



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

(43) Date of publication:
25.12.2013 Bulletin 2013/52

(51) Int Cl.:
F15B 11/02 (2006.01) E02F 9/22 (2006.01)
F15B 11/00 (2006.01)

(21) Application number: **12747270.2**

(86) International application number:
PCT/JP2012/052977

(22) Date of filing: **09.02.2012**

(87) International publication number:
WO 2012/111525 (23.08.2012 Gazette 2012/34)

(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

• **ICHIMURA Kazuhiro**
Tsuchiura-shi
Ibaraki 300-0013 (JP)
• **KODAKA Katsuaki**
Tsuchiura-shi
Ibaraki 300-0013 (JP)

(30) Priority: **14.02.2011 JP 2011028940**

(71) Applicant: **Hitachi Construction Machinery Co., Ltd.**
Bunkyo-ku
Tokyo 112-8563 (JP)

(74) Representative: **Beetz & Partner**
Patentanwälte
Steinsdorfstrasse 10
80538 München (DE)

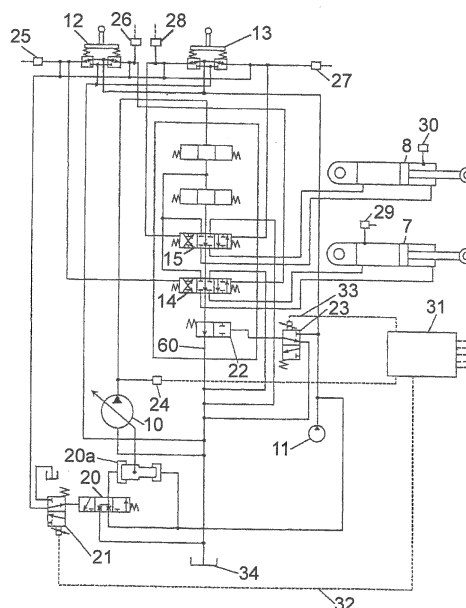
(72) Inventors:
• **KAYANE Masahiro**
Tsuchiura-shi
Ibaraki 300-0013 (JP)

(54) **HYDRAULIC DRIVE DEVICE OF WORKING MACHINE**

(57) To provide a hydraulic drive system for a working machine, which can realize the assurance of good operability in normal operation and precision operation and a reduction in energy loss in the precision operation.

A controller (31) is provided with a pump delivery rate control unit (40) and a center bypass valve control unit (50). The pump delivery rate control unit (40) performs control processing to output, to a control terminal of a solenoid-operated proportional reducing valve (21), a control signal to make a displacement of a variable displacement hydraulic pump (10) smaller than a displacement corresponding to normal operation when a working element control device is in a manipulation mode considered to correspond to precision operation. The center bypass valve control unit (50) performs control processing to output, to a control terminal of a proportional solenoid valve (23), a control signal to make a center bypass valve (22) have a relatively large opening amount despite the center bypass valve (22) is in a switched state between a fully open position and a fully closed position when the working element control device is in a manipulation mode considered to correspond to the precision operation and a load pressure on a working element actuator is in a low state.

FIG. 2



Description

Technical Field

[0001] This invention relates to a hydraulic drive system for a working machine, such as a hydraulic excavator, having working equipment that includes working elements such as a boom and arm and can perform normal operation and precision operation which is performed by a smaller manipulation stroke at a slower manipulation speed than the normal operation. The hydraulic drive system is provided with an open-center directional control valve, and positively controls a variable displacement hydraulic pump.

Background Art

[0002] As a conventional technology including an open-center positive control system of this type, there is one disclosed in Patent Document 1. This conventional technology includes an open-center boom directional control valve, arm directional control valve and the like, which are arranged in a center bypass line communicating a variable displacement hydraulic pump and a reservoir with each other, and variably controls the displacement of the variable displacement hydraulic pump according to manipulation strokes of control devices that switchingly control the boom directional control valve, arm directional control device and the like, respectively.

Prior Art Document

Patent Document

[0003]

Patent Document 1: JP-A-11-82416

Disclosure of the Invention

Problem to Be Solved by the Invention

[0004] In the above-mentioned conventional technology, an extra pump flow volume is facilitated to flow to the reservoir via the directional control valves and center bypass line in precision operation, which is performed by making, for example, the manipulation strokes or manipulation speeds of the control devices smaller or slower, when the system is set with a view to assuring good controllability in normal work such as digging work. Therefore, substantial energy is drained without effective use in work so that energy loss tends to occur. When the system is set with a view to reducing an extra flow volume to be flowed to the reservoir in precision operation as described above, the operability in normal work deteriorates conversely. With the conventional technology, it has hence been difficult to achieve both of a reduction in energy loss in precision work and the assurance of good

operability in normal work.

[0005] It is to be noted that even a variety of work performed by precision operation generally include those which are high in applied pressure and become heavy load work, such as crane work performed by a hydraulic excavator, and those which are low in applied pressure and become light load work, such as earth or sand grading work by a hydraulic excavator. However, no full consideration has heretofore been made about the control for work under different loads in such precision operation. The conventional technology is, therefore, prone to the occurrence of energy loss and a deterioration in operability due to load variations in precision operation.

[0006] With the above-mentioned actual situation of the conventional technology in view, the present invention has as an object thereof the provision of a hydraulic drive system for a working machine, which can realize the assurance of good operability in normal operation and precision operation and a reduction in energy loss in the precision operation.

Means for Solving the Problem

[0007] To achieve this object, the present invention provides a hydraulic drive system for a working machine provided with working equipment capable of performing normal operation and precision operation which is performed by a smaller manipulation stroke or at a slower manipulation speed than the normal operation, said hydraulic drive system being provided with a variable displacement hydraulic pump, a working element actuator operable by pressure oil, which is delivered from the variable displacement hydraulic pump, to drive a working element included in the working equipment, an open-center directional control valve for the working element, said open-center directional control valve being arranged in a center bypass line, which communicates the variable displacement hydraulic pump and a reservoir with each other, to control a flow of pressure oil to be fed from the variable displacement hydraulic pump to the working element actuator, and a working element control device for switchingly controlling the directional control valve for the working element, wherein the hydraulic drive system is provided with a displacement control device for controlling a displacement of the variable displacement hydraulic pump, a center bypass valve arranged in a part of the center bypass line, said part being located downstream of the directional control valve for the working element, and capable of controlling a flow volume to be returned to the reservoir via the center bypass line, a center bypass valve control device for controlling the center bypass valve, and a controller for controlling the displacement control device and center bypass valve control device; and the controller is provided with a pump delivery rate control unit for performing control processing to output a control signal to the displacement control device to control the variable displacement hydraulic pump at a displacement corresponding to the normal op-

eration when the working element control device is in a manipulation mode considered to correspond to the normal operation or to output a control signal to the displacement control device to make the displacement of the variable displacement hydraulic pump smaller than the displacement corresponding to the normal operation when the working element control device is in a manipulation mode considered to correspond to the precision operation, and a center bypass valve control unit for performing control processing to output, to the center bypass valve control unit, a control signal to open or close the center bypass valve when the working element control device is in the manipulation mode considered to correspond to the normal operation or a control signal to control the center bypass valve in a switched state between a fully open position and a fully closed position when the working element control device is in the manipulation mode considered to correspond to the precision operation, or for performing control processing to output, to the center bypass valve control unit, a control signal to make the center bypass valve have a small opening amount in a switched state between the fully open position and the fully closed position when the working element control device is in the manipulation mode considered to correspond to the precision operation and a load pressure on the working element actuator is in a high state or a control signal to make the center bypass valve have an opening amount greater than the small opening amount when the working element control device is in the manipulation mode considered to correspond to the precision operation and the load pressure on the working element actuator is in a low state.

[0008] When the work element control device is manipulated upon normal operation in the present invention configured as described above, a control signal is outputted from the pump delivery rate control unit of the controller to the displacement control device to control the variable displacement hydraulic pump at a relatively large displacement corresponding to the normal operation. As a consequence, a large flow volume is fed from the variable displacement hydraulic pump to the working element actuator via the directional control valve for the working element. In the meantime, a control signal is outputted from the center bypass valve control unit of the controller to the center bypass valve control device to open or close the center bypass valve. As a consequence, a large flow volume can be returned from the working element actuator to the reservoir via the center bypass line and center bypass valve. These controls can assure good normal operability that makes it possible to drive the working element at fast operation speed.

[0009] When the work element control device is manipulated by a small manipulation stroke or at a slow manipulation speed upon work to be performed by precision operation in the present invention, a control signal is outputted from the pump delivery rate control unit of the controller to the displacement control device to make the displacement of the variable displacement hydraulic

pump smaller than the displacement corresponding to normal operation. As a consequence, a flow volume which is smaller compared with that at the time of the normal operation is fed from the variable displacement hydraulic pump to the working element actuator via the directional control valve for the working element. In the meantime, a control signal is outputted from the center bypass valve control unit of the controller to the center bypass valve control device to control the center bypass valve in a switched state between the fully open position and the fully closed position. As a consequence, it is possible to keep small a flow volume to be returned from the working element actuator to the reservoir via the center bypass line and center bypass valve. These controls can assure good precision operability that makes it possible to drive the working element at slow operation speed. It is also possible to limit the output of the variable displacement hydraulic pump at this time and hence to realize a reduction in energy loss.

[0010] At the time of heavy load that the load on the working element actuator is high in the present invention, a control signal is outputted, even at the time of precision operation, from the center bypass valve control unit of the controller to the center bypass valve control device to make the opening amount of the center bypass valve still smaller in a predetermined switched state between the fully open position and the fully closed position. By this control, the delivery pressure of the variable displacement hydraulic pump becomes high, thereby assuring good operability upon work that relies upon the precision and heavy load operation.

[0011] At the time of light load that the load on the working element actuator is low in the present invention, a control signal is outputted, even at the time of precision operation, from the center bypass valve control unit of the controller to the center bypass valve control device to make the opening amount of the center bypass valve greater compared with the above-mentioned opening amount at the time of the heavy load in a predetermined switched state between the fully open position and the fully closed position. By this control, the delivery pressure of the variable displacement hydraulic pump is kept low, thereby assuring good operability upon work that relies upon the precision and light load operation. It is also possible to limit the output of the variable displacement hydraulic pump at this time and hence to reduce energy loss.

[0012] In the present invention as described above, the controller may perform, based on the manipulation stroke, the manipulation speed or a manipulation acceleration of the working element control device, processing to compute that the working element control device is in the manipulation mode considered to correspond to the precision operation.

[0013] In the present invention as described above, the working machine may be a hydraulic excavator, the working element may comprise a boom and an arm, the working element actuator may comprise a boom cylinder

for actuating the boom and an arm cylinder for actuating the arm, the directional control valve for the working element may comprise a boom directional control valve for controlling the boom cylinder and an arm directional control valve for controlling the arm cylinder, and the working element control device may comprise a boom control device for switchingly controlling the boom directional control valve, and an arm control device for switchingly controlling the arm directional control valve.

[0014] In the present invention as described above, the hydraulic drive system may be further provided with a delivery pressure sensor for detecting a delivery pressure of the variable displacement hydraulic pump, or a bottom pressure sensor for detecting a bottom pressure of the boom cylinder and a rod pressure sensor for detecting a rod pressure of the arm cylinder, and the center bypass valve control unit of the controller may perform, according to at least one of a manipulation stroke of the boom control device and a manipulation stroke of the arm control device and the delivery pressure detected at the delivery pressure sensor or according to at least one of the manipulation stroke of the boom control device and the manipulation stroke of the arm control device, the bottom pressure detected at the bottom pressure sensor and the rod pressure detected at the rod pressure sensor, control processing to output a control signal to control the center bypass valve at a relatively large opening amount when the working element control device is in the manipulation mode considered to correspond to the precision operation and the load pressure on the working element actuator is in the low state.

