

(19)



(11)

EP 4 480 807 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
25.12.2024 Bulletin 2024/52

(51) International Patent Classification (IPC):
B63H 21/20 (2006.01) **B63H 23/30** (2006.01)
B63H 23/12 (2006.01) **B63H 21/38** (2006.01)

(21) Application number: **23180308.1**

(52) Cooperative Patent Classification (CPC):
B63H 21/20; B63H 21/38; B63H 23/30;
B63B 79/40; B63H 23/12; B63H 2021/202;
B63H 2021/205

(22) Date of filing: **20.06.2023**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

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(54) MARINE HYBRID DRIVE UNIT AND METHOD TO DRIVE SUCH A MARINE HYBRID DRIVE UNIT

(57) Marine hybrid drive unit (100) with an electric motor (2) and a transmission (3). The transmission (3) comprises an input shaft (4), an output shaft (5) and a pressure actuated transmission clutch (6) to selectively connect the input shaft (4) to the output shaft (5). The input shaft (4) can selectively be driven solely by a combustion engine (1), solely by the electric motor (2) or by the combustion engine (1) and the electric motor (2)

simultaneously. The transmission (3) further comprises a main oil pump (7), which is driven by the input shaft (4) to provide oil pressure for actuating the pressure actuated transmission clutch (6). The marine hybrid drive unit further comprises an auxiliary oil pump (8) for providing oil pressure to the pressure actuated transmission clutch (6) during operation in a low-speed range. A method for driving such a marine hybrid drive unit (100).

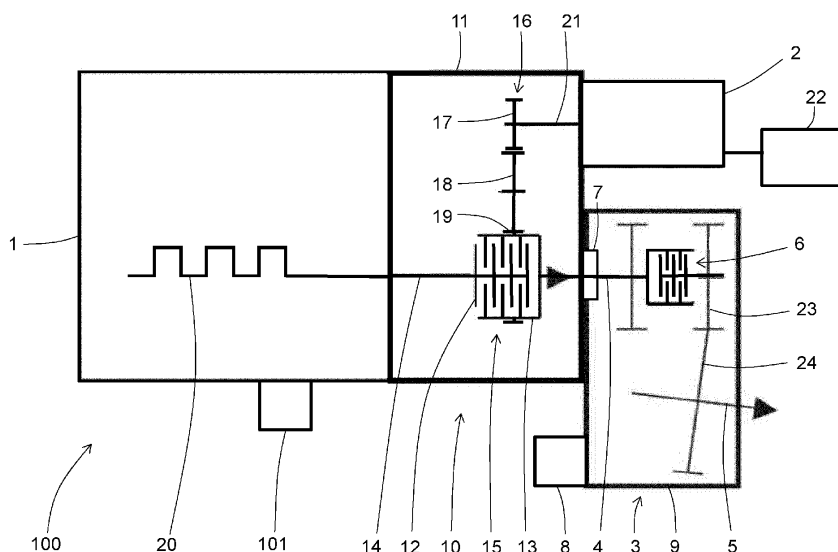


Fig. 1

Description

[0001] The present invention relates to a marine hybrid drive unit comprising a transmission with a pressure actuated transmission clutch and to a method to drive such a marine hybrid drive unit.

[0002] A typical conventional marine propulsion system comprises one or two drive trains, each with a diesel engine and a transmission with speed reduction gear steps interposed between the engine and the propeller. This type of propulsion, in which the propeller characteristics and a certain reduction ratio between the engine and the propeller are preset at the design stage, often includes a pressure actuated transmission clutch for operating at lower speeds than a nominal speed.

[0003] In recent years 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 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 motor, especially if a boat shall be propelled in a low-speed range, for example in a no-wake zone. Such no-wake zones might be in place to protect a marina by minimizing the wake created by passing boats, or because the waterway is congested. In this situation, the function of a no wake zone is like that of a speed limit on a city street. If the waterway is narrow, and perhaps especially congested, having every boat slow down simply makes for safer navigation. The combustion engine of the hybrid drive unit provides sufficient power for normal and high-speed cruising.

