(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 358 202 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
08.08.2018 Bulletin 2018/32

(21) Application number: **16850879.4**

(22) Date of filing: **03.08.2016**

(51) Int Cl.:
F15B 21/14 *(2006.01)* ***F15B 11/00*** *(2006.01)*

(86) International application number:
PCT/JP2016/072738

(87) International publication number:
WO 2017/056702 (06.04.2017 Gazette 2017/14)

(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 MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **28.09.2015 JP 2015190291**

(71) Applicant: **Bosch Rexroth Corporation**
Tokyo 150-0002 (JP)

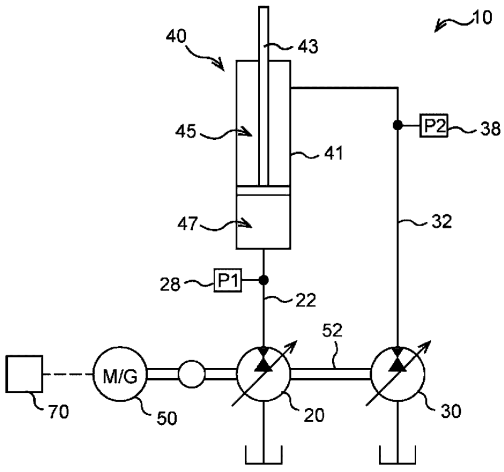
(72) Inventors:
- **HOMMA Yoshikazu**
  Tokyo 150-0002 (JP)
- **YAMAGUCHI Masahito**
  Tsuchiura-shi
  Ibaraki 300-8588 (JP)
- **WATANABE Shingo**
  Tsuchiura-shi
  Ibaraki 300-8588 (JP)

(74) Representative: **Bee, Joachim**
Robert Bosch GmbH, C/IPE
P.O. Box 30 02 20
70442 Stuttgart (DE)

(54) HYDRAULIC CYLINDER DRIVE DEVICE

(57) A hydraulic cylinder drive device includes: a hydraulic cylinder that includes a piston rod actuating a device; a motor generator that functions as a motor actuated by electric power from outside of the device and functions as a generator supplying the electric power to the outside of the device; a first variable displacement pump motor coupled to the motor generator, functions as a hydraulic pump supplying a pressure to a cap-side pressure chamber in the hydraulic cylinder, and functions as a power unit of the motor generator by the pressure supplied from the cap-side pressure chamber; and a second variable displacement pump motor coupled to the motor generator, functions as a hydraulic pump supplying a pressure to a rod-side pressure chamber in the hydraulic cylinder, and functions as a power unit of the motor generator by the pressure supplied from the rod-side pressure chamber.

[FIG. 2]



EP 3 358 202 A1

Description

Technical Field

[0001] The invention relates to a hydraulic cylinder drive device for actuating a device to be actuated.

Background Art

[0002] As a hydraulic cylinder drive device for actuating a device to be actuated, a hydraulic cylinder drive system that supplies a hydraulic pressure to each of a rod-side pressure chamber and a cap-side pressure chamber in a hydraulic cylinder provided with a piston rod so as to actuate the device to be actuated has been available. For example, a boom of an operating machine, such as a construction machine or an unloader, is raised or lowered by using such a hydraulic cylinder drive device. For example, in the operating machine, the boom is tiltably supported by a boom support section in a manner that the boom can freely be raised or lowered, an operated portion such as a bucket is provided on a tip side of said boom, a counterweight is attached to a rear end side thereof, and the operated portion and the counterweight can move vertically with respect to each other with the boom support section being a support point. In such an operating machine, the hydraulic cylinder is driven to raise or lower the boom.

[0003] When the boom is raised, the hydraulic cylinder is actuated in a rod extending direction. At this time, a raising speed of the boom is controlled by controlling a supply amount of hydraulic oil to the cap-side pressure chamber and a discharge amount of the hydraulic oil from the rod-side pressure chamber in the hydraulic cylinder. Meanwhile, when the boom is lowered, the hydraulic cylinder is actuated in a rod retracting direction. At this time, a lowering speed of the boom is controlled by controlling the supply amount of the hydraulic oil to the rod-side pressure chamber and the discharge amount of the hydraulic oil from the cap-side pressure chamber in the hydraulic cylinder.

[0004] In Non-Patent Literature 1, an example of a hydraulic circuit that is applied to such a hydraulic cylinder drive device is disclosed. Such a hydraulic circuit includes: a hydraulic pump that supplies the hydraulic oil; and plural valves used to supply the hydraulic oil, which is supplied by the hydraulic pump, to the rod-side pressure chamber or the cap-side pressure chamber in the hydraulic cylinder or to discharge the hydraulic oil from the rod-side pressure chamber or the cap-side pressure chamber.

Citation List

Non-Patent Literature

[0005] Non-Patent Literature 1: Fujikoshi Kenkyu Group, "Shiritai Yuatsu/Kisohen" (What You Want to Know About Hydraulic Pressure/Basic Edition), 8th Edition, issued by Japan Machinist-Sha, p.315, 1989-09-20

Disclosure of Invention

Technical Problem

[0006] By the way, the hydraulic oil that is discharged to a tank may reach a high temperature in the hydraulic cylinder drive device as described above. For this reason, a hydraulic cylinder drive device that includes an oil cooler in a discharge oil path, through which the hydraulic oil is returned to the tank, has been available. Fig. 5 is an exemplary diagram of a hydraulic circuit 200 that includes an oil cooler 230. Such a hydraulic circuit 200 includes: a hydraulic cylinder 240 that has a piston rod 243 capable of extending and retracting in a cylinder tube 241; a hydraulic pump 220 that is driven by a motor 250 and supplies the hydraulic oil; and a direction selector valve 260 that leads the supplied hydraulic oil to a rod-side pressure chamber 245 or a cap-side pressure chamber 247.