Advantageous Effects of the Invention

[0015] In the present invention, the controller is provided with the pump delivery rate control unit and the center bypass valve control unit. The pump delivery rate control unit outputs, to the displacement control device that controls the displacement of the variable displacement hydraulic pump, a control signal to control the variable displacement hydraulic pump at corresponding one of mutually-different displacements according to normal operation or precision operation, while the center bypass valve control unit outputs, to the center bypass valve control device that controls the center bypass valve, a control signal to control the center bypass valve at corresponding one of mutually-different center bypass opening amounts according to the normal operation or precision operation, and outputs, to a control terminal of the above-mentioned proportional solenoid valve, a control signal to control the proportional solenoid valve at corresponding one of mutually-different center bypass opening amounts according to the level of a load pressure on the working element actuator at the time of the precision operation. Owing to this configuration, it is possible to realize the assurance of good operability at the time of normal operation and the assurance of good operability in commensurate with a load pressure on the working element actuator at the

time of the precision operation, and also to realize a reduction in energy loss at the time of the precision operation. It is, therefore, possible to realize an economical, excellent-practicality and high-reliability hydraulic drive system capable of realizing the assurance of high-precision operability compared with the conventional.

Brief Description of the Drawings

[0016]

FIG. 1 is a side view showing a hydraulic excavator exemplified as a working machine.

FIG. 2 is an electrical and hydraulic circuit diagram illustrating a hydraulic drive system according to a first embodiment, which is arranged on the hydraulic excavator shown in FIG. 1.

FIG. 3 is a block diagram illustrating the configuration of a pump delivery rate control unit included in a controller arranged in the hydraulic drive system according to the first embodiment illustrated in FIG. 2.

FIG. 4 is a block diagram illustrating the configuration of a center bypass valve control unit included in the controller arranged in the hydraulic drive system according to the first embodiment illustrated in FIG. 2.

FIG. 5 is a diagram depicting control to be performed by the hydraulic drive system according to the first embodiment.

FIG. 6 is a diagram depicting control to be performed by a hydraulic drive system according to a second embodiment of the present invention.

FIG. 7 is a block diagram illustrating the configuration of an essential part of a pump delivery rate control unit included in a controller arranged in a hydraulic drive system according to a third embodiment of the present invention.

FIG. 8 is a block diagram illustrating the configuration of an essential part of a center bypass valve control unit included in the controller arranged in the hydraulic drive system according to the third embodiment of the present invention.

Modes for Carrying out the Invention

[0017] Embodiments of the hydraulic drive system according to the present invention for the working machine will hereinafter be described with reference to the drawings.

[0018] FIG. 1 is a side view showing a hydraulic excavator exemplified as a working machine.

[0019] The hydraulic drive system according to the first embodiment is arranged, for example, on a hydraulic excavator, which is provided with a travel base 1, an upperstructure 2 mounted on the travel base 1, and working equipment 3 attached tiltably in an up-and-down direction to the upperstructure 2. The working equipment 3 includes, together with a boom 4, arm 5 and bucket 6 that make up a working element, working element actuators,

for example, a boom cylinder 7 for actuating the boom 4, an arm cylinder 8 for actuating the arm 5, and a bucket cylinder 9 for actuating the bucket 6.

[0020] FIG. 2 is an electrical and hydraulic circuit diagram illustrating a hydraulic drive system according to a first embodiment, which is arranged on the hydraulic excavator shown in FIG. 1, FIG. 3 is a block diagram illustrating the configuration of a pump delivery rate control unit included in a controller arranged in the hydraulic drive system according to the first embodiment illustrated in FIG. 2, and FIG. 4 is a block diagram illustrating the configuration of a center bypass valve control unit included in the controller arranged in the hydraulic drive system according to the first embodiment illustrated in FIG. 2.

[0021] As illustrated in FIG. 2, the hydraulic drive system according to the first embodiment is provided with a variable displacement hydraulic pump 10, a servo valve 20 and control actuator 20a included in a regulator for the variable displacement hydraulic pump 10, and a control device for controlling the servo valve 20, specifically a displacement control device, for example, a solenoid-operated proportional reducing valve 21 for controlling the displacement of the variable displacement hydraulic pump 10.

[0022] This embodiment is also provided, in addition to the above-mentioned boom cylinder 7 and arm cylinder 8 that are operated by pressure oil delivered from the variable displacement hydraulic pump 10 and make up the working element actuators, with open-center directional control valves for the working elements, specifically a boom directional control valve 14 and arm directional control valve 15, which are arranged in a center bypass line 60 communicating the variable displacement hydraulic pump 10 and a reservoir 34 with each other and control flows of pressure oil to be fed from the variable displacement hydraulic pump 10 to the boom cylinder 7 and arm cylinder 8. Also provided are working element control devices for switchingly controlling the boom directional control valve 14 and arm directional control valve 15, specifically a boom control device 12 and arm control device 13.

[0023] The first embodiment is also provided with a center bypass valve 22, which is arranged in a part of the center bypass line 60, said part being located downstream of the boom directional control valve 14, and can control a flow volume to be returned to the reservoir 34 via the center bypass line 60, and a center bypass valve control device, for example, a proportional solenoid valve 23 for controlling the center bypass valve 22. The first embodiment is further provided with a controller 31, which controls the solenoid-operated proportional reducing valve 21 via a signal line 32 and also the proportional solenoid valve 23 via a signal line 33.

[0024] This controller 31 is provided with a below-described pump delivery rate control unit 40 for performing control processing to output a control signal to a control terminal of the solenoid-operated proportional reducing valve 21 via the signal line 32 to control the variable dis-

placement hydraulic pump 10 at a displacement corresponding to normal operation when the boom control device 12 and arm control device 13 are in manipulation modes considered to correspond to the normal operation or to output a control signal to the control terminal of the solenoid-operated proportional reducing valve 21 via the signal line 32 to make the displacement of the variable displacement hydraulic pump 10 smaller than the displacement corresponding to the normal operation when the boom control device 12 and arm control device 13 are in manipulation modes considered to correspond to the precision operation.

[0025] The controller 31 is also provided with a below-described center bypass valve control unit 50 for performing control processing to output, to a control terminal of the proportional solenoid valve 23 via the signal line 33, a control signal to open or close the center bypass valve 22 when the boom control device 12 and arm control device 13 are in the manipulation modes considered to correspond to the normal operation or a control signal to control the center bypass valve 22 in a predetermined switched state (a state that the center bypass line 60 is restricted by the center bypass valve 22) between the fully open position and the fully closed position. This center bypass valve control unit 50 also performs control processing to output, to the control terminal of the proportional solenoid valve 23 via the signal line 33, a control signal to make the opening amount of the center bypass valve 22 still smaller in a predetermined switched state between the fully open position and the fully closed position when the boom control device 12 and arm control device 13 are in the operation modes considered to correspond to the precision operation or a control signal to make the opening amount of the center bypass valve 22 greater compared with that at the time of the above-mentioned high load pressure despite the center bypass valve 22 is in a predetermined switched position between the fully open position and the fully closed position when the boom control device 12 and arm control device 13 are in the manipulation modes considered to correspond to the precision operation and the load pressures on the boom cylinder 7 and arm cylinder 8 are in low states.

[0026] The first embodiment is also provided with a pilot pump 11 for feeding a pilot pressure to the boom control device 12 and arm control device 13, and a delivery pressure sensor 24 for detecting a delivery pressure of the variable displacement hydraulic pump 10. Also provided are a boom-raising pressure sensor 25 for detecting a pilot pressure to be produced upon boom-raising operation by the boom control device 12, a boom-lowering pressure sensor 26 for detecting a pilot pressure to be produced upon boom-lowering operation by the boom control device 12, an arm-dumping pressure sensor 27 for detecting a pilot pressure to be produced upon arm-dumping operation by the arm control device 13, and an arm-crowding pressure sensor 28 for detecting a pilot pressure to be produced upon arm-crowding operation by the arm control device 13.

[0027] The first embodiment is also provided with a bottom pressure sensor 29 for detecting a bottom pressure of the boom cylinder 7 and a rod pressure sensor 30 for detecting a rod pressure of the arm cylinder 8.

[0028] As illustrated in FIG. 3, the above-mentioned pump delivery rate control unit 40 of the controller 31 is provided with a function generating unit 40a for the boom, which includes a boom-raising function generating unit 40a1 and a boom-lowering function generating unit 40a2. The boom-raising function generating unit 40a1 computes a displacement of the variable displacement hydraulic pump 10, which corresponds to a signal outputted from the boom-raising pressure sensor 25 in commensurate with a boom-raising manipulation stroke of the boom control device 12. The boom-lowering function generating unit 40a2 computes a displacement of the variable displacement hydraulic pump 10, which corresponds to a signal outputted from the boom-lowering pressure sensor 26 in commensurate with a boom-lowering manipulation stroke of the boom control device 12. The function generating unit 40a for the boom is configured to produce a displacement such that it takes a greater value as the lever manipulation stroke of the boom control device 12 becomes greater.

[0029] The pump delivery rate control unit 40 is also provided with a function generating unit 40b for the arm, which includes an arm-crowding function generating unit 40b1 and an arm-dumping function generating unit 40b2. The arm-crowding function generating unit 40b1 computes a displacement of the variable displacement hydraulic pump 10, which corresponds to a signal outputted from the arm-crowding pressure sensor 28 in commensurate with an arm-crowding manipulation stroke of the arm control device 13. The arm-dumping function generating unit 40b2 computes a displacement of the variable displacement hydraulic pump 10, which corresponds to a signal outputted from the arm-dumping pressure sensor 27 in commensurate with an arm-dumping manipulation stroke of the arm control device 13. This function generating unit 40b for the arm is also configured to produce a displacement such that it takes a greater value as the lever manipulation stroke of the arm control device 13 becomes greater.

[0030] The pump delivery rate control unit 40 is also provided with a maximum selection unit 40c, which selects one having a maximum value from a displacement outputted from the boom-raising function generating unit 40a1 and a displacement outputted from the boom-lowering function generating unit 40a2 in the function generating unit 40a for the boom. The pump delivery rate control unit 40 is also provided with a maximum selection unit 40d, which selects one having a maximum value from a displacement outputted from the arm-crowding function generating unit 40b1 and a displacement outputted from the arm-dumping function generating unit 40b2 in the function generating unit 40b for the arm.

[0031] The pump delivery rate control unit 40 also includes an addition unit 40e and a control function gen-

erating unit 40f. The addition unit 40e adds the displacement outputted from the maximum selection unit 40c and the displacement outputted from the maximum selection unit 40d. The control function generating unit 40f outputs, to the control terminal of the solenoid-operated proportional reducing valve 21, a control signal corresponding to a displacement outputted from the addition unit 40e. The control function generating unit 40f is configured to output, to the control terminal of the solenoid-operated proportional reducing valve 21, the control signal such that it takes a smaller value as the value of the displacement outputted from the addition unit 40e becomes greater.

[0032] As illustrated in FIG. 4, the above-mentioned center bypass valve control unit 50 of the controller 31 is provided with a first differential pressure generating unit 50a that outputs a target differential pressure, which is a target value for a differential pressure between a pump delivery pressure and a boom bottom pressure, corresponding to a boom-raising manipulation stroke of the boom control device 12. This first differential pressure generating unit 50a is configured to output a greater target differential pressure as the pressure outputted from the boom-raising pressure sensor 25 becomes higher.