[0004] Different marine hybrid drive units comprising a combustion engine and an electric motor are already known from prior art. One example of a marine hybrid drive unit with a transmission has been disclosed in US 8 393 926 A. Said transmission comprising a transmission input shaft for accepting power into the transmission and a transmission output shaft for outputting power to a propeller. A first prime mover in form of a combustion engine is selectively coupled to the transmission input shaft, whereas a second prime mover in form of an electric motor is permanently coupled to the transmission input shaft. A modulatable transmission clutch assembly is operably coupled to the transmission input and output shafts such that the power and speed from the input shaft can be variably transferred to the output shaft. Such a modulatable transmission clutch assembly is configured to modulate or vary the amount of power transmitted therethrough. In a troll or trolling mode the modulatable transmission clutch is operated with a slip, i.e. with different input and output speeds. At very low speeds it is not possible to achieve a reliable and constant propeller speed with this method.

[0005] The purpose of the present invention is to provide an improved marine hybrid drive unit with a pressure actuated transmission clutch, which allows energy opti-

mized cruising conditions especially in a low-speed range.

[0006] This purpose is achieved by a marine hybrid drive unit according to claim 1 and by a method according to claim 8. Further embodiments are claimed in dependent claims.

[0007] The present invention provides a marine hybrid drive unit with an electric motor and a transmission. The transmission comprising an input shaft, an output shaft and a pressure actuated transmission clutch to selectively connect the input shaft to the output shaft. The transmission may comprise a transmission housing to, at least partially, enclose the input shaft, the pressure actuated transmission clutch and the output shaft. The input shaft can selectively be driven solely by a combustion engine, solely by the electric motor or by the combustion engine and the electric motor simultaneously. The selection of a corresponding driving mode can be controlled by a control unit of the boat, depending on the demanded speed and/or other operating conditions like charging status of batteries.

[0008] The transmission further comprises a main oil pump, which is driven by the input shaft to provide oil pressure for actuating the pressure actuated transmission clutch. Such main oil pumps which are driven by an input shaft or another transmission shaft are well-known as integral parts of transmissions in conventional marine propulsion systems. The present invention now proposes an auxiliary oil pump for supplying oil to the pressure actuated transmission clutch during operation in a low-speed range.

[0009] The auxiliary oil pump shall be installed additional to the main oil pump. The auxiliary oil pump can provide hydraulic pressure in the low-speed range, when the main pump driven by the input shaft does not supply sufficient oil pressure or volume, because the rotational speed of the driving input shaft is too slow.

[0010] In one embodiment the low-speed range can be defined to boat speeds below 5 knots. Hence, a control unit of the marine hybrid drive unit or the boat can be configured to actuate the auxiliary oil pump when a speed control signal is below 5 knots, so that the auxiliary oil pump can provide hydraulic pressure when boat is driven with a speed between 0 and 5 knots. In one alternative embodiment the low-speed range can be defined to operation with rotation speeds of the input shaft below a preset threshold in a range between 500 and 700 rpm (revolutions per minute).

[0011] In the low-speed range the boat can be driven solely by the electric motor, which is able to drive the input shaft in the low-speed range with the required torque. There can be gears installed between a motor shaft of the electric motor and the input shaft to provide for an adequate transmission ratio for a maximum efficiency of the electric motor in a drive mode and in a recharge mode. The auxiliary oil pump can be actuated as soon as the rotational speed of the input shaft is below a certain threshold. A control unit can be configured to actuate

the auxiliary oil pump when the input shaft is driven in the low-speed range and/or when the input shaft is driven solely by the electric motor. Additionally the auxiliary oil pump may be actuated, depending on current operating conditions or modes, for example when the oil pressure which is generated by the main oil pump falls under a preset threshold value.