[0007] A first control oil path 224 communicates between the direction selector valve 260 and the cap-side pressure chamber 247, and a second control oil path 226 communicates between the direction selector valve 260 and the rod-side pressure chamber 245. The first control oil path 224 and the second control oil path 226 respectively include flow rate control valves 270, 280 and one-way valves 272, 282. In addition, the oil cooler 230 is provided in a discharge oil path 228 through which the hydraulic oil discharged via the direction selector valve 260 is led to a tank 234. A relief valve 232 is provided between a supply-side oil path 222 of the hydraulic pump 220 and the discharge oil path 228.

[0008] In such a hydraulic cylinder drive device, in the case where the hydraulic cylinder 240 is actuated in the rod extending direction, the direction selector valve 260 communicates between the supply-side oil path 222 of the hydraulic pump 220 and the first control oil path 224 and communicates between the second control oil path 226 and the discharge oil path 228. In this way, the hydraulic oil is supplied to the cap-side pressure chamber 247 through the one-way valve 272, and the hydraulic oil in the rod-side pressure chamber 245 is returned to the tank 234 through the second control oil path 226 and the discharge oil path 228 while a flow rate of the hydraulic oil is controlled by the flow rate control valve 280.

[0009] Meanwhile, in the case where the hydraulic cylinder 240 is actuated in the rod retracting direction, the direction selector valve 260 communicates between the supply-side oil path 222 of the hydraulic pump 220 and the second control oil path 226 and communicates between the first control oil path 224 and the discharge oil path 228. In this way, the hydraulic oil is supplied to the rod-side pressure chamber 245 through the one-way valve 282, and the hydraulic oil in the cap-side pressure chamber 247 is returned to the tank 234 through the first control oil path 224 and the discharge oil path 228 while

the flow rate of the hydraulic oil is controlled by the flow rate control valve 270.

[0010] At this time, the hydraulic oil, which is discharged from the hydraulic cylinder 240, and the flow rate of which is lowered by either one of the flow rate control valves 270, 280, reaches the high temperature. Such high-temperature hydraulic oil is cooled by the oil cooler 230 and is then returned to the tank 234, and energy generated in the hydraulic cylinder drive system is released as thermal energy. Thus, energy efficiency is degraded. In addition, due to requirement of the large oil cooler 230 and the large number of the valves to be used, simplification of such a hydraulic cylinder drive device has been desired.

[0011] The invention has been made in view of the above problems; therefore, the invention has a purpose of providing a novel and improved hydraulic cylinder drive device capable of having a simple configuration and improving energy efficiency.

Solution to Problem

[0012] In order to solve the above problems, an aspect of the invention provides a hydraulic cylinder drive device that includes: a hydraulic cylinder that includes a piston rod actuating a device to be actuated; a motor generator that functions as a motor actuated by electric power from outside of the device and functions as a generator supplying the electric power to the outside of the device; a first variable displacement pump motor that is coupled to the motor generator, functions as a hydraulic pump supplying a hydraulic pressure to a cap-side pressure chamber in the hydraulic cylinder, and functions as a power unit of the motor generator by using the hydraulic pressure supplied from the cap-side pressure chamber; and a second variable displacement pump motor that is coupled to the motor generator, functions as a hydraulic pump supplying a hydraulic pressure to a rod-side pressure chamber in the hydraulic cylinder, and functions as a power unit of the motor generator by using the hydraulic pressure supplied from the rod-side pressure chamber.

[0013] The first variable displacement pump motor and the second variable displacement pump motor may be connected to the same driveshaft, and the motor generator may be coupled to the driveshaft.

[0014] The motor generator may be subjected to inverter control.

[0015] The motor generator may include: a first motor generator that is coupled to a first driveshaft of the first variable displacement pump motor; and a second motor generator that is coupled to a second driveshaft of the second variable displacement pump motor.

[0016] At least one of the first motor generator and the second motor generator may be subjected to the inverter control.

[0017] The device to be actuated may be a boom drive system in an operating machine.

Advantageous Effects of Invention

[0018] As it has been described so far, according to the invention, a device configuration can be simplified, and energy efficiency can be improved.

Brief Description of Drawings

[0019]

Fig. 1 is a view illustrating a boom drive system to which a hydraulic cylinder drive device according to the invention can be applied.

Fig. 2 is a circuit diagram illustrating a configuration of a hydraulic cylinder drive device according to a first embodiment of the invention.

Fig. 3 is a cross-sectional view of a variable displacement pump motor of an over center type.

Fig. 4 is a circuit diagram illustrating a configuration of a hydraulic cylinder drive device according to a second embodiment of the invention.

Fig. 5 is a circuit diagram illustrating a configuration of a conventional hydraulic cylinder drive device.

Description of Embodiments

[0020] A detailed description will hereinafter be made on preferred embodiments of the invention with reference to the accompanying drawings. In the specification and the drawings, components that have substantially the same functional configurations will be denoted by the same reference signs, and a description thereon will not be repeated.

<1. First Embodiment>

(1-1. Boom Drive System)

[0021] First, a simple description will be made on a boom drive device to which a hydraulic cylinder drive system according to this embodiment can be applied. The boom drive system is an example of the device to be actuated. Fig. 1 is a schematic view of a boom drive system 100. For example, the boom drive system 100 is mounted on an operating machine such as a construction machine or an unloader.

[0022] The boom drive system 100 includes a boom support section 110, a boom 120, an operation section 130, an arm 140, and a hydraulic cylinder 40. On the boom support section 110, the boom 120 is tiltably supported in a manner that the boom 120 can freely be raised or lowered. In the hydraulic cylinder 40, a cylinder tube is attached to the boom support section 110, and a piston rod is attached to the boom 120. The hydraulic cylinder 40 controls a raising/lowering operation of the boom 120.

[0023] The arm 140 is supported at a tip of the boom 120 in a freely turnable manner. The operation section 130 is provided at a lower end of the arm 140. A coun-

terweight 126 is provided at a rear end of the boom 120. In this way, in conjunction with the raising/lowering operation of the boom 120, the operation section 130 and the counterweight 126 can move vertically with respect to each other with an upper portion of the boom support section 110 being a support point. The raising/lowering operation of the boom 120 is performed through drive control of the hydraulic cylinder 40.

