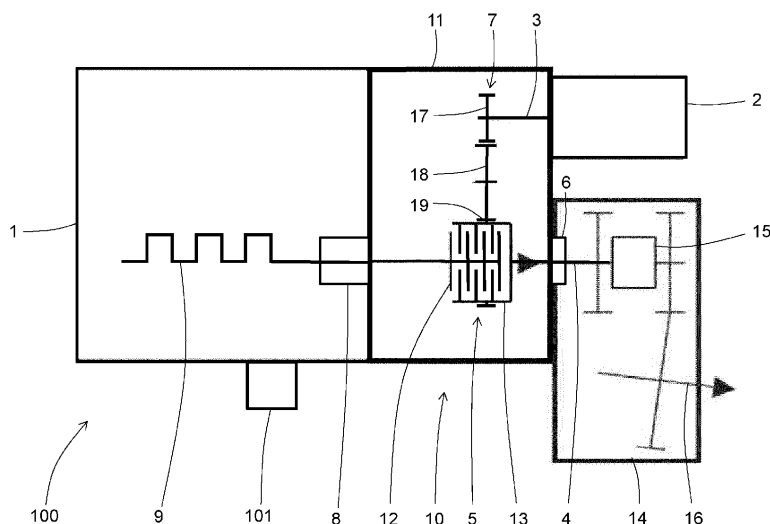


Fig. 1

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Description

[0001] The present invention relates to a method for starting a combustion engine in a marine hybrid drive unit.

[0002] There is an increasing demand for marine hybrid drive units for environmental and efficiency reasons. With a marine hybrid drive unit a boat can be propelled solely by an electric drive motor without any local emissions especially in ecologically sensitive areas or in harbors and mooring areas. During certain operating phases it is also more efficient to propel a boat solely by the electric drive motor, for example if a boat shall be propelled with low speed in a trolling mode or in a no-wake area. Whereas the combustion engine provides sufficient power for normal and high speed cruising.

[0003] Different marine hybrid drive units comprising a combustion engine and an electric drive motor to propel a water vehicle are already known from prior art. One example of a marine drive hybrid drive unit has been disclosed in US 2009/0209146 A1. This document describes a hybrid module for installation between an internal combustion engine and a transmission of a watercraft. The combustion engine and an electric drive motor of the hybrid module may be selectively used to propel a watercraft. Different embodiments of such a hybrid module and different start and driving modes are disclosed with this document. One embodiment is described with a separate starter unit being required to start the combustion engine.

[0004] The purpose of the present invention is to provide an improved method for starting a combustion engine in a marine hybrid drive unit and a marine hybrid drive unit comprising a control unit, which is arranged to implement such a method.

[0005] This purpose is achieved by a method for starting a combustion engine in a marine hybrid drive unit according to claim 1 and a marine hybrid drive unit according to claim 5. Further embodiments are claimed in dependent claims.

[0006] The present invention provides a method for starting a combustion engine in a marine hybrid drive unit, wherein the marine hybrid drive unit comprises the combustion engine and an electric drive motor. The combustion engine comprises an electric starter unit containing a further electric motor.

[0007] A driven shaft of the marine hybrid drive unit can be driven in different modes. It may be driven solely by the combustion engine in a combustion engine mode. In an electric propulsion mode the driven shaft may solely be driven by the electric drive motor. In this electric propulsion mode the boat can be propelled at zero noise and zero emissions, especially during low speed cruising and docking. In a combined mode the driven shaft may be driven by the combustion engine and the electric drive motor simultaneously. The electric drive motor is permanently connected to the driven shaft. This way, the electric drive motor can be used as a generator to recharge the batteries, while the driven shaft is driven by the combustion engine in the combustion engine mode.

tion engine in the combustion engine mode.

[0008] The combustion engine of such a marine hybrid drive unit can be started according to the proposed method comprising the steps:

- a) starting the electric drive motor,
- b) starting the combustion engine by the electric starter unit.