[0012] The invention benefits from the fact, that conventional hybrid boat drive units have a relatively high energy demand in the low-speed range. Conventional hybrid drive boat units use a modulatable transmission clutch with a pressure actuated piston, which operates on clutch disks which are disposed between a rotatable driving disk-carrier and a rotatable driven disk-carrier to effect clutch modulation. In the low-speed range such a modulatable clutch is operated with slip between the driving and driven disks to achieve the requested low-speed rotation of the propeller shaft. Such low-speed operation is also called trolling mode. However, the slipping operation of the modulatable transmission clutch is demanding a significant amount of energy which does not contribute to the propulsion of the boat. A hybrid drive unit according to the present invention can be operated in the low-speed range without any slip in the transmission clutch. With other words the transmission clutch can be fully engaged during operation in the low-speed range. Hence, a significant amount of energy can be saved. The electric motor directly drives the input shaft in the low-speed range without a minimum speed limit. With other words, the invention enables an energy efficient operation in the low-speed range without any clutch trolling in the transmission. The hybrid boat drive unit according to the invention allows for operations with very low rotation speed at the output shaft corresponding to a propeller speed near to 0 rpm. A controlled and constant operation with such a low propeller speed is not possible in the conventional trolling mode with a slipping clutch.

[0013] The pressure actuated transmission clutch of the present marine hybrid drive unit does not need to be a modulatable clutch. Hence, the transmission clutch can be a modulatable clutch or another switchable clutch like a dog clutch. However, significant benefits can be achieved, when a conventional marine hybrid drive unit with a modulatable clutch is modified to the proposed marine hybrid drive unit and driven according to the method proposed further below.

[0014] The hybrid boat drive unit may further include a pressure actuated input clutch, which is provided to connect and disconnect the combustion engine to/from the input shaft. The oil pressure for the actuation of the pressure actuated input clutch may also be provided by the main oil pump when the input shaft rotates with sufficient speed. Especially in the low-speed range, the oil pressure for the actuation of the input clutch can be provided by the auxiliary oil pump.

[0015] The transmission may comprise an oil lubrication system. The main oil pump and the auxiliary oil pump can be connected to the oil lubrication system to supply

oil to the oil lubrication system. This way a correct lubrication in terms of oil flow rate and lubrication oil pressure can be ensured in all speed ranges. The control unit may control oil pressure and oil flow in the oil lubrication system for the lubrication of elements in the transmission and in the hybrid module.

[0016] The auxiliary oil pump can be an electric pump. It can be positioned outside of the transmission housing. The auxiliary oil pump may be fixed to the transmission housing and connected by oil tubes and ducts to an oil supply system of the transmission and/or marine hybrid drive unit. The auxiliary oil pump shall be configured in size and power, to provide sufficient oil volume and pressure to allow the functionality of the transmission clutch, the input clutch, and the oil lubrication system at least in the low-speed range.

[0017] Another aspect of the invention is a method for driving a marine hybrid drive unit as described above in a low-speed range solely by the electric motor, while the pressure for the pressure operated clutch is being provided by the auxiliary oil pump. The proposed method allows to operate a boat in the low-speed range with significant energy savings.

[0018] The invention will be further and more particularly described in the following, by way of example only, and with reference to the accompanying figure.

Fig. 1 shows a marine hybrid drive unit according to the invention in a schematic drawing.

[0019] The 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 motor 2 for propelling the boat in different operation modes.

[0020] The marine hybrid drive unit 100 further comprises a transmission 3 with an input shaft 4 and an output shaft 5. The input shaft 4 can selectively be driven solely by the combustion engine 1, solely by the electric motor 2 or by the combustion engine 1 and the electric motor 2 simultaneously. The output shaft 5 in this embodiment being arranged with a downward angle with regard to the input shaft 4. The output shaft 5 being connected to a propeller shaft of the boat either directly or via further transmitting elements.

[0021] The combustion engine 1 includes a crankshaft 20 which is connected to a drive shaft 14 of a hybrid module 10. The connection between the crankshaft 20 and the drive shaft 14 may comprise a flywheel and/or a torsional damper which are not shown in the scheme of Fig. 1.