[0024] In such a boom drive system 100, the counterweight 126 has weight that possibly causes the tip of the boom 120 to rotate upward in an unloaded state of the boom drive system 100, that is, a state where no heavy object is loaded on the operation section 130. In order to raise or lower the tip of the boom 120, the hydraulic cylinder drive device according to this embodiment executes control to supply hydraulic oil to the hydraulic cylinder 40 or to discharge the hydraulic oil from the hydraulic cylinder 40, and thereby controls the raising/lowering operation of the boom 120.

(1-2. Hydraulic Cylinder Drive Device)

[0025] Next, a description will be made on an exemplary configuration of a hydraulic cylinder drive device 10 according to the first embodiment of the invention. Fig. 2 is a circuit diagram illustrating a configuration of a hydraulic circuit in the hydraulic cylinder drive device 10. The hydraulic cylinder drive device 10 includes a first variable displacement pump motor 20, a second variable displacement pump motor 30, a motor generator 50, and the hydraulic cylinder 40.

(1-2-1. Hydraulic Cylinder)

[0026] The hydraulic cylinder 40 is attached to the boom 120 and the boom support section 110 in the boom drive system 100 depicted in Fig. 1, and includes a cylinder tube 41 and a piston rod 43 capable of extending and retracting in the cylinder tube 41. The cylinder tube 41 is attached to the boom support section 110, and the piston rod 43 is attached to the boom 120. The cylinder tube 41 is divided into a rod-side pressure chamber 45 and a cap-side pressure chamber 47 through the piston rod 43.

[0027] The cap-side pressure chamber 47 communicates with a first control oil path 22 that is connected to the first variable displacement pump motor 20. The rod-side pressure chamber 45 communicates with a second control oil path 32 that is connected to the second variable displacement pump motor 30. The first control oil path 22 and the second control oil path 32 are respectively provided with pressure detectors 28, 38, each of which measures a pressure in the corresponding oil path.

(1-2-2. Variable Displacement Pump Motors)

[0028] The first variable displacement pump motor 20 has a function as a hydraulic pump that supplies the hydraulic oil to the cap-side pressure chamber 47 in the hydraulic cylinder 40, and also has a function as a hydraulic motor that rotationally drives a driveshaft 52 by using the hydraulic oil discharged from the cap-side pressure chamber 47. The second variable displacement pump motor 30 has a function as a hydraulic pump that supplies the hydraulic oil to the rod-side pressure chamber 45 in the hydraulic cylinder 40, and also has a function as a hydraulic motor that rotationally drives the driveshaft 52 by using the hydraulic oil discharged from the rod-side pressure chamber 45.

[0029] In the hydraulic cylinder drive device 10 according to this embodiment, the first variable displacement pump motor 20 and the second variable displacement pump motor 30 are coupled to the same driveshaft 52. Accordingly, in the case where one of the variable displacement pump motors functions as the hydraulic pump and the other variable displacement pump motor functions as the hydraulic motor, rotation drive energy that is generated by the hydraulic motor for the driveshaft 52 is used as energy for driving the hydraulic pump.

[0030] Thus, in the case where energy that is required to drive the variable displacement pump motor as the hydraulic pump is higher than the rotation drive energy generated by the variable displacement pump motor as the hydraulic motor, electric power consumption for driving the motor generator 50 can be reduced. Meanwhile, in the case where the energy that is required to drive the variable displacement pump motor as the hydraulic pump is lower than the rotation drive energy generated by the variable displacement pump motor as the hydraulic motor, a surplus of the rotation drive energy is used for rotation of the motor generator 50, and thus regenerative power can be generated.

[0031] A simple description will be made on configuration examples of the first variable displacement pump motor 20 and the second variable displacement pump motor 30. Fig. 3 is a cross-sectional view of an example of the variable displacement pump motor. Here, the first variable displacement pump motor 20 and the second variable displacement pump motor 30 may basically have the same configuration.

[0032] The variable displacement pump motor depicted in Fig. 3 is a piston pump motor of a variable displacement swash plate type. The variable displacement pump motor includes a cover 161, a pump housing 168, and a driveshaft 170 axially supported by the cover 161 and the pump housing 168. The cover 161 is provided with a first supply/discharge passage 163 through which the hydraulic oil to be suctioned flows when the variable displacement pump motor functions as the hydraulic pump and through which the discharged hydraulic oil flows when the variable displacement pump motor functions as the hydraulic motor. In addition, the cover 161 is provided with a second supply/discharge passage 165 through which the discharged hydraulic oil flows when the variable displacement pump motor functions as the hydraulic pump and through which the hydraulic oil to be

suctioned flows when the variable displacement pump motor functions as the hydraulic motor.

[0033] The first supply/discharge passage 163 communicates with an unillustrated tank in which the hydraulic oil is stored. The second supply/discharge passage 165 communicates with the pressure chamber in the hydraulic cylinder 40. In a case of the first variable displacement pump motor 20, the second supply/discharge passage 165 communicates with the cap-side pressure chamber 47. In a case of the second variable displacement pump motor 30, the second supply/discharge passage 165 communicates with the rod-side pressure chamber 45.

[0034] A cylinder block 180 is coupled to the driveshaft 170, and the cylinder block 180 integrally rotates with the driveshaft 170. A port plate 190 is provided on one end side of the cylinder block 180, and a swash plate 175 is provided on the other side of the cylinder block 180. A surface on the one end side of the cylinder block 180 slidably contacts the port plate 190. In the cylinder block 180, plural cylinders 182 are placed along an axial direction of the driveshaft 170. A piston 185 is inserted in each of the cylinders 182 in an axially movable manner, and a volume chamber 188 is configured by the cylinders 182 and the piston 185. The volume chamber 188 can communicate with the first supply/discharge passage 163 and the second supply/discharge passage 165, which are formed in the cover 161, via hydraulic ports 192, 194 provided in the port plate 190.