[0033] The center bypass valve control unit 50 is provided with a first subtraction unit 50b and a second subtraction unit 50c. The first subtraction unit 50b subtracts a pressure, which is outputted by the bottom pressure sensor 29 of the boom cylinder 7, from a pressure, which is outputted by the delivery pressure sensor 24, to compute an actual differential pressure as the differential pressure between the actual pump delivery pressure and the actual boom bottom pressure. The second subtraction unit 50c subtracts the actual differential pressure, which is outputted by the first subtraction unit 50b, from the target differential pressure outputted by the first differential pressure generating unit 50a.

[0034] The center bypass valve control unit 50 is also provided with a second differential pressure generating unit 50b that outputs a target differential pressure, which is a target value for a differential pressure between a pump delivery pressure and an arm rod pressure, corresponding to an arm-dumping manipulation stroke of the arm control device 13. This second differential pressure generating unit 50d is also configured to output a greater target differential pressure as the pressure outputted from the arm-dumping pressure sensor 27 becomes higher.

[0035] The center bypass valve control unit 50 is provided with a third subtraction unit 50e and a fourth subtraction unit 50f. The third subtraction unit 50e subtracts a pressure, which is outputted by the rod pressure sensor 30 of the arm cylinder 8, from a pressure, which is outputted by the delivery pressure sensor 24, to compute an actual differential pressure as the differential pressure between the actual pump delivery pressure and the actual arm rod pressure. The fourth subtraction unit 50f subtracts the actual differential pressure, which is out-

putted by the third subtraction unit 50e, from the target differential pressure outputted by the second differential pressure generating unit 50d.

[0036] The center bypass valve control unit 50 also includes a maximum selection unit 50g, a control signal computing unit 50h, and an addition unit 50i. The maximum selection unit 50g selects one having a maximum value from the difference between the target differential pressure and the actual differential pressure as outputted from the second subtraction unit 50c and the difference between the target differential pressure and the actual differential pressure as outputted from the fourth subtraction unit 50f. The control signal computing unit 50h converts, to a control signal, the difference outputted from the maximum selection unit 50g. The addition unit 50i adds the current control signal, which has been converted at the control signal computing unit 50h, to the preceding control value to produce a new control signal. It is to be noted that the control signal computing unit 50 performs computing processing to output, for example, a control signal of a smaller value as the difference outputted from the maximum selection unit 50g becomes greater. Owing to such a configuration as described above, the pump delivery pressure is controlled to become higher than the load pressure on the actuator by the difference between the target differential pressure selected at the maximum selection unit 50g and the actual differential pressure.

[0037] According to the first embodiment configured as described above, when it is desired to perform normal operation of fast operating speed through combined boom-raising and arm-dumping operation by manipulating the boom control device 12 and arm control device over large manipulation strokes, respectively, for example, upon earth or sand digging work, the large manipulation stroke of the boom control device 12 is detected at the boom-raising pressure sensor 25 and is inputted to the boom-raising function generating unit 40a1 included in the pump delivery rate control unit 40 of the controller 31, as illustrated in FIG. 3. Further, the large manipulation stroke of the arm control device 13 is detected at the arm-dumping pressure sensor 27 and is inputted to the arm-dumping function generating unit 40b2 included in the pump delivery rate control unit 40. Therefore, displacements of large values are outputted from the boom-raising function generating unit 40a1 and arm-dumping function generating unit 40b2 to the maximum selection units 40c, 40d, respectively, and these values are added at the addition unit 40e, from which the thus-added value is outputted to the control function generating unit 40f. Corresponding to the displacement of the large value, a control signal of a small value is outputted from the control function generating unit 40f to the solenoid-operated proportional reducing valve 21 illustrated in FIG. 2.

[0038] Therefore, the solenoid-operated proportional reducing valve 21 tends to be switched under its spring force to a side of an upper valve chamber as viewed in

FIG. 2, so that a control port of the servo valve 20 tends to be connected to the boom control device 12 and arm control device 13 via the solenoid-operated proportional reducing valve 21, and under a pilot pressure outputted corresponding to the manipulation strokes of the boom control device 12 and arm control device 13, the servo valve 20 tends to be switched to a side of a left position as viewed in FIG. 2. As a consequence, the pilot pressure from the pilot pump 11 is fed to a small-diameter chamber of the control piston 20a via the servo valve 20, a large-diameter chamber of the control piston 20a is connected to the reservoir 34, and the control piston 20a moves in a left direction in FIG. 2. As a consequence, the variable displacement hydraulic pump 10 is controlled to have a large displacement so that a large flow volume is delivered from the variable displacement hydraulic pump 10.

[0039] In the meantime, responsive to the boom-raising manipulation of the boom control device 12, the boom directional control valve 14 is switched to a left position in FIG. 2, and responsive to the arm-dumping manipulation of the arm control device 13, the arm directional control valve 15 is switched to a right position in FIG. 2. Therefore, the pressure oil of the large flow volume delivered from the hydraulic pump 10 is fed to a rod chamber of the arm cylinder 8 via the arm directional control valve 15, and is also fed to a bottom chamber of the boom cylinder 7 via the boom directional control valve 14. As a consequence, the boom cylinder 7 extends to perform boom-raising operation, while the arm cylinder 8 retracts to perform arm-dumping operation.

[0040] In association with these operations, pressures, for example, high pressures are detected from the bottom pressure sensor 29 for detecting the bottom pressure of the boom cylinder 7 and the rod pressure sensor 30 for detecting the rod pressure of the arm cylinder 8, respectively. At the subtraction unit 50b included in the center bypass valve control unit 50 of the controller 31 illustrated in FIG. 4, the pressure detected at the bottom pressure sensor 29 is, therefore, subtracted from the pressure detected at the delivery pressure sensor 24 to compute a small actual differential pressure between the pump delivery pressure and the boom bottom pressure, and the small actual differential pressure is outputted to the subtraction unit 50c. Corresponding to the large boom-raising manipulation stroke outputted from the boom-raising pressure sensor 25, on the other hand, the first differential pressure generating unit 50a outputs a large target differential pressure to the subtraction unit 50c. At the subtraction unit 50c, the actual differential pressure outputted by the subtraction unit 50b is subtracted from the target differential pressure outputted by the first differential pressure generating unit 50a, and the difference between the target differential pressure and the actual differential pressure, said difference having a relatively large value, is outputted to the maximum selection unit 50g.

[0041] Similarly, at the subtraction unit 50e included in the center bypass valve control unit 50, the pressure de-

tected at the rod pressure sensor 30 is subtracted from the pressure detected at the delivery pressure sensor 24 to compute a small actual differential pressure between the pump delivery pressure and the arm rod pressure, and the small actual differential pressure is outputted to the subtraction unit 50f. Corresponding to the large arm-dumping manipulation stroke outputted from the arm-dumping pressure sensor 27, on the other hand, the second differential pressure generating unit 50d outputs a large target differential pressure to the subtraction unit 50f. At the subtraction unit 50f, the actual differential pressure outputted by the subtraction unit 50e is subtracted from the target differential pressure outputted by the second differential pressure generating unit 50d, and the difference between the target differential pressure and the actual differential pressure, said difference being relatively large, is outputted to the maximum selection unit 50g.

[0042] The maximum selection unit 50g selects the larger difference from the difference between the target differential pressure and the actual differential pressure as outputted from the subtraction unit 50c and the difference between the target differential pressure and the actual differential pressure as outputted from the subtraction unit 50f, and the thus-selected relatively large difference is outputted to the control signal computing unit 50h. At this control signal computing unit 50h, the relatively large difference outputted from the maximum selection unit 50g is converted to a relatively small control signal of a value corresponding to the difference, and this relatively small control signal is outputted to the addition unit 50i. At this addition unit 50i, this control signal so converted is added to the preceding control value to perform corrective computation for the production of a new control signal, and the thus-computed value is outputted to the control terminal of the proportional solenoid valve 23 illustrated in FIG. 2.

[0043] As the value of the control signal delivered to the control terminal of the proportional solenoid valve 23 is small as mentioned above, the proportional solenoid valve 23 tends to be switched under its spring force to a side of a lower valve chamber as viewed in FIG. 2 so that the pilot pump 11 and the control port of the center bypass valve 22 are connected with each other. As a consequence, the pilot pressure of the pilot pump 11 is delivered to the control port of the center bypass valve 22 via the proportional solenoid valve 23, and the center bypass valve 22 operates to assume a predetermined switched state between the fully open position and the fully closed position. Therefore, the drain amount of pressure oil from the center bypass line 60 to the reservoir 34 is reduced, combined boom-raising and arm-dumping operation is performed by normal operation of fast operation speed, and by such combined boom-raising and arm-dumping operation, the desired earth or sand digging work can be performed.

[0044] When it is desired to perform precision and heavy load operation, in which the operation speeds are

slow and the load pressures on the actuators become high, by manipulating the boom control device 12 and arm control device 13 a little upon crane work to be performed, different from the above-mentioned earth or sand digging work, with a load suspended from the part of the bucket 6, for example, by combined boom-raising and arm-dumping operation, the small manipulation stroke of the boom control device 12 is detected at the boom-raising pressure sensor 25 and is inputted to the boom-raising function generating unit 40a1 included in the pump delivery rate control unit 40 of the controller 31, as illustrated in FIG. 3. Further, the small manipulation stroke of the arm control device 13 is detected at the arm-dumping pressure sensor 27 and is inputted to the arm-dumping function generating unit 40b2 included in the pump delivery rate control unit 40, as illustrated in FIG. 3.

[0045] Therefore, displacements of smaller values compared with those at the time of the above-mentioned earth or sand digging work are outputted from the boom-raising function generating unit 40a1 and arm-dumping function generating unit 40b2 to the maximum selection units 40c, 40d, respectively, and these values are added together at the addition unit 40e, from which the thus-added value is outputted to the control function generating unit 40f. Corresponding to the displacements of the small values, a control signal of a large value is outputted from the control function generating unit 40f to the solenoid-operated proportional reducing valve 21 illustrated in FIG. 2.

[0046] Therefore, the solenoid-operated proportional reducing valve 21 tends to be switched against its spring force to a side of a lower valve chamber as viewed in FIG. 2, so that the control port of the servo valve 20 and the reservoir 34 tend to be communicated with each other, and the servo valve 20 tends to be switched under its spring force to a side of a right position as viewed in FIG. 2. As a consequence, the pilot pressure from the pilot pump 11 is also fed to the large-diameter chamber of the control piston 20a, and for the difference in area between the large-diameter chamber and the small-diameter chamber, the control piston 20a moves in a right direction in FIG. 2. As a consequence, the variable displacement hydraulic pump 10 is controlled to have a small displacement so that a small flow volume is delivered from the variable displacement hydraulic pump 10.

[0047] In the meantime, responsive to the boom-raising manipulation of the boom control device 12 over the small manipulation stroke, the boom directional control valve 14 is switched slightly toward the left position in FIG. 2, and responsive to the arm-dumping manipulation of the arm control device 13 over the small stroke, the arm directional control valve 15 is switched slightly toward the right position in FIG. 2. Therefore, the pressure oil of the small flow volume delivered from the hydraulic pump 10 is fed to the rod chamber of the arm cylinder 8 via the arm directional control valve 15, and is also fed to the bottom chamber of the boom cylinder 7 via the boom directional control valve 14.