Starting the electric drive motor before starting the combustion engine excludes the inertia from the elements of the electric drive motor and all components being connected to it, during the subsequent starting of the combustion engine. This way an overload of the electric starter unit of the combustion engine is avoided, even so the electric starter unit had been designed to start a conventional combustion engine without any additional hybrid components. This means, that an existing conventional marine drive unit without electric driving motor can be modified by a hybrid module comprising the electric drive motor without modifying the combustion engine with its electric starter unit. Said hybrid module may include its own housing to enclose at least some components of the electric drive train. The electric drive motor can either be enclosed in said housing or it can be located outside the housing.

[0009] One embodiment of such a marine hybrid drive unit comprises a freewheel unit, wherein an input part of the freewheel unit is connected to a crankshaft of the combustion engine and wherein an output part of the freewheel unit is connected to the electric drive motor and to the driven shaft. The freewheel unit allows different rotational speed between the crankshaft of the combustion engine and the driven shaft. A freewheel or over-running unit is a cheap and simple solution compared to an active clutch which requires additional efforts for the actuation and control of the active clutch. The freewheel unit can be a part of the hybrid module.

[0010] However, in other embodiments and for other applications an active clutch can be used. This means that the combustion engine can be disconnected and connected to the driven shaft by means of a pressure actuated input clutch. In such an embodiment the proposed method shall include a step to close the pressure actuated clutch before starting the combustion engine. The oil pressure for actuating the input clutch can be provided by an oil pump, which is driven by the electric drive motor via the driven shaft. Hence, the pressure actuated input clutch can be actuated as soon as the electric drive motor has been started and the driven shaft is rotating with a certain speed. The pressure actuated input clutch can be closed after starting the electric drive motor and before starting the combustion engine. In an embodiment that comprises at least one gear step between the electric drive motor and the driven shaft, the gear ratio of the at least one gear step can be optimized to build up an appropriate oil flow rate and oil pressure provided by the oil pump. This way, the use of an auxiliary

electric pump is not necessary during the starting procedure.

[0011] The marine hybrid drive unit may be switched in the combustion engine mode when the combustion engine has reached a preset engine speed. Preferably the preset engine speed is set to a value in a range between 600 rpm and 800 rpm. This speed shall be the idling speed of the corresponding combustion engine, which is also appropriate to drive the electric drive motor in a recharge mode.

[0012] The invention includes a marine hybrid drive unit comprising a control unit, which is arranged to implement a method as described above. The electric drive motor preferably is part of a hybrid module comprising at least one gear step between the electric drive motor and the driven shaft. The at least one gear step is used to apply an optimized gear ratio between the electric drive motor and the driven shaft. One target of the optimized gear ratio is to maximize the efficiency of the electric drive motor either in the electric propulsion mode or in the recharge mode. For that purposes the gear ratio of the at least one gear step preferably is set to a value in the range between 2 and 3.

[0013] The driven shaft can be an input shaft of a gearbox, so that the hybrid module can be installed between the combustion engine and the gearbox. In this embodiment, the mentioned oil pump can be an integral part of the gearbox and it can be driven by said input shaft. Transmission elements are arranged in the gearbox to transfer the rotational speed of the input shaft to a required speed of an output shaft which is connected to a propeller shaft of the boat. Further transmission elements like one or more clutches can be arranged in the gearbox to connect or disconnect the input shaft from the output shaft and/or to change the direction of rotation between the input shaft and the output shaft.

[0014] The invention will be further and more particularly described in the following, by way of example only, and with reference to the accompanying figures.

- Fig. 1 shows a first embodiment of a marine hybrid drive unit according to the invention in a schematic drawing,
 Fig. 2 shows an alternative embodiment of a marine hybrid drive unit according to the invention and
 Fig. 3 shows a scheme of the steps of a method according to the invention.

[0015] A marine hybrid drive unit 100 as shown in Fig. 1 can be mounted inside the hull of a boat. The marine hybrid drive unit 100 comprises a combustion engine 1 and an electric drive motor 2 for propelling the boat in different operation modes. The marine hybrid drive unit 100 can be driven in a combustion engine mode solely by the combustion engine 1, in an electric propulsion mode solely by the electric drive motor 2. In a combined mode the marine hybrid drive unit 100 can be driven simultaneously by the combustion engine 1 and the electric drive

motor 2.