[0035] An end of the piston 185 that protrudes from the cylinder 182 slidably contacts the swash plate 175. When the cylinder block 180 rotates with the driveshaft 170, the piston 185 rotates about the driveshaft 170 while slidably contacting the swash plate 175. In a state where the swash plate 175 is tilted with respect to a surface that is orthogonal to the driveshaft 170, the piston 185 reciprocates in the cylinder 182 in conjunction with this rotation, which expands or contracts the volume chamber 188.

[0036] When the variable displacement pump motor functions as the hydraulic pump, the swash plate 175 is tilted such that the first supply/discharge passage 163 in the cover 161 communicates with the volume chamber 188 in a region where the volume chamber 188 expands and that the second supply/discharge passage 165 communicates with the volume chamber 188 in a region where the volume chamber 188 contracts. In this way, in conjunction with the rotation of the variable displacement pump motor, the hydraulic oil that is stored in the tank is suctioned into the volume chamber 188 via the first supply/discharge passage 163, is then pressurized in the volume chamber 188, and is thereafter supplied via the second supply/discharge passage 165. A pump supply flow rate can be adjusted by controlling a tilt amount.

[0037] When the variable displacement pump motor functions as the hydraulic motor, the swash plate 175 is tilted such that the first supply/discharge passage 163 communicates with the volume chamber 188 in the region where the volume chamber 188 contracts and that the second supply/discharge passage 165 communicates with the volume chamber 188 in the region where the volume chamber 188 expands. In this way, the variable displacement pump motor is rotationally driven by using the hydraulic pressure that is discharged from the pressure chamber in the hydraulic cylinder 40, and output torque is generated by the driveshaft 170.

[0038] Tilt (the tilt amount) of the swash plate 175 can be adjusted by a hydraulic actuator 195. In particular, in this embodiment, the variable displacement pump motor of an over center type is used, and the swash plate 175 is configured to be tiltable not only in one direction but in both directions. Such a hydraulic actuator 195 is constructed of a hydraulic circuit that includes a direction selector valve and the like, selectively increases the pressure of the hydraulic oil that is supplied to either one pressure chamber of the two pressure chambers, and can thereby tilt the swash plate 175 in either one of the directions. In addition, the hydraulic actuator 195 supplies the hydraulic oil to the two pressure chambers in specified balance and can thereby set the tilt amount to zero. In this way, the function of the variable displacement pump motor as the hydraulic pump or the hydraulic motor can be stopped.

[0039] The hydraulic actuator 195, which adjusts the tilt amount, is controlled by an unillustrated electronic control unit. The electronic control unit controls the direction selector valve and the like on the basis of an actuation direction of the boom 120, hydraulic pressures P1, P2 that are measured by the pressure detectors 28, 38 provided in the first control oil path 22 and the second control oil path 32, and the like, and thereby appropriately adjusts a tilt direction and the tilt amount of the swash plate 175.

(1-2-3. Motor Generator)

[0040] The motor generator 50 functions as a motor that is actuated by electric power supplied from an electric power supply 70 on the outside of the hydraulic cylinder drive device 10 and rotationally drives the driveshaft 52. The motor generator 50 also functions as a generator that rotates by using a rotation driving force of the driveshaft 52 and supplies the electric power to the outside of the hydraulic cylinder drive device 10, the rotation driving force being generated by the first variable displacement pump motor 20 or the second variable displacement pump motor 30 that functions as the hydraulic motor.

[0041] The motor generator 50 is constructed of a three-phase AC motor, for example. The motor generator 50 generates the rotation driving force that is applied to the driveshaft 52. The generated rotation driving force is output in accordance with required driving forces of the first variable displacement pump motor 20 and the second variable displacement pump motor 30. In addition, the motor generator 50 rotates by using rotation torque of the driveshaft 52 and generates the regenerative power. The generated regenerative power is supplied to unillustrated electric power load equipment. For example,

the generated regenerative power is used as the electric power in a plant in which the boom drive system 100 is installed. The regenerative power maybe stored in a battery, an electrical storage device, or the like.

(1-3. Examples of Use)

[0042] A description will hereinafter be made on examples of using the hydraulic cylinder drive device 10 that drives the boom drive system 100.

(1-3-1. During Raising of Boom)

[0043] When the tip of the boom 120 in the boom drive system 100 is raised, the first variable displacement pump motor 20 functions as the hydraulic pump, and the second variable displacement pump motor 30 functions as the hydraulic motor. That is, in the hydraulic cylinder 40, while the hydraulic oil is supplied to the cap-side pressure chamber 47, the hydraulic oil is discharged from the rod-side pressure chamber 45. At the time, the electronic control unit controls the tilt amounts in the first variable displacement pump motor 20 and the second variable displacement pump motor 30 on the basis of a boom speed that is set on the outside and measurement values of the pressure detectors 28, 38 that are respectively provided in the first control oil path 22 and the second control oil path 32.

[0044] More specifically, while monitoring the hydraulic pressures P1, P2 in the first control oil path 22 and the second control oil path 32, the electronic control unit controls the tilt amounts in the first variable displacement pump motor 20 and the second variable displacement pump motor 30 such that an extending speed of the piston rod 43 matches a desired speed.

[0045] At this time, the second variable displacement pump motor 30 functions as the hydraulic motor that rotationally drives the driveshaft 52 by using the hydraulic oil discharged from the rod-side pressure chamber 45, and thereby generates the rotation driving force for the driveshaft 52. Accordingly, the rotation driving force for the driveshaft 52, which is generated by the second variable displacement pump motor 30, can be used for the first variable displacement pump motor 20 to supply the hydraulic oil. Thus, a magnitude of the electric power of the motor generator 50 can be set low.

[0046] In the case where the rotation driving force for the driveshaft 52, which is generated by the second variable displacement pump motor 30, exceeds the required rotation driving force for the first variable displacement pump motor 20 to supply the hydraulic oil, a surplus of the rotation driving force for the driveshaft 52, which is generated by the second variable displacement pump motor 30, is converted to the electric power by the motor generator 50. The generated electric power is supplied to the unillustrated electric power load equipment.