[0022] In this embodiment the drive shaft 14 can be connected and disconnected to an input shaft 4 by means of a pressure actuated input clutch 15. The crankshaft 20 and the input shaft 4 are arranged coaxial to each other. The crankshaft 20 is fastened to an input element 12 of the input clutch 15 whereas the input shaft 4 is fastened to an output element 13 of the input clutch 15. The input

clutch 15 in this embodiment is a multi-disk-friction-clutch with inner and outer friction disks. The input element 12 being designed as an inner disk-carrier, whereas the output element 13 is designed as an outer disk-carrier. The inner and outer friction disks are pressed against each other to provide for the required transmission of torque.

[0023] The input clutch 15 and the electric motor 2 are part of the hybrid module 10 which is mounted in between the combustion engine 1 and the transmission 3. The electric motor 2 is mounted to a module housing 11 of the hybrid module 10 such, that a motor shaft 21 of the electric motor 2 is arranged in parallel to the input shaft 4. The electric motor 2 is permanently connected to the input shaft 4 and to the output element 13 of the input clutch 15. The input shaft 4 is permanently connected to the electric motor 2 via gear steps 16, wherein a gear ratio of the gear steps 16 is set to drive the input shaft 4 with the main oil pump 7. The gear ratio of the gear steps 16 is in a range between 2 and 3 which allows for efficient operation when the electric motor 2 is driving the input shaft 4 and when the electric motor 2 is driven as a generator to recharge an electric battery 22 which is connected to the electric motor 2. The gear steps 16 are part of the hybrid module 10 and arranged inside the module housing 11. The gear steps 16 comprise a first spur gear 17 which is fastened to the motor shaft 21. The first spur gear 17 meshes with a second spur gear 18 which is supported in the module housing 11. 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 15. The pressure actuated input clutch 15 is also a part of the hybrid module 10.

[0024] The transmission 3 further includes a pressure actuated transmission clutch 6 to selectively connect the input shaft 4 to the output shaft 5. The pressure actuated transmission clutch 6 is arranged inside a transmission housing 9. The pressure actuated transmission clutch 6 is a hydraulically actuated multi-disk clutch. The input shaft 4 is fastened to an outer disk carrier of the transmission clutch 6, whereas an inner disk carrier of the transmission clutch 6 is rigidly fastened to a pinion 23. Pinion 23 is permanently meshing with an output gear 24 which is fastened to the output shaft 5.

[0025] The pressure actuated transmission clutch 6 can be fully engaged, fully disengaged or it can be operated in slipping operation. The slipping operation of the transmission clutch 6 can be used to adjust the speed of the output shaft 5 continuously in a range between 100% and 25% with regard to the speed of the input shaft 4. However, the present invention provides an arrangement and a method to avoid the energy consuming slipping operation of the transmission clutch 6 in the low-speed range, by using only the electric motor 2 for generating the required drive torque and speed, while the transmission clutch 6 is fully engaged.

[0026] The transmission 3 comprises a main oil pump 7 and an auxiliary oil pump 8. The main oil pump 8 is driven

by the input shaft 4 to provide oil to the oil lubrication system, for actuating the pressure actuated input clutch 15 and for actuating the pressure actuated transmission clutch 6. An auxiliary oil pump 8 is positioned outside of the transmission housing 9 and shall be actuated during operation in the low-speed range. The auxiliary oil pump 8 is an electric pump and comprises an electric pump motor.

[0027] A control unit 101 of the marine hybrid drive unit 100 is arranged to control the propulsion in different operating modes. Especially for operations in the low-speed range, the control unit 101 is configured to actuate the auxiliary oil pump 8 and to generate signals for driving the input shaft 4 solely by the electric motor 2. The control unit 101 contains electronic components and hydraulic components like valves for the control of oil flow and oil pressure in the oil supply system. The control unit 101 further includes interfaces to be connected to a control unit of the combustion engine 1 and/or to other control units of the boat. In other embodiments the control unit 101 may be located at another position in the boat and the control unit 101 may comprise several separate control boxes or devices.