[0048] In association with the crane work in which the load becomes large, high pressures are now detected at the bottom pressure sensor 29 for detecting the bottom pressure of the boom cylinder 7 and the rod pressure sensor 30 for detecting the rod pressure of the arm cylinder 8, respectively, and are outputted to the controller 31. At the subtraction unit 50b included in the center bypass valve control unit 50 of the controller 31 illustrated in FIG. 4, the high pressure detected at the bottom pressure sensor 29 is, therefore, subtracted from the pressure detected at the delivery pressure sensor 24 to compute a small actual differential pressure, and this small actual differential pressure is outputted to the subtraction unit 50c. Corresponding to the small boom-raising manipulation stroke outputted from the boom-raising pressure sensor 25, on the other hand, the first differential pressure generating unit 50a outputs a small target differential pressure to the subtraction unit 50c. At the subtraction unit 50c, the actual differential pressure outputted by the subtraction unit 50b is subtracted from the target differential pressure outputted by the first differential pressure generating unit 50a, and the difference between the target differential pressure and the actual differential pressure, said difference having a relatively large value, is outputted to the maximum selection unit 50g.

[0049] Similarly, at the subtraction unit 50e in the center bypass valve control unit 50, the high pressure detected at the rod pressure sensor 30 is subtracted from the pressure detected at the delivery pressure sensor 24 to compute a small actual differential pressure, and this small actual differential pressure is outputted to the subtraction unit 50f. Corresponding to the small arm-dumping manipulation stroke outputted from the arm-dumping pressure sensor 27, on the other hand, the second differential pressure generating unit 50d outputs a small target differential pressure to the subtraction unit 50f. At the subtraction unit 50f, the actual differential pressure outputted by the subtraction unit 50e is subtracted from the target differential pressure outputted by the second differential pressure generating unit 50d, and the difference between the target differential pressure and the actual differential pressure, said difference having a relatively large value, is outputted to the maximum selection unit 50g.

[0050] The maximum selection unit 50g selects the larger difference from the difference between the target differential pressure and the actual differential pressure as outputted from the subtraction unit 50c and the difference between the target differential pressure and the actual differential pressure as outputted from the subtraction unit 50f, and the thus-selected relatively large difference is outputted to the control signal computing unit 50h. At this control signal computing unit 50h, the relatively large difference outputted from the maximum selection unit 50g is converted to a small control signal of a value corresponding to the difference, and this small control signal is outputted to the addition unit 50i. At this addition unit 50i, this control signal so converted is added

to the preceding control value to perform corrective computation for the production of a new control signal, and the thus-computed value is outputted to the control terminal of the proportional solenoid valve 23 illustrated in FIG. 2.

[0051] As the control value delivered to the control terminal of the proportional solenoid valve 23 is small as mentioned above, the proportional solenoid valve 23 tends to be switched under its spring force to the side of the lower valve chamber as viewed in FIG. 2 so that the pilot pump 11 and the control port of the center bypass valve 22 are connected with each other. As a consequence, the pilot pressure of the pilot pump 11 is delivered to the control port of the center bypass valve 22, and the center bypass valve 22 assumes a predetermined switched state between the fully open position and the fully closed position and its opening amount becomes still smaller. As a consequence, the center bypass line 60 tends to be closed. It is, therefore, possible to perform combined boom-raising and arm-dumping operation, which is precision operation of slow operation speed and becomes high in the load pressures on the actuators, and hence to perform the desired crane work.

[0052] It may become desired to perform precision and light load operation, in which the operation speed is slow and the load pressures on the actuators become low, by manipulating the boom control device 12 and arm control device 13 a little upon earth or sand grading work to be performed, different from the above-mentioned crane work, for example, by combined boom-raising and arm-dumping operation. At this time, control at the pump delivery rate control unit 40 of the controller 31 is similar to that in the above-described crane operation, but control different from that at the time of the crane work is performed at the center bypass valve control unit 50.

[0053] Described specifically, in association with the earth or sand grading work in which small flow volumes are fed to the rod chamber of the arm cylinder 8 and the bottom chamber of the boom cylinder 7, respectively, and the load pressures on these actuators become low at that time, low pressures are detected at the bottom pressure sensor 29 for detecting the bottom pressure of the boom cylinder 7 and the rod pressure sensor 30 for detecting the rod pressure of the arm cylinder 8, respectively, and are outputted to the controller 31. At the subtraction unit 50b included in the center bypass valve control unit 50 of the controller 31 illustrated in FIG. 4, the low pressure detected at the bottom pressure sensor 29 is, therefore, subtracted from the pressure detected at the delivery pressure sensor 24 to compute a large actual differential pressure, and this large actual differential pressure is outputted to the subtraction unit 50c. Corresponding to the small boom-raising manipulation stroke outputted from the boom-raising pressure sensor 25, on the other hand, the first differential pressure generating unit 50a outputs a small target differential pressure to the subtraction unit 50c. At the subtraction unit 50c, the actual differential pressure outputted by the subtraction unit 50b is sub-

tracted from the target differential pressure outputted by the first differential pressure generating unit 50a, and the difference between the target differential pressure and the actual differential pressure, said difference having a relatively small value, is outputted to the maximum selection unit 50g.

[0054] Similarly, at the subtraction unit 50e in the center bypass valve control unit 50, the low pressure detected at the rod pressure sensor 30 is subtracted from the pressure detected at the delivery pressure sensor 24 to compute a large actual differential pressure, and this large actual differential pressure is outputted to the subtraction unit 50f. Corresponding to the small boom-raising manipulation stroke outputted from the arm-dumping pressure sensor 27, on the other hand, the second differential pressure generating unit 50d outputs a small target differential pressure to the subtraction unit 50f. At the subtraction unit 50f, the actual differential pressure outputted by the subtraction unit 50e is subtracted from the target differential pressure outputted by the second differential pressure generating unit 50d, and the difference between the target differential pressure and the actual differential pressure, said difference being of a relatively small value, is outputted to the maximum selection unit 50g.

[0055] The maximum selection unit 50g selects the larger but small difference from the difference between the target differential pressure and the actual differential pressure as outputted from the subtraction unit 50c and the difference between the target differential pressure and the actual differential pressure as outputted from the subtraction unit 50f, and the thus-selected difference is outputted to the control signal computing unit 50h. At this control signal computing unit 50h, the small difference outputted from the maximum selection unit 50g is converted to a control signal, and this control signal is outputted to the addition unit 50i. At this addition unit 50i, this control signal so selected is added to the preceding control value to perform corrective computation for the production of a new control signal the value of which is slightly greater, and the thus-computed value is outputted to the control terminal of the proportional solenoid valve 23 illustrated in FIG. 2.

[0056] As the value of the control signal delivered to the control terminal of the proportional solenoid valve 23 is large as mentioned above, the proportional solenoid valve 23 tends to be switched against its spring force to a side of an upper valve chamber as viewed in FIG. 2, so that the pilot pump 11 and the control port of the center bypass valve 22 tend to be cut off from each other, and on the other hand, the control port of the center bypass valve 22 and the reservoir 34 tend to be connected with each other. Therefore, the center bypass valve 22 assumes, under its spring force, a predetermined switched state between the fully open position and the fully closed position and has a slightly larger opening amount, so that the center bypass line 60 tends to be more opened than at the time of the precision and heavy load operation. As a consequence, the flow volume that flows to the reser-

voir 34 via the center bypass line 60 becomes greater, combined boom-raising and arm-dumping operation, which is precision operation of slow operation speed and becomes low in the load pressures on the actuators is performed, and hence, the desired earth or sand grading work can be performed.

[0057] FIG. 5 is a diagram depicting control to be performed by the hydraulic drive system according to the first embodiment.

[0058] In FIG. 5, the abscissa indicates the lever manipulation stroke, for example, the lever manipulation stroke of the boom control device 12 or the lever manipulation stroke of the arm control device 13, and the ordinate indicates the load pressure on an actuator such as the boom cylinder 7 or arm cylinder 8.

[0059] As depicted in FIG. 5, the first embodiment can perform control in a normal operation range A with the hydraulic pump 10 being set at a high delivery rate, for example, can perform normal work such as earth or sand digging work can be performed as mentioned above when the manipulation strokes of the boom control device 12 or the manipulation stroke of the arm control device are increased. It is to be noted that the above description is made about the case in which the bottom pressure of the boom cylinder 7 and the rod pressure of the arm cylinder 8 become high but in this normal operation range A, no limitation is fundamentally imposed on the levels of load pressures on the actuators, in other words, the loads on the actuators can fundamentally be either light or heavy.

[0060] When the manipulation strokes of the boom control device 12 and the manipulation stroke of the arm control device 13 are made smaller, the delivery rate of the hydraulic pump 10 is reduced, so that the speeds of the actuators become slow and precision operation can be performed. In this case, it is possible to perform, for example, crane work or the like as mentioned above in an operation range B for precision and heavy load operation that the load pressures on the actuators become high. Further, it is possible to perform earth or sand grading operation or the like as mentioned above in an operation range C for precision and light load operation that the load pressures on the actuators become low.

[0061] According to the first embodiment configured as described above, it is possible to assure good normal operability that enables to drive working elements such as the boom 4 and arm 5 at fast operation speeds by making greater the manipulation strokes of the boom control device 12 and arm control device 13. In addition, it is also possible to assure good precision operability that enables to drive the working element such as the boom 4 and arm 5 at slow operation speeds by making smaller the manipulation strokes of the boom control device 12 and arm control device 13. It is also possible to limit the output of the variable displacement hydraulic pump 10 at this time, and hence, to realize a reduction in energy loss. Even at the time of precision operation, the first embodiment raises the delivery pressure of the

variable displacement hydraulic pump 10 at the time of heavy load that the load pressures on the boom cylinder 7 and arm cylinder 8 become high, thereby enabling to assure good operability upon work that relies upon this precision and heavy load operation. Even at the time of precision operation, the first embodiment lowers the delivery pressure of the variable displacement hydraulic pump 10 at the time of light load that the load pressures on the boom cylinder 7 and arm cylinder 8 become low, thereby also enabling to assure good operability upon work that relies upon this precision and light load operation. It is also possible to limit the output of the variable displacement hydraulic pump 10 at this time, and hence, to reduce energy loss. Therefore, this embodiment can realize a hydraulic drive system, which can realize the assurance of high-precision operability and is economical, excellent in practicality and high in reliability.

[0062] It is to be noted that, although only the configuration relating to combined boom-raising and arm-dumping operation is described in the above-described embodiment, the embodiment may also be provided with a configuration which is similar to that in the above-described embodiment but relates to boom-lowering operation and arm-crowding operation. Further, the above-described embodiment may also be provided, as needed, with a configuration which is similar to that in the embodiment but relates to swinging, the operation of the bucket 6, or the operation of an attachment arranged in place of the bucket 6.

[0063] The first embodiment can perform not only combined operation of the boom 4 and arm 5 but also single operation of the boom 4 and single operation of the arm 5 by the above-described configuration without problem.

[0064] The above-described first embodiment is configured to perform control corresponding to the manipulation stroke of the boom control device 12 and the manipulation stroke of the arm control device 13. The first embodiment may, however, be configured to compute, at the controller 31, the lever manipulation speed of the boom control device 12 or the lever manipulation speed of the arm control device based on a signal outputted from the bottom pressure sensor 29 arranged on the boom cylinder 7 or a signal outputted from the rod pressure sensor 30 arranged on the arm cylinder 8, and to perform control corresponding to the thus-computed manipulation speed.

[0065] FIG. 6 depicts control to be performed based on such manipulation speeds by a second embodiment. In FIG. 6, sign A1 indicates a normal operation range, sign B1 indicates an operation range for precision and heavy load operation, and sign C1 indicates an operation range for precision and light load operation. When precision operation is performed, the manipulation speeds of the boom control device 12 and arm control device 13 are normally made slow by the operator. High-precision control that corresponds more to actual operation conditions can, therefore, be realized if the control is performed based on such manipulation speeds in place of manipu-

lation strokes. It is to be noted that instead of control based on such manipulation speeds, computation may be performed at the controller 31 to determine operation accelerations and control may be performed corresponding to the thus-computed operation accelerations.