(1-3-2. During Lowering of Boom)

[0047] When the tip of the boom 120 in the boom drive system 100 is lowered, the first variable displacement pump motor 20 functions as the hydraulic motor, and the second variable displacement pump motor 30 functions as the hydraulic pump. That is, while the hydraulic oil is supplied to the rod-side pressure chamber 45 in the hydraulic cylinder 40, the hydraulic oil is discharged from the cap-side pressure chamber 47. At the time, similar to the case during raising of the boom 120, the electronic control unit controls the tilt amounts in the first variable displacement pump motor 20 and the second variable displacement pump motor 30 on the basis of the boom speed that is set on the outside and the measurement values of the pressure detectors 28, 38 that are respectively provided in the first control oil path 22 and the second control oil path 32.

[0048] More specifically, while monitoring the hydraulic pressures P1, P2 in the first control oil path 22 and the second control oil path 32, the electronic control unit controls the tilt amounts in the first variable displacement pump motor 20 and the second variable displacement pump motor 30 such that a retracting speed of the piston rod 43 matches a desired speed.

[0049] At this time, the first variable displacement pump motor 20 functions as the hydraulic motor that rotationally drives the driveshaft 52 by using the hydraulic oil discharged from the cap-side pressure chamber 47, and thereby generates the rotation driving force for the driveshaft 52. Accordingly, the rotation driving force for the driveshaft 52, which is generated by the first variable displacement pump motor 20, can be used for the second variable displacement pump motor 30 to supply the hydraulic oil. Thus, the magnitude of the electric power of the motor generator 50 can be set low.

[0050] In the case where the rotation driving force for the driveshaft 52, which is generated by the first variable displacement pump motor 20, exceeds the required rotation driving force for the second variable displacement pump motor 30 to supply the hydraulic oil, the surplus of the rotation driving force for the driveshaft 52, which is generated by the first variable displacement pump motor 20, is converted to the electric power by the motor generator 50. The generated electric power is supplied to the unillustrated electric power load equipment.

[0051] As it has been described so far, the hydraulic cylinder drive device 10 according to this embodiment includes: the first variable displacement pump motor 20 that functions as the hydraulic pump supplying the hydraulic oil to the cap-side pressure chamber 47 in the hydraulic cylinder 40 and functions as a power unit of the motor generator 50 by using the hydraulic oil discharged from the cap-side pressure chamber 47; and the second variable displacement pump motor 30 that functions as the hydraulic pump supplying the hydraulic oil to the rod-side pressure chamber 45 in the hydraulic cylinder 40 and functions as a power unit of the motor generator 50

by using the hydraulic oil discharged from the rod-side pressure chamber 45.

[0052] The rotation driving force generated by one of the variable displacement pump motors that functions as the hydraulic motor assists the other variable displacement pump motor to be rotationally driven as the hydraulic pump. In this way, an electric power amount of the motor generator 50 that is used to rotationally drive the driveshaft 52 can be reduced. Furthermore, in the case where the rotation driving force generated by the variable displacement pump motor that functions as the hydraulic motor exceeds the required rotation driving force for the variable displacement pump motor that functions as the hydraulic pump, the motor generator 50 generates the regenerative electric power by using the surplus of the rotation driving force. Thus, energy efficiency is improved.

[0053] The hydraulic cylinder drive device 10 according to this embodiment does not include the direction selector valve, the flow rate control valve, the oil cooler, or the like but has a simple configuration. Thus, cost can be cut, and the energy efficiency is improved.

<2. Second Embodiment>

[0054] Next, a description will be made on a hydraulic cylinder drive device according to a second embodiment of the invention. The hydraulic cylinder drive device according to this embodiment differs from the hydraulic cylinder drive device according to the first embodiment in a point that the first variable displacement pump motor and the second variable displacement pump motor are subjected to drive control by separated motor generators.

[0055] Fig. 4 is a circuit diagram illustrating a configuration of a hydraulic circuit in a hydraulic cylinder drive device 10A according to this embodiment. The hydraulic cylinder drive device 10A includes the first variable displacement pump motor 20, the second variable displacement pump motor 30, a first motor generator 50a, a second motor generator 50b, and the hydraulic cylinder 40. Each of the first variable displacement pump motor 20, the second variable displacement pump motor 30, and the hydraulic cylinder 40 may have the same configuration as that in the hydraulic cylinder drive device 10 according to the first embodiment.

[0056] In this embodiment, the first variable displacement pump motor 20 is driven by the first motor generator 50a, and the second variable displacement pump motor 30 is driven by the second motor generator 50b. In the hydraulic cylinder drive device 10A according to this embodiment, a driveshaft 52a of the first variable displacement pump motor 20 and a driveshaft 52b of the second variable displacement pump motor 30 are independent of each other. The first motor generator 50a and the second motor generator 50b are electrically connected to the electric power supply 70. Each of the first motor generator 50a and the second motor generator 50b may have the same configuration as the motor generator in the hydraulic cylinder drive device 10 according to the first embodiment.

[0057] Also, in this embodiment, in the case where the piston rod 43 moves in the extending direction, the first variable displacement pump motor 20 functions as the hydraulic pump, and the second variable displacement pump motor 30 functions as the hydraulic motor. Meanwhile, in the case where the piston rod 43 moves in the retracting direction, the first variable displacement pump motor 20 functions as the hydraulic motor, and the second variable displacement pump motor 30 functions as the hydraulic pump.

[0058] The tilt amount in the variable displacement pump motor that functions as the hydraulic pump is controlled on the basis of the actuation direction of the boom, the boom speed, the hydraulic pressures P1, P2 that are measured by the pressure detectors 28, 38 provided in the first control oil path 22 and the second control oil path 32, and the like. That is, the unillustrated electronic control unit controls the tilt amounts in the first variable displacement pump motor 20 and the second variable displacement pump motor 30 such that the extending speed or the retracting speed of the piston rod 43 matches the desired speed. At this time, the variable displacement pump motor that functions as the hydraulic motor is driven by using the hydraulic oil that is discharged from the pressure chamber in the hydraulic cylinder 40, and the motor generator generates the regenerative power by using the rotation driving force for the driveshaft that is generated by said variable displacement pump motor. In this way, the rotation driving force for the driveshaft, which is generated by variable displacement pump motor functioning as the hydraulic motor, is converted to the electric power, and the converted electric power is then supplied to the unillustrated electric power load equipment.