[0016] The combustion engine 1 includes an electric starter unit 8 and a crankshaft 9. The crankshaft 9 can be connected to a driven shaft 4 by means of a pressure actuated input clutch 5. The crankshaft 9 and the driven shaft 4 are arranged coaxial to each other. The crankshaft 9 is fastened to an input element 12 of the input clutch 5 whereas the driven shaft 4 is fastened to an output element 13 of the input clutch 5. The input clutch 5 in this embodiment is a multi-plate-friction-clutch with inner and outer friction plates. The input element 12 being designed as an inner disk carrier, whereas the output element 13 is designed as an outer disk carrier. The input clutch 5 is configured to be pressure actuated by means of an appropriate oil supply system.

[0017] An oil pump 6 is provided to supply sufficient oil pressure for actuating the input clutch 5. The oil pump 6 is driven by the driven shaft 4. In this embodiment the driven shaft 4 is the input shaft of a gearbox 14. The gearbox 14 comprises a transmission clutch 15 which is configured to control the speed of an output shaft 16 of the gearbox 14. The transmission clutch 15 is a hydraulically actuated multi-disc clutch. The transmission clutch 15 can be fully engaged, fully disengaged or it can be operated in a slipping mode for propelling the boat with low speed. In the slipping mode a slip rate of the transmission clutch 15 can be adjusted by controlling the oil pressure in the hydraulic actuation system of the transmission clutch 15. The oil pressure in said hydraulic actuation system is provided by the oil pump 6.

[0018] The input clutch 5 and the electric drive motor 2 are part of a hybrid module 10 which is mounted in between the combustion engine 1 and a gearbox 14. The electric motor 2 is mounted to a housing 11 of the hybrid module 10 such, that a motor shaft 3 of the electric drive motor 2 is arranged in parallel to the driven shaft 4. The electric drive motor 2 is permanently connected to the driven shaft 4 and to the output element 13 of the input clutch 5.

[0019] The hybrid module 10 further includes gear steps 7 between the electric drive motor 2 and the driven shaft 4. The gear steps 7 in this embodiment comprises a first spur gear 17 which is fastened to the motor shaft 3. The first spur gear 17 meshes with a second spur gear 18. The second spur gear 18 further meshes with a toothing 19 which is an integral part of the output element 13 of the input clutch 5. The gear steps 7 are designed to provide a transmission ratio in the range between 2 and 3, as this has proven to be the optimum range in view of the efficiency of the electric drive motor 2 in the electric propulsion mode and in the recharge mode. The pressure actuated input clutch 5 is also a part of the hybrid module 10.

[0020] A control unit 101 of the marine hybrid drive unit 100 is configured to execute the proposed method for starting the combustion engine 1. The control unit 101 is further configured to control the engagement of the pressure actuated transmission clutch 15 in a way to control

the speed of the output shaft 16 and the speed of a propeller which is connected to the output shaft 16. For these purposes the control unit 101 contains electronic and hydraulic components like valves for the control of oil flow and oil pressure. The control unit 101 further includes interfaces to be connected to a control unit of the combustion engine 1 and/or other control units of the boat. The control unit 101 may additionally control oil pressure and oil flow for the lubrication of elements in the gearbox 14 and in the hybrid module 10.

[0021] An alternative embodiment of a marine hybrid drive unit 200 as shown in Fig. 2 differs from the embodiment of Fig. 1 in the type of the input clutch 23, which is part of the hybrid module 20. The input clutch 23 in this alternative embodiment is designed as a freewheel unit with an input element 21 and an output element 22. The crankshaft 9 is fastened to the input element 21 whereas the driven shaft 4 is fastened to an output element 22 of the input clutch 23. Hence the input clutch 23 of this embodiment is a passive clutch, which does not need an active actuation. This type of input clutch 23 allows the output element 22 and the driven shaft 4 to rotate faster than the input element 21, which is usually the case in the electric propulsion mode. The control unit 201 in this embodiment does not need to control the input clutch 23. The control unit 201 in this embodiment controls the oil pressure for lubricating the elements in the gearbox 14 and in the hybrid modul 20 and the oil pressure for the actuation of the transmission clutch 15.