[0066] FIG. 7 is a block diagram illustrating the configuration of an essential part of a pump delivery rate control unit included in a controller arranged in a hydraulic drive system according to a third embodiment of the present invention, and FIG. 8 is a block diagram illustrating the configuration of an essential part of a center bypass valve control unit included in the controller arranged in the hydraulic drive system according to the third embodiment of the present invention.

[0067] Based on a signal outputted from the delivery pressure sensor 24 or signals outputted from the bottom pressure sensor 29 for detecting the bottom pressure of the boom cylinder 7 and the rod pressure sensor 30 for detecting the rod pressure of the arm cylinder 8, the third embodiment according to the present invention determines whether the work, which is being performed by the working equipment 3, is heavy load work or light load work. When determined to be heavy load work, neither a pump delivery rate control unit 40 nor a center bypass valve control unit 70 of a controller 31, said pump delivery rate control unit 40 and center bypass valve control unit 70 being illustrated in FIGS. 7 and 8, functions, and normal control is performed. As illustrated in FIG. 7, the pump delivery rate control unit 40 in the third embodiment is provided with a switch unit 40g connected to the addition unit 40e. The switch unit 40g is turned ON when the signal outputted from the delivery pressure sensor 24 or the signals outputted from the bottom pressure sensor 29 for detecting the bottom pressure of the boom cylinder 7 and the rod pressure sensor 30 for detecting the rod pressure of the arm cylinder 8 is a signal or are signals that corresponds or correspond to light load, but is turned OFF when the signal or signals is a signal or are signals that corresponds or correspond to heavy load. When the switch unit 40g is turned ON, an added value from the addition unit 40e is converted to a control signal, which is then outputted to the control function generating unit 40f that controls the solenoid-operated proportional reducing valve 21 for adjusting the displacement of the variable displacement hydraulic pump 10.

[0068] The third embodiment is also different from the first embodiment in the configuration of the center bypass valve control unit 70 in the controller 31. The center bypass valve control unit 70 in the third embodiment is provided with a boom function generating unit 70a for outputting an opening area of the center bypass valve 22, which corresponds to a manipulation stroke of the boom control device 12, and an arm function generating unit 70b for outputting an opening area of the center bypass valve 22, which corresponds to a manipulation stroke of the arm control device 13.

[0069] The boom function generating unit 70a includes a boom-raising function generating unit 70a1 and a

boom-lowering function generating unit 70a2. The boom-raising function generating unit 70a1 outputs a larger opening amount as the opening amount of the center bypass valve 22 as the boom-raising manipulation stroke becomes smaller, in other words, as the load becomes lighter in precision operation, and the boom-lowering function generating unit 70a2 outputs a larger opening amount as the opening amount of the center bypass valve 22 as the boom-lowering manipulation stroke becomes smaller, in other words, as the load becomes lighter in precision operation. The relationship between the boom-raising manipulation stroke and the opening amount of the center bypass valve 22 in the boom-raising function generating unit 70a1 and the relationship between the boom-lowering manipulation stroke and the opening amount of the center bypass valve 22 in the boom-lowering function generating unit 70a2 have been set beforehand. It is to be noted that a boom tends to apply a smaller load pressure in its lowering direction under the influence of its dead load, and therefore, compared with the opening amount in the precision operation range set, for example, in the boom-raising function generating unit 70a1, the opening amount in the same precision operation range, said opening amount being to be set in the boom-lowering function generating unit 70a2, can be set greater.

[0070] Similarly, the arm function generating unit 70b includes an arm-crowding function generating unit 70b1 and an arm-dumping function generating unit 70b2. The arm-crowding function generating unit 70b1 outputs a larger opening amount as the opening amount of the center bypass valve 22 as the arm-crowding manipulation stroke becomes smaller, in other words, as the load becomes lighter in precision operation, and the arm-dumping function generating unit 70b2 outputs a larger opening amount as the opening amount of the center bypass valve 22 as the arm-dumping manipulation stroke becomes smaller, in other words, as the load becomes lighter in precision operation. The relationship between the arm-crowding manipulation stroke and the opening amount of the center bypass valve 22 in the arm-crowding function generating unit 70b1 and the relationship between the arm-dumping manipulation stroke and the opening amount of the center bypass valve 22 in the arm-dumping function generating unit 70b2 have been set beforehand.

[0071] The center bypass valve control unit 70 also includes a maximum selection unit 70c and another maximum selection unit 70d. The maximum selection unit 70c selects greater one of the opening amount of the center bypass valve 22 as outputted from the boom-raising function generating unit 70a1 and the opening amount of the center bypass valve 22 as outputted from the boom-lowering function generating unit 70a2. The maximum selection unit 70d, on the other hand, selects greater one of the opening amount of the center bypass valve 22 as outputted from the arm-crowding function generating unit 70b1 and the opening amount of the cent-

er bypass valve 22 as outputted from the arm-dumping function generating unit 70b2.

[0072] The center bypass valve control unit 70 is also provided with an addition unit 70e for adding the opening amount of the center bypass valve 22 as outputted from the above-mentioned maximum selection unit 70c and the opening amount of the center bypass valve 22 as outputted from the above-mentioned maximum selection unit 70d.

[0073] The center bypass valve control unit 70 is also provided with a switch unit 70f connected to the addition unit 70e. The switch unit 70 is turned ON when the signal outputted from the delivery pressure sensor 24 or the signals outputted from the bottom pressure sensor 29 for detecting the bottom pressure of the boom cylinder 7 and the rod pressure sensor 30 for detecting the rod pressure of the arm cylinder 8 is a signal or are signals that corresponds or correspond to light load but is turned OFF when the signal or signals is a signal or are signals that corresponds or correspond to heavy load.

[0074] This center bypass valve control unit 70 is also provided with a control function generating unit 70g. When the switch unit 70f is turned ON, the control function generating unit 70g converts the added value, which relates to the opening amount of the center bypass valve 22 and has been obtained at the addition unit 70e, to a control signal and outputs this control signal to the proportional solenoid valve 23 that controls the center bypass valve 22. In this control function generating unit 70g, a relationship that the value of the control signal increases with the added value obtained at the addition unit 70e has been set beforehand. The remaining configuration in this third embodiment is equivalent to that in the above-described first embodiment.

[0075] In the third embodiment configured as described above, when precision operation is performed by manipulation of the boom control device 12 and arm control device 13, the precision operation is detected at the boom function generating unit 40a and arm function generating unit 40b, small values outputted from the boom function generating unit 40a and small values outputted from the arm function generating unit 40b are added at the addition unit 40e subsequent to selection processings at the maximum selection units 40c, 40d, respectively, and the thus-added value is outputted to the switch unit 40g. If a pressure value detected by the delivery pressure sensor 24 is (or pressure values detected by the bottom pressure sensor 29 and rod pressure sensor 30 are) high at this time and the condition of heavy load is detected despite the precision operation, the switch unit 40g is turned OFF so that the output of the added value, which has been obtained at the addition unit 40e, to the control function generating unit 40f is cut off. In this state, processing operation corresponding to heavy load work in a state of normal precision operation is performed.

[0076] When a pressure value detected by the delivery pressure sensor 24 is (or pressure values detected by the bottom pressure sensor 29 and rod pressure sensor

30 are) low at the time of the precision operation and the condition of light load is detected in the precision operation, the switch unit 40g is turned ON so that the added value obtained at the addition unit 40e is outputted to the control function generating unit 40f. The control function generating unit 40f outputs, to the solenoid-operated proportional reducing valve 21, a control signal of large value corresponding to the relatively small value obtained at the addition unit 40e. The proportional solenoid valve 21, therefore, tends to be switched to the side of the lower position in FIG. 2. As a consequence, the displacement of the variable displacement hydraulic pump 10 is controlled to become small as mentioned above, and from this variable displacement hydraulic pump 10, a small flow volume is delivered.

[0077] When a pressure value detected by the delivery pressure sensor 24 is (or pressure values detected by the bottom pressure sensor 29 and rod pressure sensor 30 are) high at the time of the precision operation and the condition of heavy load is detected despite the precision operation, the switch unit 70f of the center bypass valve control unit 70 in this third embodiment is turned OFF so that the output of the added value, which has been obtained at the addition unit 70e, to the control function generating unit 70g is cut off. In this state, processing operation corresponding to heavy load work in a state of normal precision operation is performed. At this time, the proportional solenoid valve 23 tends to be held at the side of the lower position in FIG. 2 such that the pilot pressure from the pilot pump 11 is guided to the control port of the center bypass valve 22. As a consequence, the center bypass valve 22 is controlled such that it assumes a predetermined switched state between the fully closed position and the fully open position and its opening amount becomes relatively small. A pressure, therefore, arises in the center bypass line 60, thereby making it possible to perform the desired heavy load work by precision operation.

[0078] When a pressure value detected by the delivery pressure sensor 24 is (or pressure values detected by the bottom pressure sensor 29 and rod pressure sensor 30 are) low at the time of the precision operation and the condition of light load is detected in the precision operation, the switch unit 70f in the center bypass valve control unit 70 is turned ON so that the added value obtained at the addition unit 70e is outputted to the control function generating unit 70g. The control function generating unit 70g outputs, to the proportional solenoid valve 23, a large control signal value corresponding to the large added value. The proportional solenoid valve 23, therefore, tends to be switched to the side of the upper position in FIG. 2. As a consequence, the center bypass valve 22 is controlled such that it assumes a predetermined switched state between the fully closed position and the fully open position and its opening amount becomes greater compared with that at the time of the above-described precision operation under heavy load. Therefore, the flow volume that flows to the reservoir 34 via the cent-

er bypass line 60 increases, thereby making it possible to perform the desired light load work by precision operation.

[0079] According to the third embodiment configured as described above, similar advantageous effects as those available from the first embodiment can be obtained, and moreover, it is necessary to arrange, as pressure sensors for detecting load pressures on the actuators, only either the delivery pressure sensor 24 or the bottom pressure sensor 29 and rod pressure sensor 30. Therefore, the third embodiment can reduce the number of pressure sensors compared with the first embodiment, and can simplify the configuration of the system.