[0059] As it has been described so far, similar to the hydraulic cylinder drive device 10 according to the first embodiment, the hydraulic cylinder drive device 10A according to this embodiment includes the first variable displacement pump motor 20 and the second variable displacement pump motor 30, each of which functions as the hydraulic pump or the hydraulic motor. The motor generator generates the regenerative power by using the rotation driving force of the variable displacement pump motor that functions as the hydraulic motor. Thus, the energy efficiency is improved. In addition, the hydraulic cylinder drive device 10A according to this embodiment does not include the direction selector valve, the flow rate control valve, or the like but has a simple configuration. Thus, the cost can be cut, and the energy efficiency is improved.

[0060] The preferred embodiments of the invention have been described in detail so far with reference to the accompanying drawings. However, the invention is not limited to such examples. It is obvious that a person who has basic knowledge in the technical field to which the invention pertains could have easily arrived at various modification examples and correction examples that fall

within the scope of the technical idea described in the claims. It is understood that these modification examples and correction examples naturally fall within the technical scope of the invention.

[0061] For example, in the above embodiments, the hydraulic cylinder drive devices 10, 10A are each used in the boom drive system 100. However, the invention is not limited to such examples. Each of the hydraulic cylinder drive devices 10, 10A may be applied to another device to be actuated such as a hydraulic cylinder drive device that is used for a raising/lowering operation of an arm supporting a bucket of a hydraulic shovel as long as each of the hydraulic cylinder drive devices 10, 10A may apply a force in a tensile direction and a force in a compression direction to a hydraulic cylinder.

[0062] In each of the above embodiments, an inverter circuit that controls the motor generators 50, 50a, 50b may be provided. In the case where the motor generators 50, 50a, 50b can be subjected to inverter control, responsiveness of hydraulic control is improved. Thus, the operation of the hydraulic cylinder 40 can be improved in a region where the hydraulic pressure in the hydraulic cylinder 40 has a high change rate. In addition, in the case where each of the hydraulic cylinder drive devices 10, 10A is operated intermittently, the motor generators 50, 50a, 50b are stopped during a stop of the system. In this way, required energy can further be reduced.

Claims

1. A hydraulic cylinder drive device comprising:

a hydraulic cylinder that includes a piston rod actuating a device to be actuated;
a motor generator that functions as a motor actuated by using electric power from outside of the device and functions as a generator supplying the electric power to the outside of the device;
a first variable displacement pump motor that is coupled to the motor generator, functions as a hydraulic pump supplying a hydraulic pressure to a cap-side pressure chamber in the hydraulic cylinder, and functions as a power unit of the motor generator by using the hydraulic pressure supplied from the cap-side pressure chamber; and
a second variable displacement pump motor that is coupled to the motor generator, functions as a hydraulic pump supplying a hydraulic pressure to a rod-side pressure chamber in the hydraulic cylinder, and functions as a power unit of the motor generator by using the hydraulic pressure supplied from the rod-side pressure chamber.

2. The hydraulic cylinder drive device according to claim 1, wherein
the first variable displacement pump motor and the second variable displacement pump motor are connected to the same driveshaft, and the motor generator is coupled to the driveshaft.

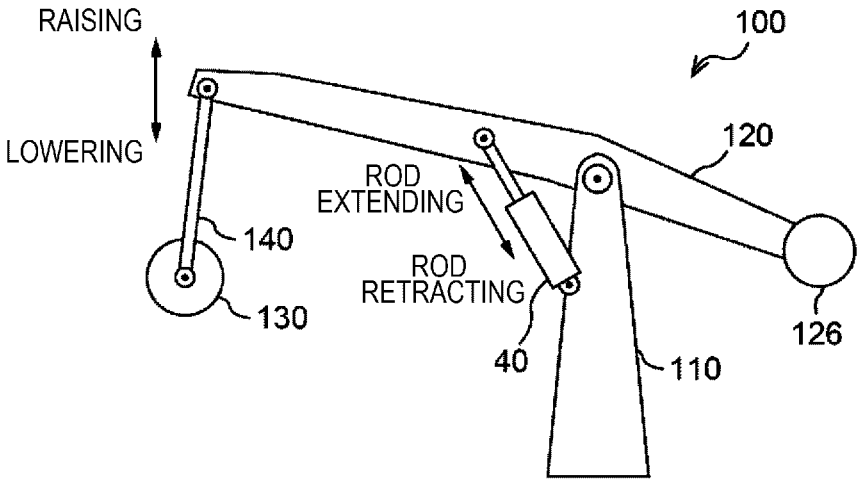
3. The hydraulic cylinder drive device according to claim 2, wherein
the motor generator is subjected to inverter control.

4. The hydraulic cylinder drive device according to claim 1, wherein
the motor generator includes: a first motor generator that is coupled to a first driveshaft of the first variable displacement pump motor; and a second motor generator that is coupled to a second driveshaft of the second variable displacement pump motor.