[0028] The auxiliary oil pump 8 can be actuated by a control unit 101, which is configured to actuate the auxiliary oil pump 8 when a speed control signal is below 5 knots. The speed control signal can be generated by a human machine interface like a control or command lever at the helmstand of the boat. The control unit 101 will receive the speed control signal and generate corresponding command signals to the combustion engine 1, the electric motor 2 and to the auxiliary oil pump 8, depending on the position of the control or command lever. In alternative embodiments the low speed range can be defined to rotation speeds below a preset threshold in a range between 500 and 700 rpm at the input shaft 4, so that the control unit 101 can actuate the auxiliary oil pump 8 when a sensor signal from an input shaft speed sensor signals a speed of the input shaft 4 below 700 rpm.

[0029] The oil supply system includes the main oil pump 7, the auxiliary oil pump 8, as well as all required connecting ducts and/or pipes, valves and further hydraulic components to provide and to control an appropriate oil pressure for the actuation of the transmission and the input clutches 6, 15 and for the oil lubrication system.

Referrals

[0030]

1	combustion engine
2	electric motor
3	transmission
4	input shaft
5	output shaft
6	transmission clutch
7	main oil pump

8 auxiliary oil pump
 9 transmission housing
 10 hybrid module
 11 module housing
 12 input element
 13 output element
 14 drive shaft
 15 input clutch
 16 gear steps
 17 first spur gear
 18 second spur gear
 19 toothing
 20 crankshaft
 21 motor shaft
 22 electric battery
 23 pinion
 24 output gear
 100 marine hybrid drive unit
 101 control unit

Claims

1. Marine hybrid drive unit (100) with an electric motor (2) and a transmission (3),

the transmission (3) comprising an input shaft (4), an output shaft (5) and a pressure actuated transmission clutch (6) to selectively connect the input shaft (4) to the output shaft (5), wherein the input shaft (4) can selectively be driven solely by a combustion engine (1), solely by the electric motor (2) or by the combustion engine (1) and the electric motor (2) simultaneously, the transmission (3) further comprising a main oil pump (7), which is driven by the input shaft (4) to provide oil pressure for actuating the pressure actuated transmission clutch (6), **characterized by** an auxiliary oil pump (8) for providing oil pressure to the pressure actuated transmission clutch (6) during operation in a low-speed range.

2. Marine hybrid drive unit (100) according to claim 1, wherein a control unit (101) is configured to actuate the auxiliary oil pump (8) when a speed control signal is below 5 knots.

3. Marine hybrid drive unit (100) according to claim 1 or 2, wherein a control unit (101) is configured to actuate the auxiliary oil pump (8) when a rotation speed of the input shaft (4) is below a preset threshold in a range between 500 and 700 rpm.

4. Marine hybrid drive unit (100) according to one of the preceding claims, wherein a control unit (101) is configured to actuate the auxiliary oil pump (8) when the input shaft (4) is driven solely by the electric motor (2).

5. Marine hybrid drive unit (100) according to one of the preceding claims, wherein a pressure actuated input clutch (15) is provided to connect and disconnect the combustion engine (1) to the input shaft (4), and wherein the main oil pump (7) and the auxiliary oil pump (8) are arranged to provide oil for the actuation of the pressure actuated input clutch (15).

6. Marine hybrid drive unit (100) according to one of the preceding claims, wherein the transmission (3) comprises an oil lubrication system, and wherein the main oil pump (7) and the auxiliary oil pump (8) are connected to the oil lubrication system to supply oil to the oil lubrication system.

7. Marine hybrid drive unit (100) according to one of the preceding claims, wherein the auxiliary oil pump (8) is positioned outside of a transmission housing (9) of the transmission (3).

8. Method for driving a marine hybrid drive unit (100) according to one of the preceding claims, wherein the input shaft (4) is driven in a low-speed range solely by the electric motor (2), while the pressure for the pressure actuated transmission clutch (6) is being provided by an auxiliary oil pump (8).

9. Method according to claim 8, wherein the low-speed range is defined to boat speeds between 0 and 5 knots.

10. Method according to claim 8, wherein the low-speed range is defined to rotation speeds of the input shaft (4) below a preset threshold in a range between 500 and 700 rpm.