15 Legend

[0080]

3	Working equipment
4	Boom (working element)
5	Arm (working element)
7	Boom cylinder (working element actuator)
8	Arm cylinder (working element actuator)
10	Variable displacement hydraulic pump
11	Pilot pump
12	Boom control device (working control device)
13	Arm control device (working control device)
14	Boom directional control valve (directional control valve for working element)
15	Arm directional control valve (directional control valve for working element)
20	Servo valve
20a	Control piston
21	Solenoid-operated proportional reducing valve (displacement control device)
22	Center bypass valve
23	Proportional solenoid valve (center bypass valve control device)
24	Delivery pressure sensor
25	Boom-raising pressure sensor
27	Arm-dumping pressure sensor
29	Bottom pressure sensor
30	Rod pressure sensor
31	Controller
34	Reservoir
40	Pump delivery rate control unit
40a	Function generating unit for boom
40b	Function generating unit for arm
40c	Maximum selection unit
40d	Maximum selection unit
40e	Addition unit
40f	Control function generating unit
40g	Switch unit
50	Center bypass valve control unit
50a	First differential pressure generating unit
50b	First arithmetic unit
50c	Second arithmetic unit
50d	Second differential pressure generating unit

50e	Third arithmetic unit	
50f	Fourth arithmetic unit	
50g	Maximum selection unit	
50h	Control signal computing unit	
50i	Addition unit	5
60	Center bypass line	
70	Center bypass valve control unit	
70a	Function generating unit for boom	
70b	Function generating unit for arm	
70c	Maximum selection unit	10
70d	Maximum selection unit	
70e	Addition unit	
70f	Switch unit	
70g	Control function generating unit	
A	Normal control	15
B	Control of precision and heavy load operation	
C	Control of precision and light load operation	
A1	Normal control	
B1	Control of precision and heavy load operation	
C1	Control of precision and light load operation	20

Claims

1. A hydraulic drive system for a working machine provided with working equipment capable of performing normal operation and precision operation which is performed by a smaller manipulation stroke or at a slower manipulation speed than the normal operation, 25
said hydraulic drive system being provided with a variable displacement hydraulic pump, a working element actuator operable by pressure oil, which is delivered from the variable displacement hydraulic pump, to drive a working element included in the working equipment, an open-center directional control valve for the working element, said open-center directional control valve being arranged in a center bypass line, which communicates the variable displacement hydraulic pump and a reservoir with each other, to control a flow of pressure oil to be fed from the variable displacement hydraulic pump to the working element actuator, and a working element control device for switchingly controlling the directional control valve for the working element, wherein: 30
the hydraulic drive system is provided with a displacement control device for controlling a displacement of the variable displacement hydraulic pump, a center bypass valve arranged in a part of the center bypass line, said part being located downstream of the directional control valve for the working element, and capable of controlling a flow volume to be returned to the reservoir via the center bypass line, a center bypass valve control device for controlling the center bypass valve, and a controller for controlling the displacement control device and center 35
40
45
50
55

bypass valve control device; and the controller is provided with:

a pump delivery rate control unit for performing control processing to output a control signal to the displacement control device to control the variable displacement hydraulic pump at a displacement corresponding to the normal operation when the working element control device is in a manipulation mode considered to correspond to the normal operation or to output a control signal to the displacement control device to make the displacement of the variable displacement hydraulic pump smaller than the displacement corresponding to the normal operation when the working element control device is in a manipulation mode considered to correspond to the precision operation, and

a center bypass valve control unit for performing control processing to output, to the center bypass valve control unit, a control signal to open or close the center bypass valve when the working element control device is in the manipulation mode considered to correspond to the normal operation or a control signal to control the center bypass valve in a switched state between a fully open position and a fully closed position when the working element control device is in the manipulation mode considered to correspond to the precision operation, or for performing control processing to output, to the center bypass valve control unit, a control signal to make the center bypass valve have a small opening amount in a switched state between the fully open position and the fully closed position when the working element control device is in the manipulation mode considered to correspond to the precision operation and a load pressure on the working element actuator is in a high state or a control signal to make the center bypass valve have an opening amount greater than the small opening amount when the working element control device is in the manipulation mode considered to correspond to the precision operation and the load pressure on the working element actuator is in a low state.

2. The hydraulic drive system according to claim 1, wherein:

the controller performs, based on the manipulation stroke, the manipulation speed or a manipulation acceleration of the working element con-

trol device, processing to compute that the working element control device is in the manipulation mode considered to correspond to the precision operation.

5

3. The hydraulic drive system according to claim 2, wherein:

the working machine is a hydraulic excavator,
the working element comprises a boom and an arm, 10
the working element actuator comprises a boom cylinder for actuating the boom and an arm cylinder for actuating the arm,
the directional control valve for the working element comprises a boom directional control valve for controlling the boom cylinder and an arm directional control valve for controlling the arm cylinder, and 15
the working element control device comprises a boom control device for switchingly controlling the boom directional control valve, and an arm control device for switchingly controlling the arm directional control valve. 20

25

4. The hydraulic drive system according to claim 3, wherein:

the hydraulic drive system is further provided with a delivery pressure sensor for detecting a delivery pressure of the variable displacement hydraulic pump, or a bottom pressure sensor for detecting a bottom pressure of the boom cylinder and a rod pressure sensor for detecting a rod pressure of the arm cylinder, and 30
the center bypass valve control unit of the controller performs, according to at least one of a manipulation stroke of the boom control device and a manipulation stroke of the arm control device and the delivery pressure detected at the delivery pressure sensor or according to at least one of the manipulation stroke of the boom control device and the manipulation stroke of the arm control device, the bottom pressure detected at the bottom pressure sensor and the rod-pressure detected at the rodpressure sensor, control processing to output a control signal to control the center bypass valve at a relatively large opening amount when the working element control device is in the manipulation mode 40
considered to correspond to the precision operation and the load pressure on the working element actuator is in the low state. 45 50