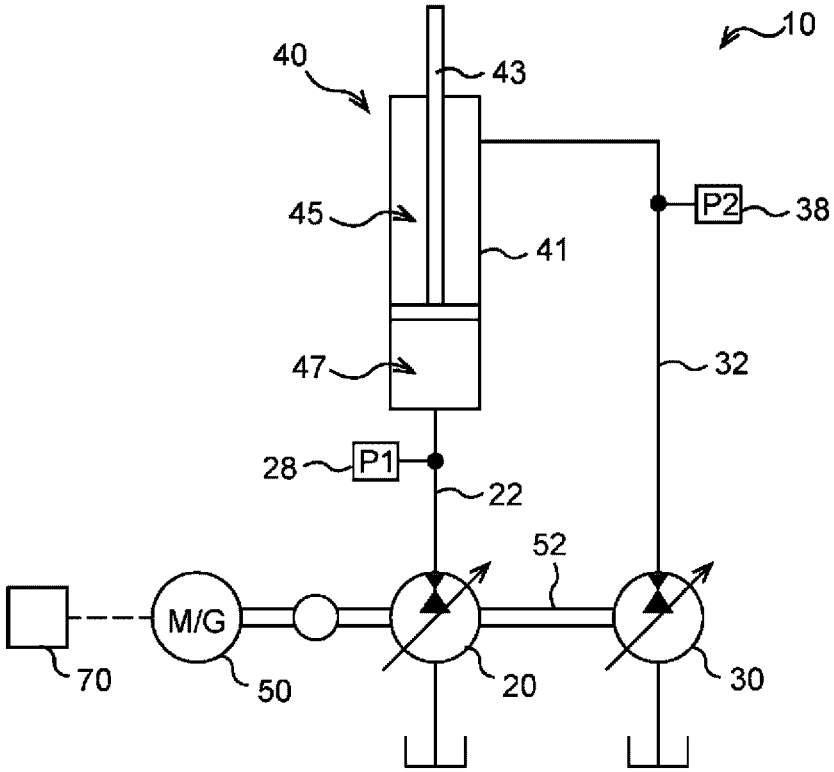
5. The hydraulic cylinder drive device according to claim 4, wherein
at least one of the first motor generator and the second motor generator is subjected to inverter control.

6. The hydraulic cylinder drive device according to any one of claims 1 to 5, wherein
the device to be actuated is a boom drive system in an operating machine.

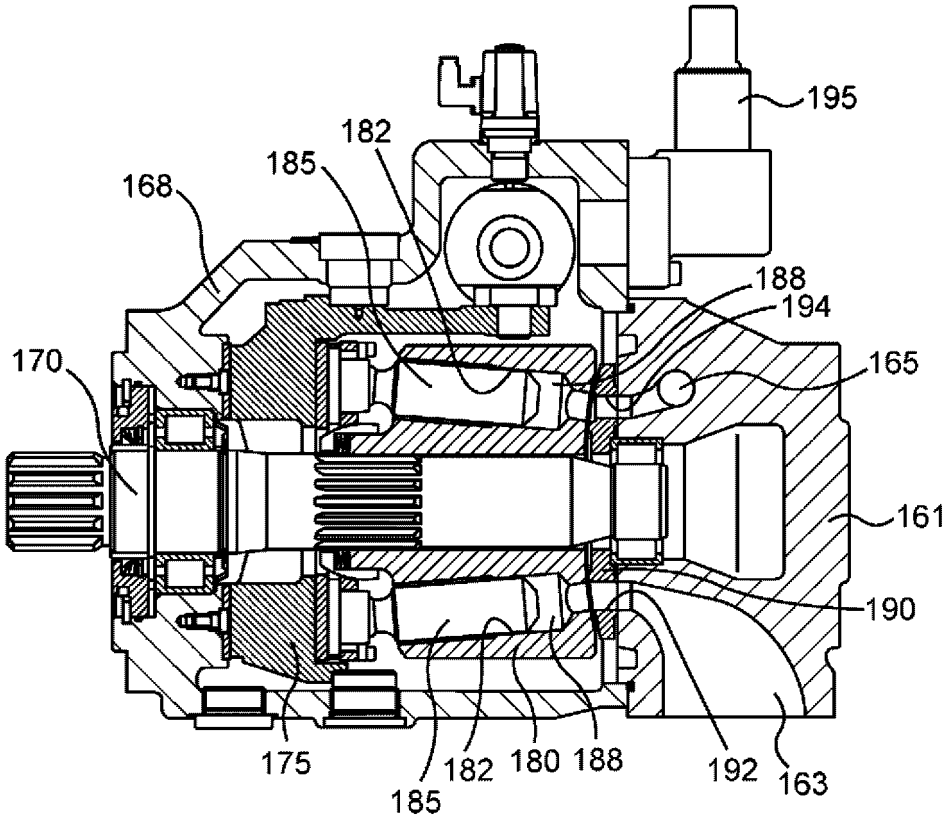
[FIG. 1]