[0022] Fig. 3 shows schematically the steps of the proposed method. In a first step S1 the electric drive motor 2 is started. In the following step S2 a pressure actuated input clutch 5 is closed after starting the electric drive motor 2. The combustion engine 1 is connected to the driven shaft 4 by applying pressure to the pressure actuated input clutch 5, wherein the oil pressure is provided by an oil pump 6, which is driven by the driven shaft 4. In step S3 the combustion engine is started by the electric starter unit 8, wherein the electric starter unit 8 has to overcome only the inertia of the elements from the combustion engine 1 to the input element 12, 21 of the input clutch 5, because all further elements of the drive train are already driven by the electric drive motor 2. Step S2 and step S3 can be activated almost simultaneously or with a very short time lag, in order to avoid an overload of the electric drive motor 2 during the start of the combustion engine 1. A recharge mode to operate the electric drive motor 2 as a generator can be activated in step S4 as soon as the combustion engine 1 is running with a preset speed.

Referrals

[0023]

- 1 combustion engine
- 2 electric drive motor
- 3 motor shaft

- 4 driven shaft
- 5 input clutch
- 6 oil pump
- 7 gear step
- 8 electric starter unit
- 9 crankshaft
- 10 hybrid module
- 11 housing
- 12 input element
- 13 output element
- 14 gearbox
- 15 transmission clutch
- 16 output shaft
- 17 first spur gear
- 18 second spur gear
- 19 toothing
- 20 hybrid module
- 21 input element
- 22 output element
- 23 input clutch
- 100 marine hybrid drive unit
- 101 control unit
- 200 marine hybrid drive unit
- 201 control unit

Claims

1. Method for starting a combustion engine (1) in a marine hybrid drive unit (100, 200), wherein the marine hybrid drive unit (100, 200) comprises the combustion engine (1) and an electric drive motor (2), wherein the combustion engine (1) comprises an electric starter unit (8), wherein a driven shaft (4) of the marine hybrid drive unit (100, 200) can be driven in a combustion engine mode solely by the combustion engine (1), in an electric propulsion mode solely by the electric drive motor (2) and in a combined mode by the combustion engine (1) and the electric drive motor (2), wherein the electric drive motor (2) is permanently connected to the driven shaft (4), the method comprising the steps:
 - a) starting the electric motor (2) and
 - b) starting the combustion engine (1) by the electric starter unit (8).
2. Method according to claim 1, wherein the combustion engine (1) is connected to the driven shaft (4) by means of a pressure actuated input clutch (5) before starting the combustion engine (1), wherein the oil pressure for actuating the input clutch (5) is provided by an oil pump (6), which is driven by the driven shaft (4), and wherein the pressure actuated input clutch is (5) closed after starting the electric drive motor (2).
3. Method according to claim 1 or 2, wherein the marine hybrid drive unit (100, 200) is switched in the combustion engine mode, when the combustion engine

(1) has reached a preset engine speed.

4. Method according to claim 3, wherein the preset engine speed is set to a value in a range between 600 rpm and 800 rpm.
5. Marine hybrid drive unit (100, 200) comprising a control unit (101, 201), which is configured to execute a method according to one of the preceding claims.
6. Marine hybrid drive unit (100, 200) according to claim 5, wherein the electric drive motor (2) is part of a hybrid module (10, 20) comprising at least one gear step (7) between the electric drive motor (2) and the driven shaft (4).
7. Marine hybrid drive unit (100, 200) according to claim 6, wherein the ratio of the at least one gear step (7) is set to a value in the range between 2 and 3.
8. Marine hybrid drive unit (100, 200) according to one of the claims 5 to 7, wherein the hybrid module (10) comprises the pressure actuated input clutch (5).
9. Marine hybrid drive unit (100, 200) according to one of the claims 5 to 7, wherein the hybrid module (10) comprises a an input clutch (23) in form of a free-wheel unit, wherein an input element (21) of the freewheel unit is connected to a crankshaft (9) of the combustion engine (1) and wherein an output element (22) of the freewheel unit is connected to the electric drive motor (2) and to the driven shaft (4).
10. Marine hybrid drive unit according to one of the claims 6 to 9 driven shaft (4) is an input shaft of a gearbox (14) and wherein the oil pump (6) is an integral part of the gearbox (14).