55

FIG. 1

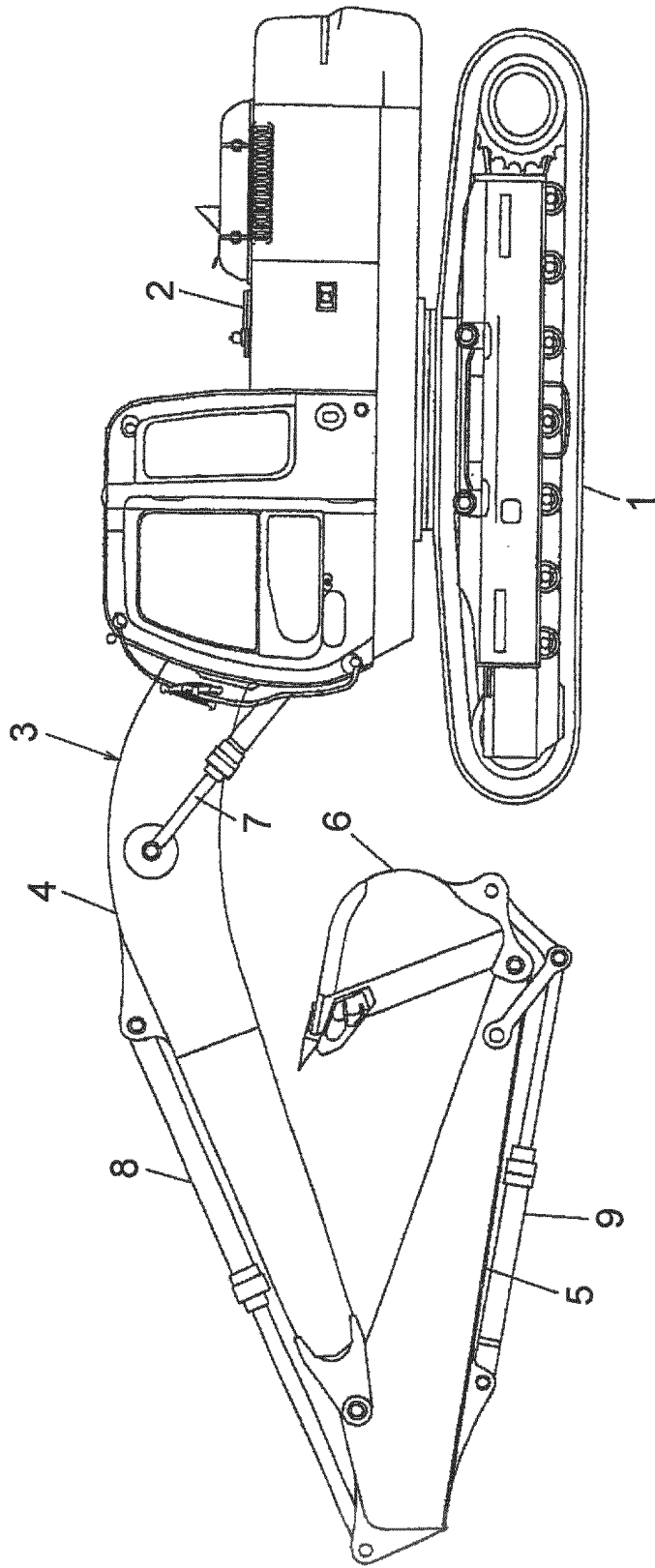


FIG. 2

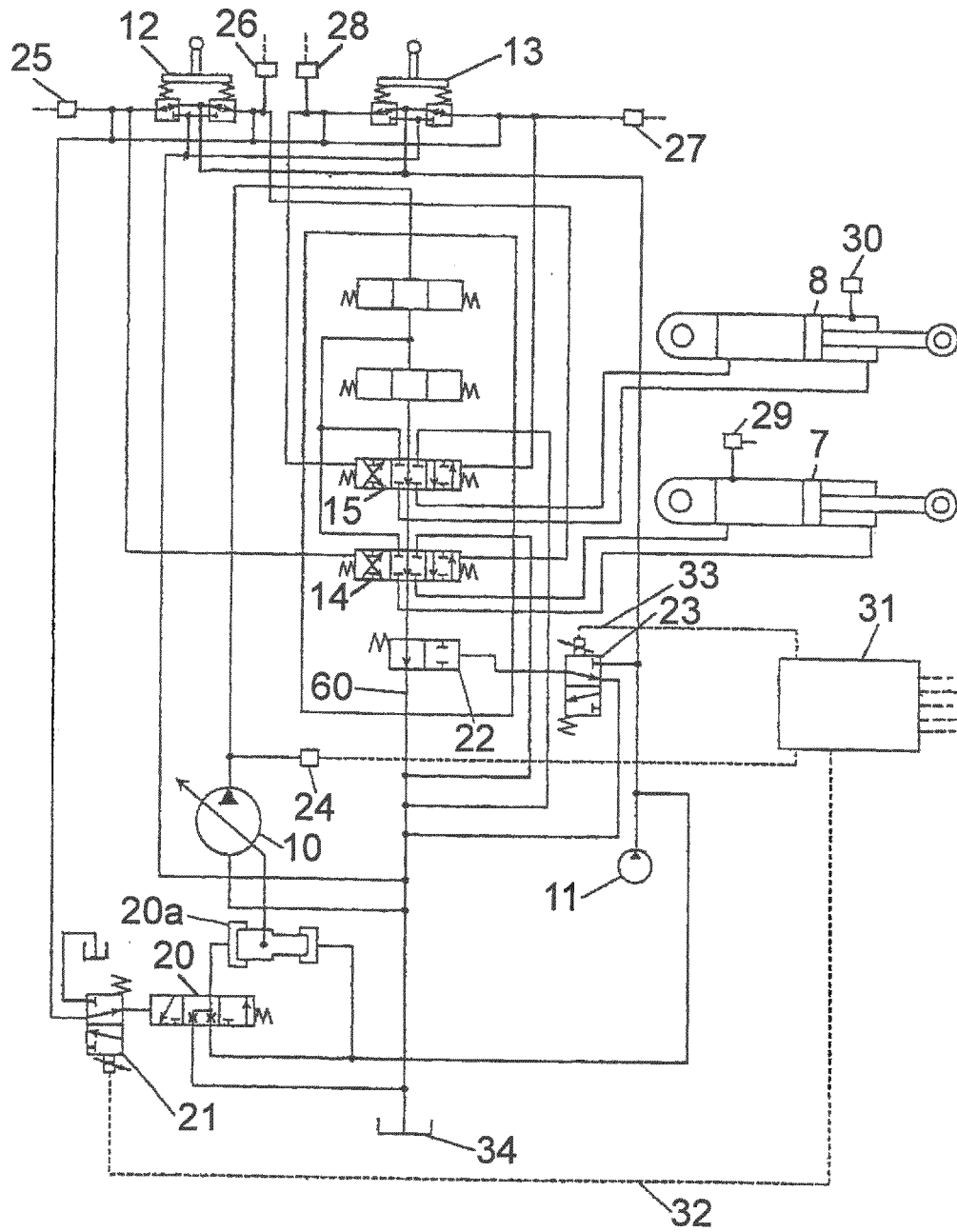


FIG. 3

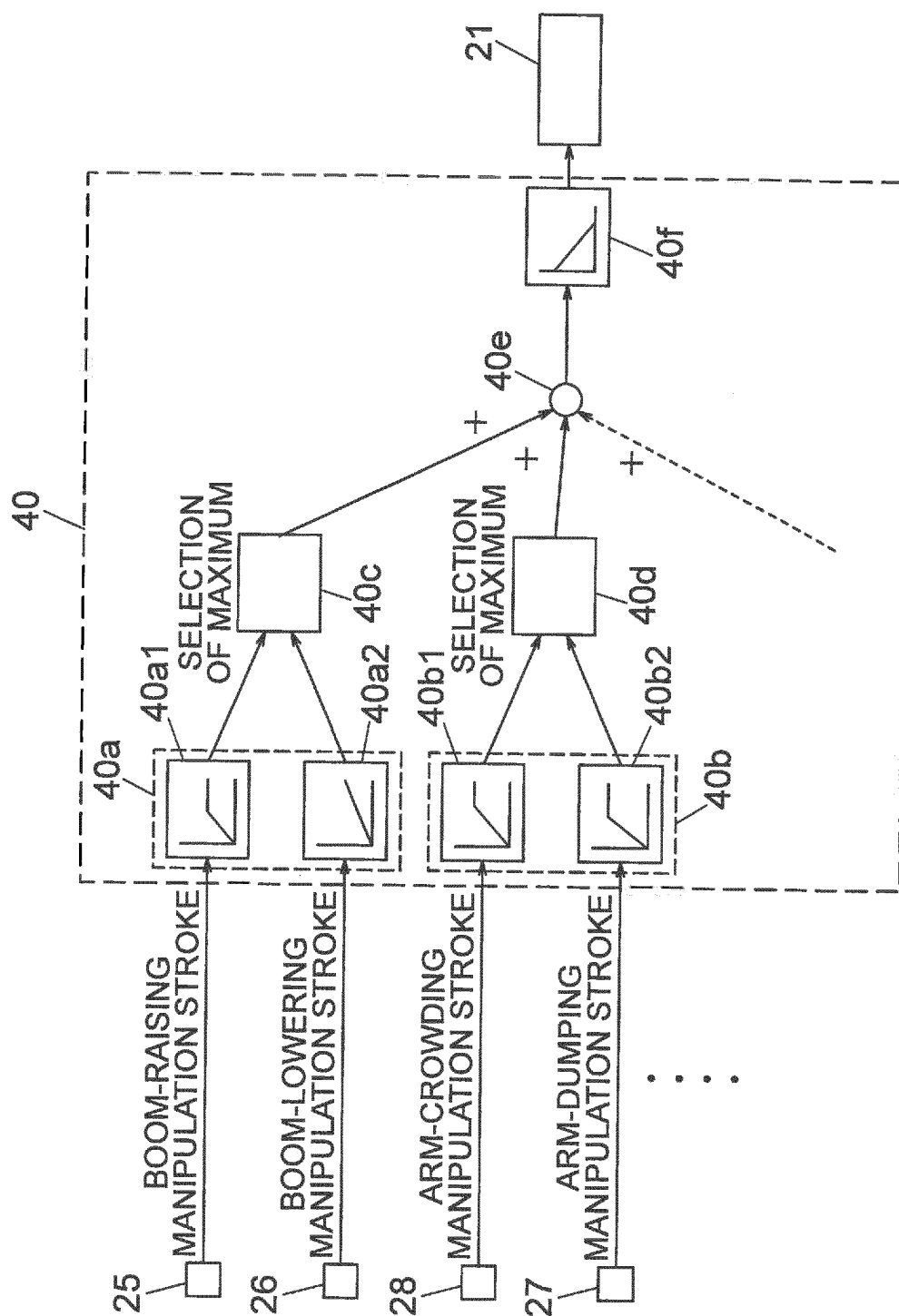


Fig. 4

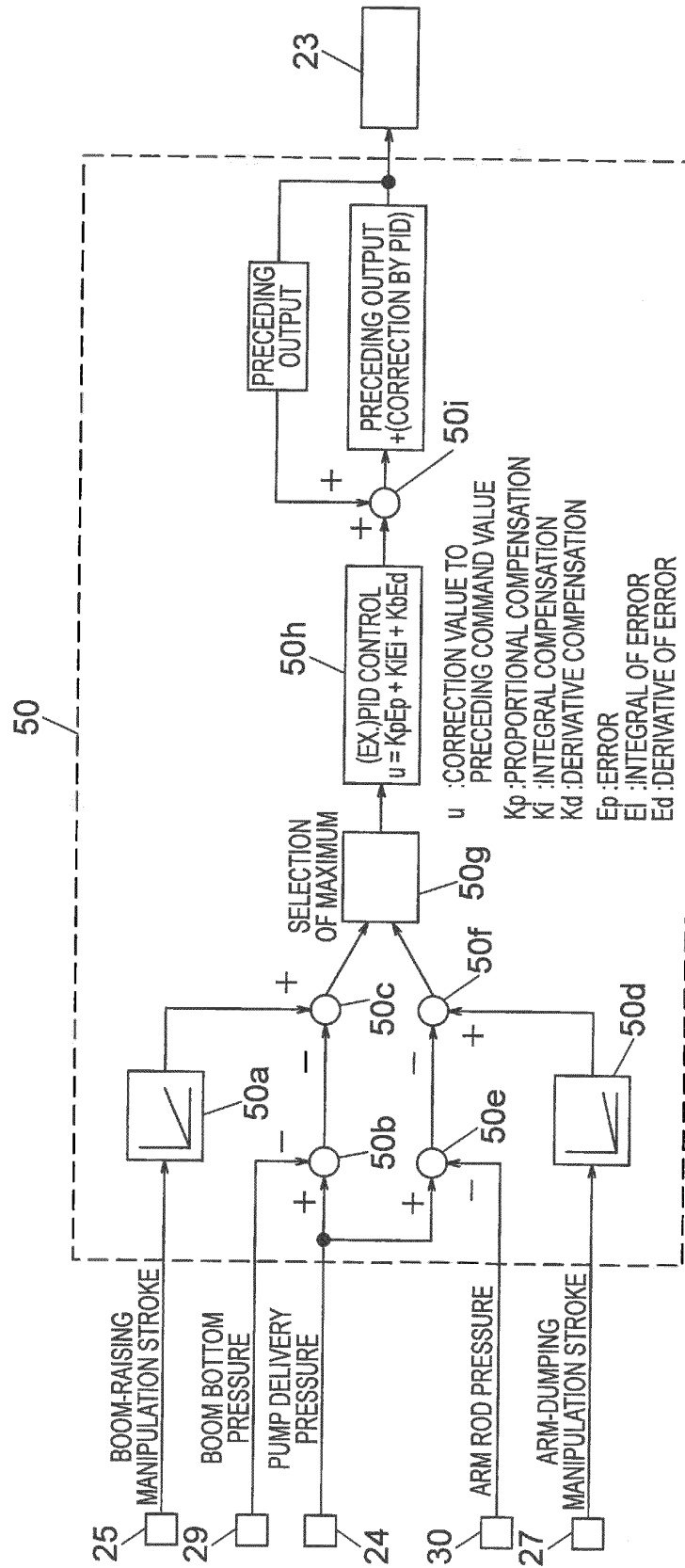


FIG. 5

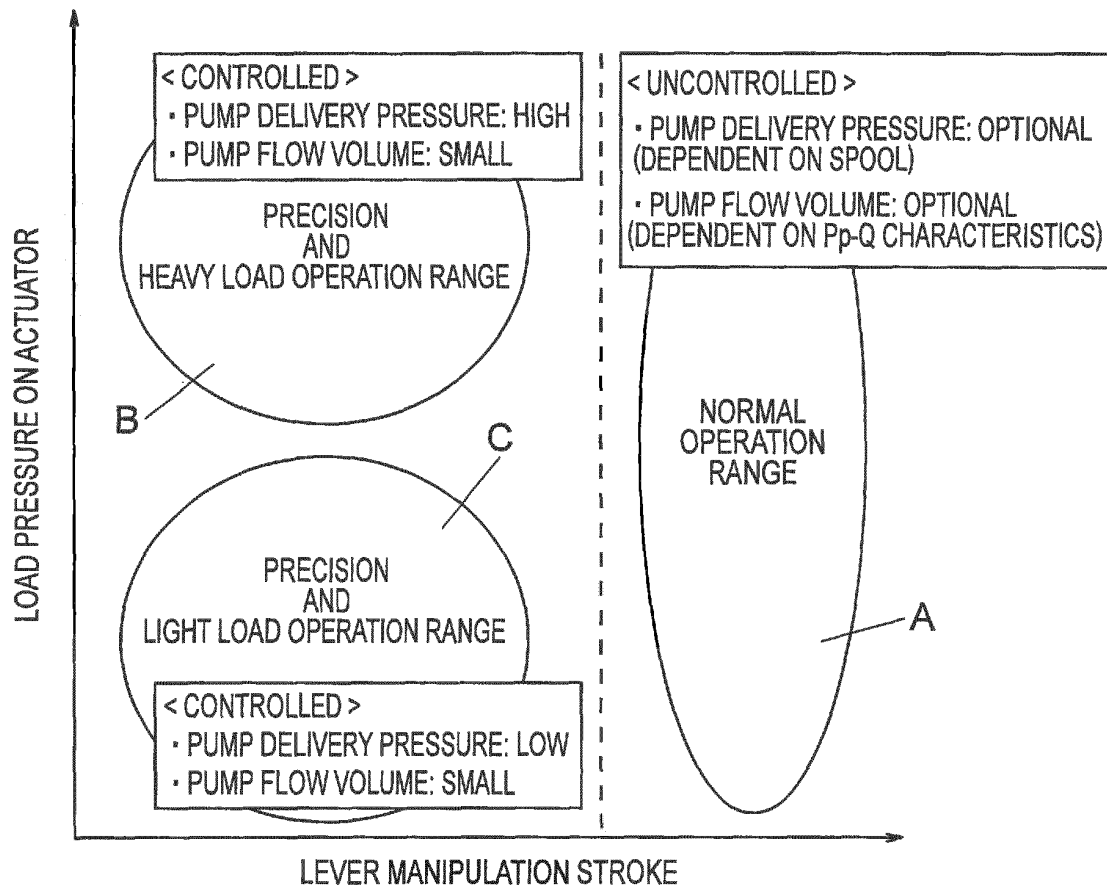


FIG. 6

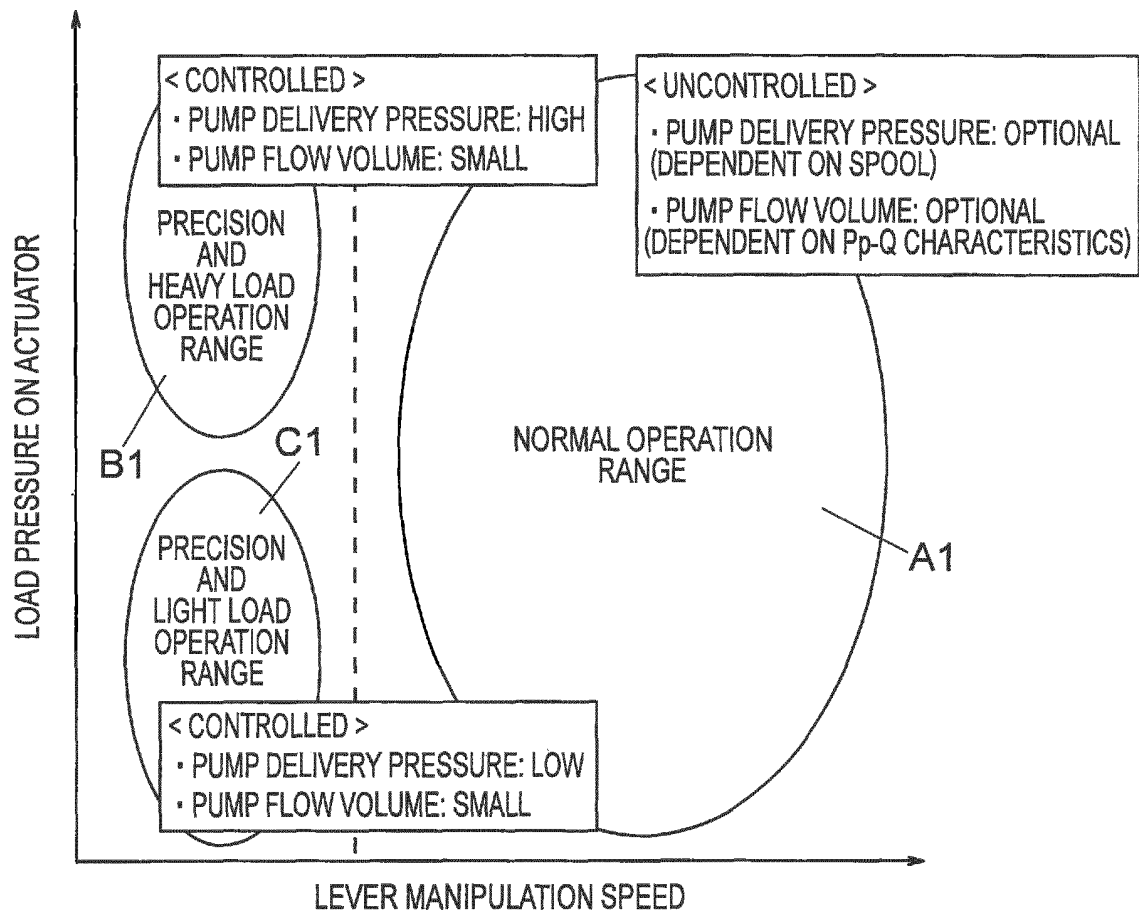


FIG. 7

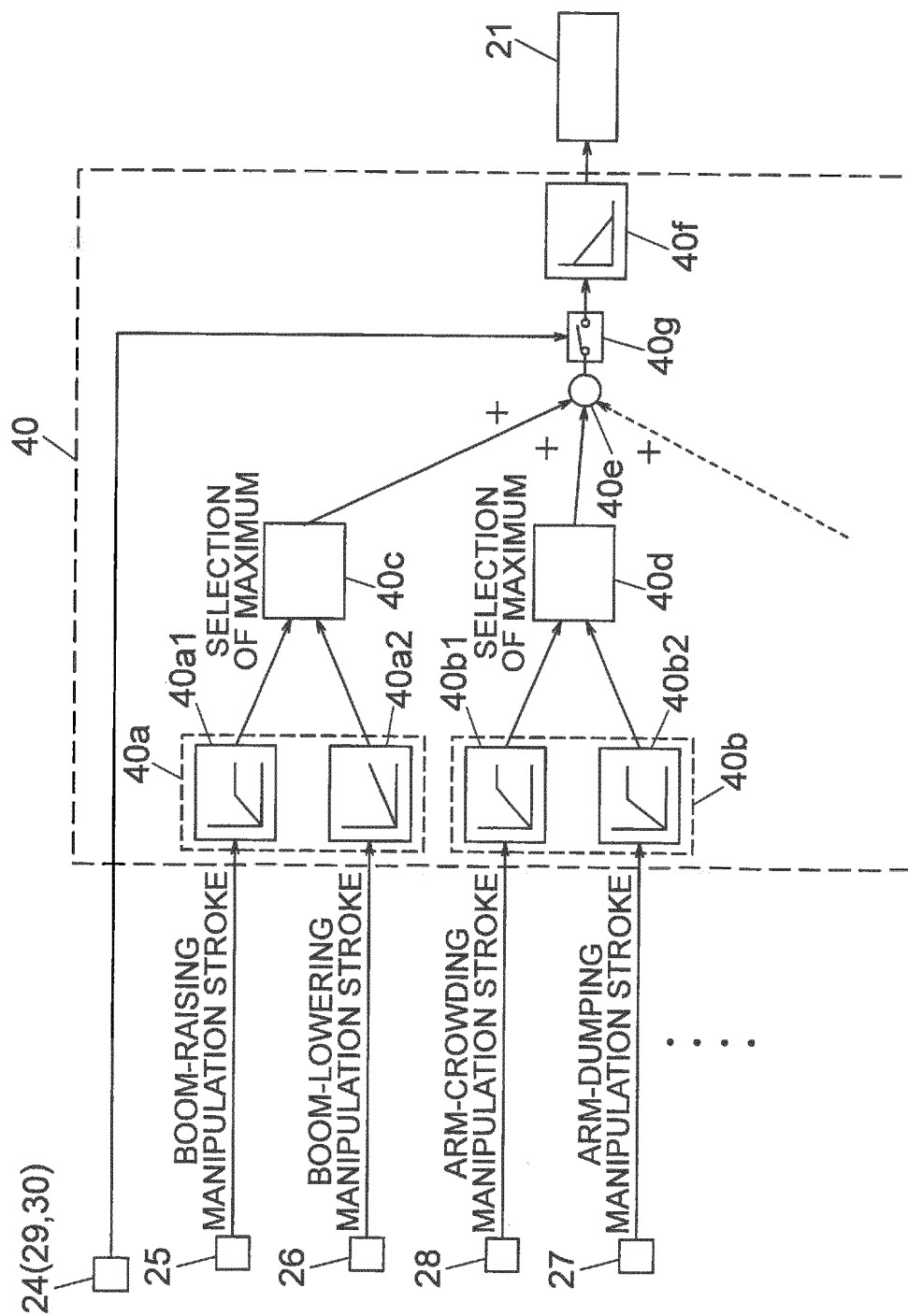
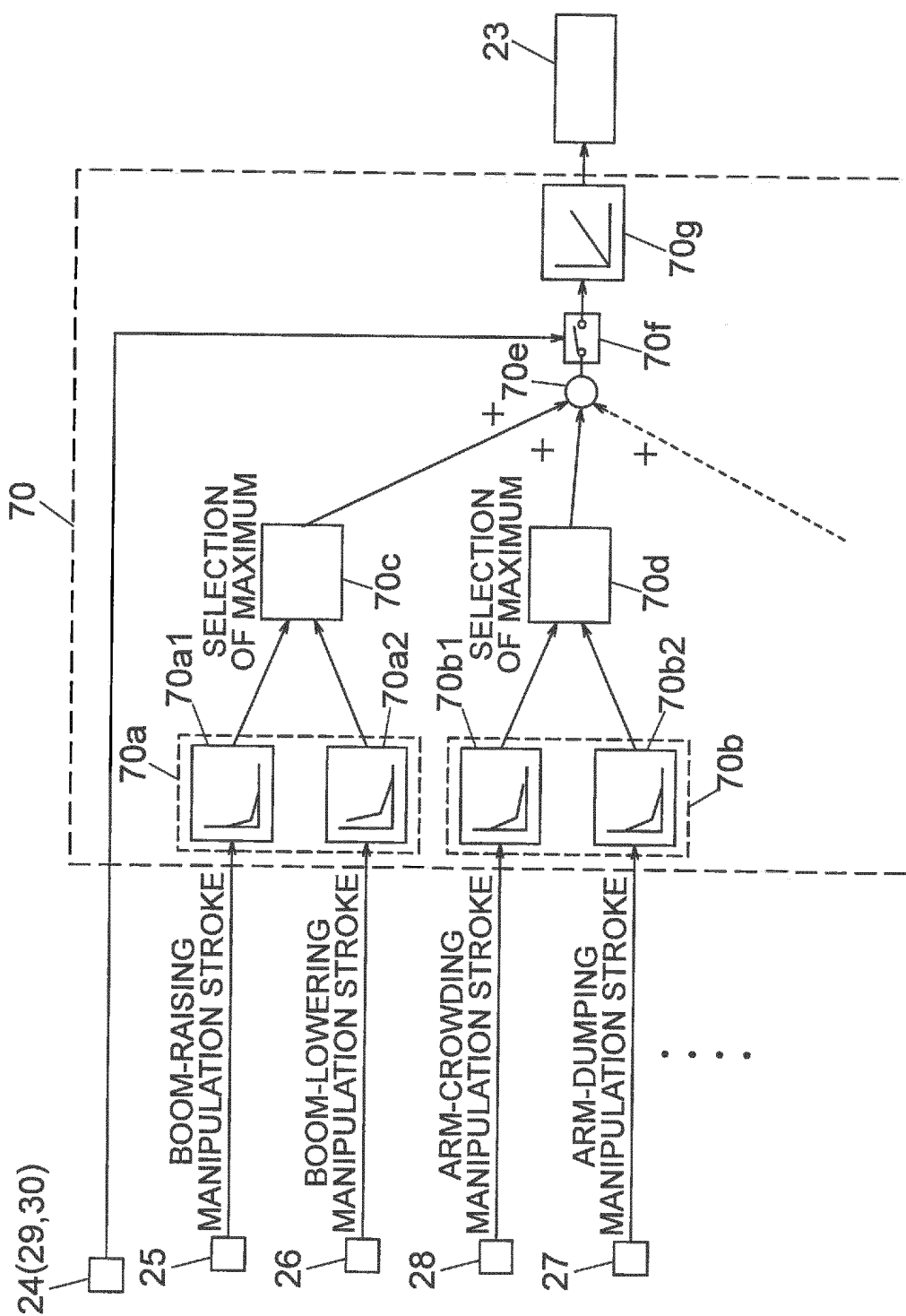


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/052977

A. CLASSIFICATION OF SUBJECT MATTER

F15B11/02 (2006.01) i, E02F9/22 (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)

F15B11/0-11/22

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 1996-2012

Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

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.
A	JP 10-18359 A (Yutani Heavy Industries, Ltd.), 20 January 1998 (20.01.1998), paragraphs [0019], [0020]; fig. 7, 8 & US 5950430 A & EP 816576 A1 & DE 69728217 D & KR 10-0206148 B	1-4
A	JP 10-103306 A (Yutani Heavy Industries, Ltd.), 21 April 1998 (21.04.1998), paragraphs [0006] to [0014]; fig. 1 to 5 & US 5970709 A	1-4
A	JP 11-303809 A (Komatsu Ltd.), 02 November 1999 (02.11.1999), paragraphs [0033] to [0052], [0063] to [0071]; fig. 1 to 3, 5 (Family: none)	1-4

☒ 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

"I" 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
09 April, 2012 (09.04.12)Date of mailing of the international search report
17 April, 2012 (17.04.12)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/052977

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2010-230039 A (Caterpillar S.A.R.L.), 14 October 2010 (14.10.2010), paragraphs [0021] to [0056]; fig. 1 to 6 (Family: none)	1-4
P, A	JP 2011-85159 A (Hitachi Construction Machinery Co., Ltd.), 28 April 2011 (28.04.2011), entire text; all drawings (Family: none)	1-4
P, A	JP 2011-127727 A (Sumitomo Construction Machinery Co., Ltd.), 30 June 2011 (30.06.2011), entire text; fig. 1 to 5 (Family: none)	1-4

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

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.

Patent documents cited in the description

- JP 11082416 A [0003]