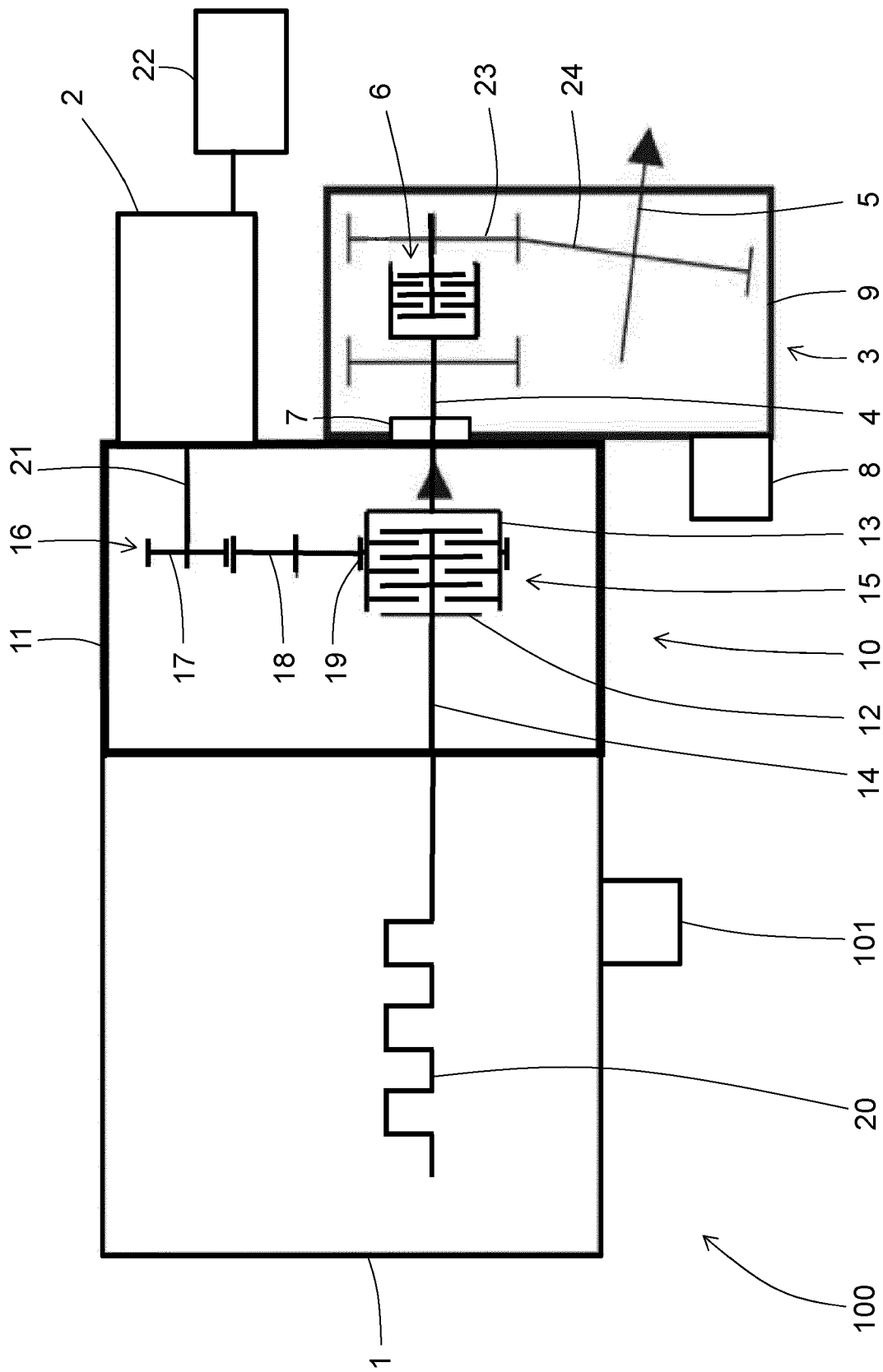


Fig. 1



EUROPEAN SEARCH REPORT

Application Number

EP 23 18 0308

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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
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