Amended claims in accordance with Rule 137(2) EPC.

1. Method for starting a combustion engine (1) in a marine hybrid drive unit (100, 200), wherein the marine hybrid drive unit (100, 200) comprises the combustion engine (1) and an electric drive motor (2), wherein the combustion engine (1) comprises an electric starter unit (8), wherein a driven shaft (4) of the marine hybrid drive unit (100, 200) can be driven in a combustion engine mode solely by the combustion engine (1), in an electric propulsion mode solely by the electric drive motor (2) and in a combined mode by the combustion engine (1) and the electric drive motor (2), wherein the electric drive motor (2) is permanently connected to the driven shaft (4), the method comprising the steps:

a) starting the electric motor (2) before the com-

bustion engine and

b) starting the combustion engine (1) by the electric starter unit (8).

2. Method according to claim 1, wherein the combustion engine (1) is connected to the driven shaft (4) by means of a pressure actuated input clutch (5) before starting the combustion engine (1), wherein the oil pressure for actuating the input clutch (5) is provided by an oil pump (6), which is driven by the driven shaft (4), and wherein the pressure actuated input clutch is (5) closed after starting the electric drive motor (2).
3. Method according to claim 1 or 2, wherein the marine hybrid drive unit (100, 200) is switched in the combustion engine mode, when the combustion engine (1) has reached a preset engine speed.
4. Method according to claim 3, wherein the preset engine speed is set to a value in a range between 600 rpm and 800 rpm.
5. Marine hybrid drive unit (100, 200) comprising a control unit (101, 201), which is configured to execute a method according to one of the preceding claims.
6. Marine hybrid drive unit (100, 200) according to claim 5, wherein the electric drive motor (2) is part of a hybrid module (10, 20) comprising at least one gear step (7) between the electric drive motor (2) and the driven shaft (4).
7. Marine hybrid drive unit (100, 200) according to claim 6, wherein the ratio of the at least one gear step (7) is set to a value in the range between 2 and 3.
8. Marine hybrid drive unit (100, 200) according to one of the claims 6 to 7, wherein the hybrid module (10) comprises the pressure actuated input clutch (5).
9. Marine hybrid drive unit (100, 200) according to one of the claims 6 to 7, wherein the hybrid module (10) comprises a an input clutch (23) in form of a free-wheel unit, wherein an input element (21) of the freewheel unit is connected to a crankshaft (9) of the combustion engine (1) and wherein an output element (22) of the freewheel unit is connected to the electric drive motor (2) and to the driven shaft (4).
10. Marine hybrid drive unit according to one of the claims 6 to 9 driven shaft (4) is an input shaft of a gearbox (14) and wherein the oil pump (6) is an integral part of the gearbox (14).