RAISING
LOWERING
100
120
ROD
EXTENDING
ROD
RETRACTING
140
130
40
110
126

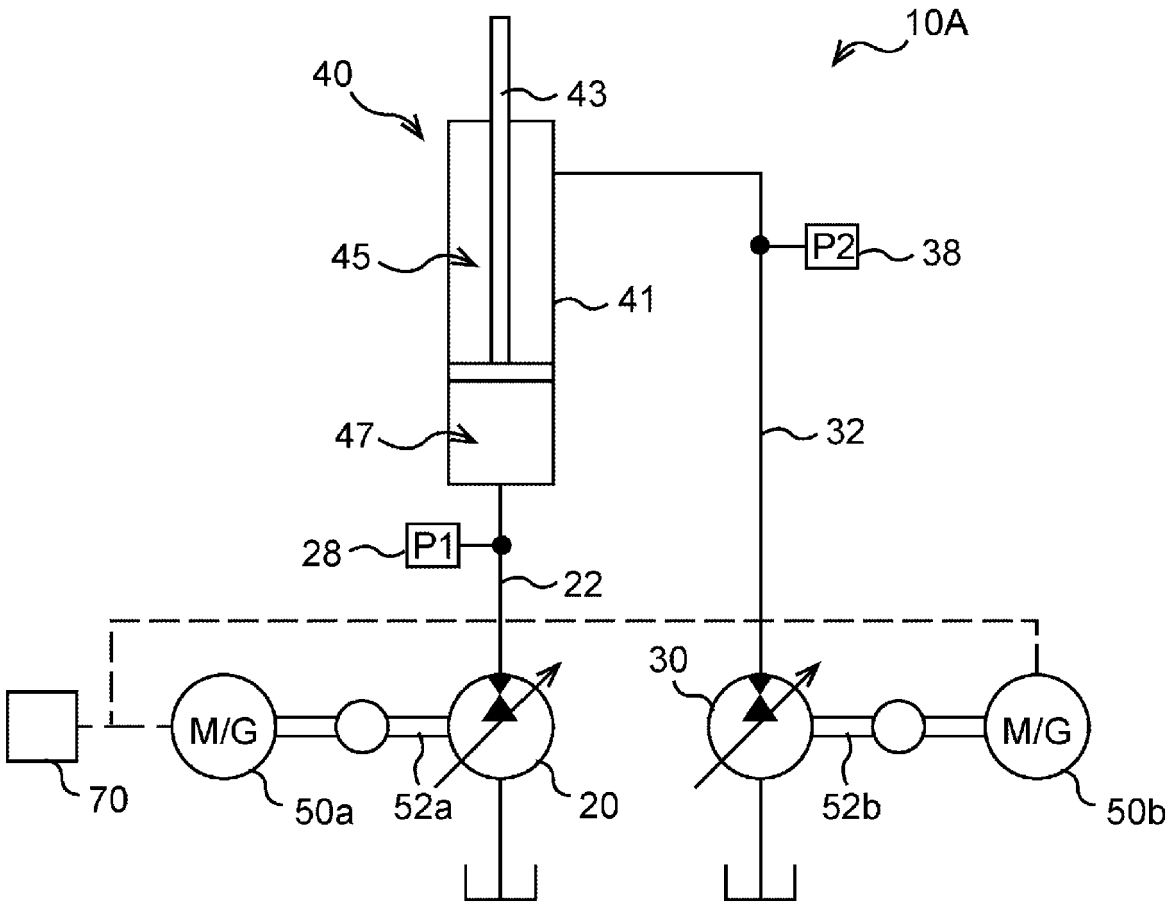
[FIG. 2]


10
40
43
45
41
P2
38
47
32
28
P1
22
52
M/G
70
50
20
30

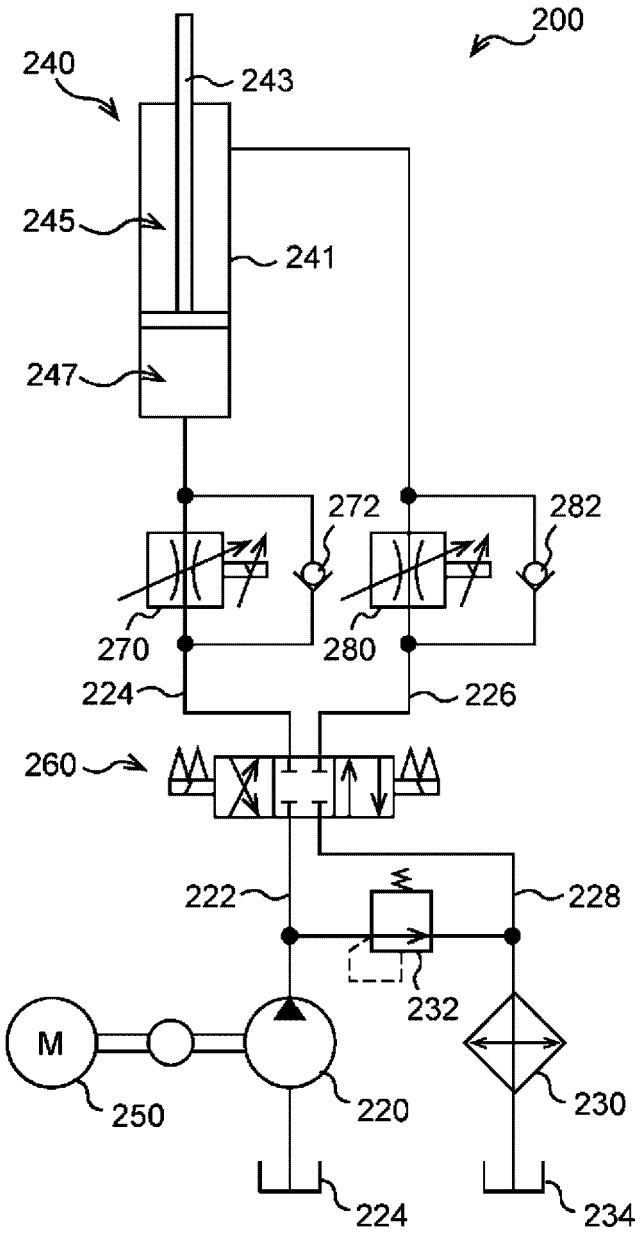
[FIG. 3]


195
182
185
168
188
194
170
165
161
190
175
182
185
180
188
192
163

[FIG. 4]



[FIG. 5]


200
240
243
245
241
247
272
282
270
280
224
226
260
222
228
232
M
250
220
230
224
234

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/072738

A. CLASSIFICATION OF SUBJECT MATTER
F15B21/14(2006.01)i, *F15B11/00*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F15B21/14, F15B11/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016
Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2001-90704 A (Tokimec Inc.), 03 April 2001 (03.04.2001), paragraphs [0024] to [0037]; fig. 1 (Family: none)	1-6
Y	JP 2002-39110 A (Kobelco Construction Machinery Co., Ltd.), 06 February 2002 (06.02.2002), paragraphs [0021] to [0037]; fig. 1 to 3 & JP 2002-21807 A & WO 2002/004820 A1	1-6
Y	JP 2002-349505 A (Kobelco Construction Machinery Co., Ltd.), 04 December 2002 (04.12.2002), paragraphs [0020] to [0067]; fig. 1 to 4 (Family: none)	6

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 October 2016 (17.10.16)	25 October 2016 (25.10.16)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Non-patent literature cited in the description

- Shiritai Yuatsu/Kisohen. **FUJIKOSHI KENKYU GROUP.** What You Want to Know About Hydraulic Pressure. Japan Machinist-Sha, 20 September 1989, 315 **[0005]**