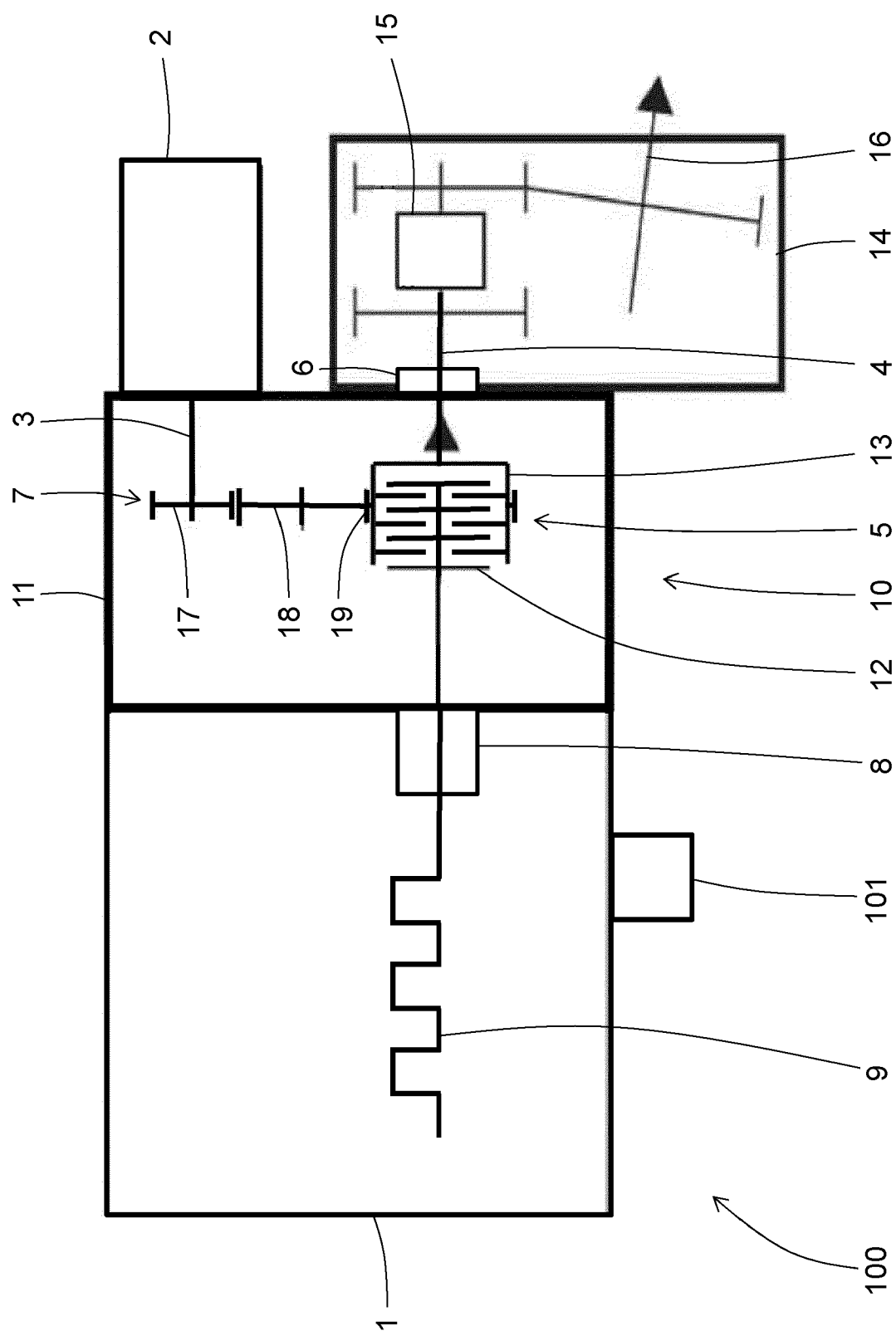


Fig. 1

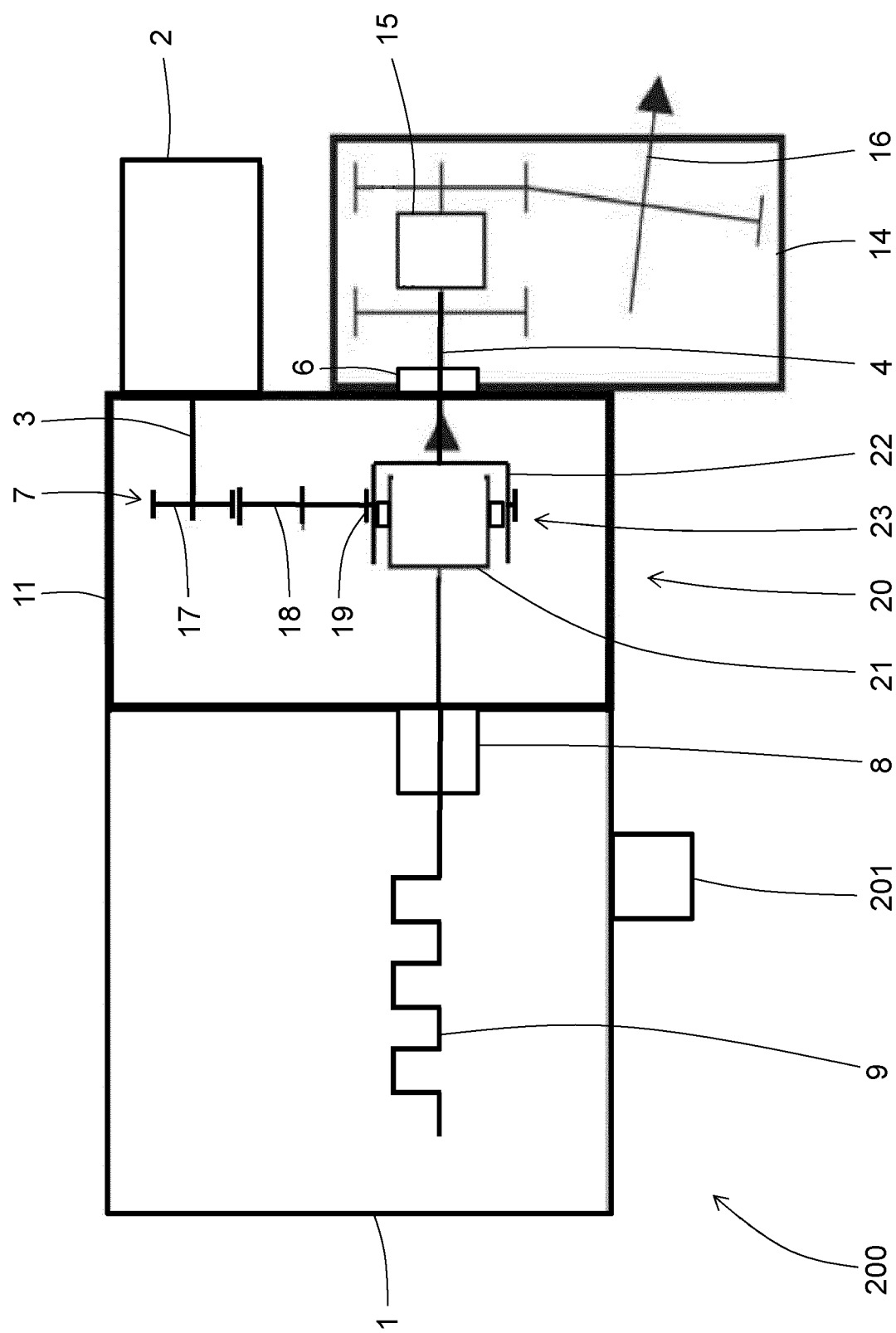


Fig. 2

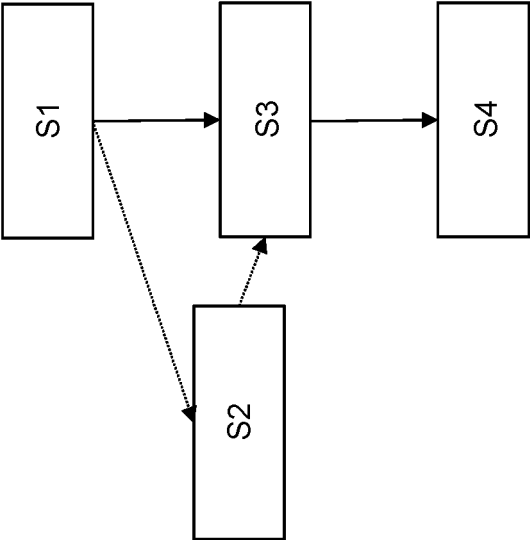


Fig. 3



EUROPEAN SEARCH REPORT

Application Number

EP 23 18 0297

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