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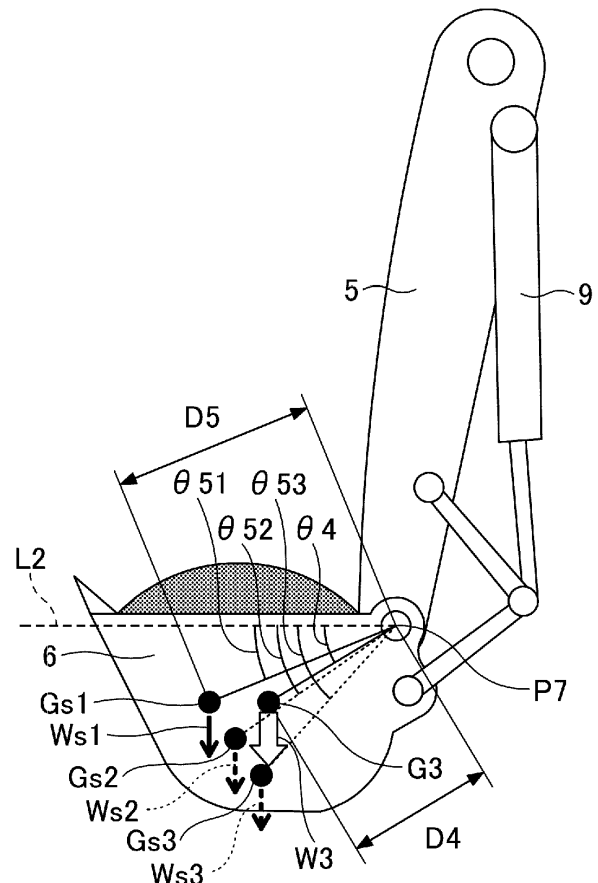
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SHOVEL CONTROL DEVICE AND SHOVEL

(57) A shovel control device according to an embodiment is configured to receive an input of a shape of a bucket provided at a tip of an attachment attached to a shovel, and calculate a weight of an object in the bucket, based on the input shape of the bucket and an output of a detection part whose detection result changes according to the weight of the object in the bucket.

FIG.8



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a shovel control device and a shovel.

BACKGROUND ART

10 **[0002]** In the related art, a technique is known for measuring the weight of an object being transported by a shovel in order for the shovel to load an object such as an earth and sand sediment on a loading bed or the like of a dump truck (for example, see Patent Document 1).

RELATED ART DOCUMENT

15 PATENT DOCUMENT

[0003] Patent Document 1: Japanese Unexamined Patent Publication No. 2002-4337

SUMMARY OF THE INVENTION

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PROBLEMS TO BE SOLVED BY THE INVENTION

25 **[0004]** For example, in the technique described in Patent Document 1, the weight of an object loaded on the shovel is detected based on the thrust of a boom cylinder. In order to detect the weight of the loaded object by the thrust of the boom cylinder, a position of the center of gravity of the loaded object is required. The position of the center of gravity of the loaded object varies according to a shape of a bucket in which the object is loaded.

[0005] An aspect of an embodiment of the present invention provides a technique for improving the accuracy in detection of a weight of an object to be transported in consideration of a shape of a bucket.

30 MEANS FOR SOLVING THE PROBLEMS

35 **[0006]** A shovel control device according to an embodiment of the present invention is configured to receive an input of a shape of a bucket provided at a tip of an attachment attached to a shovel, and calculate a weight of an object in the bucket, based on the input shape of the bucket and an output of a detection part whose detection result changes according to the weight of the object in the bucket.

EFFECTS OF THE INVENTION

40 **[0007]** According to an embodiment of the invention, a technique capable of improving the accuracy in detection of a weight of an object in a bucket can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

45 **[0008]**

[FIG. 1] FIG. 1 is a side view illustrating a shovel according to an embodiment.

[FIG. 2] FIG. 2 is a diagram schematically illustrating an example of a configuration of the shovel according to the embodiment.

50 [FIG. 3] FIG. 3 is a view schematically illustrating an example of a configuration of a hydraulic system of the shovel according to the embodiment.

[FIG. 4A] FIG. 4A is a diagram illustrating a part of the hydraulic system of the shovel according to the embodiment.

[FIG. 4B] FIG. 4B is a diagram illustrating a part of the hydraulic system of the shovel according to the embodiment.

[FIG. 4C] FIG. 4C is a diagram illustrating a part of the hydraulic system of the shovel according to the embodiment.

55 [FIG. 4D] FIG. 4D is a diagram illustrating a part of the hydraulic system of the shovel according to the embodiment.
[FIG. 5] FIG. 5 is a diagram schematically illustrating an example of a configuration portion relating to a sediment weight detection function of the shovel according to the embodiment.

[FIG. 6] FIG. 6 is a diagram illustrating a configuration example of a main screen displayed on a display device of the shovel according to the embodiment.

[FIG. 7] FIG. 7 is a schematic diagram illustrating parameters relating to calculation of the weight of sediment loaded on the bucket of the shovel according to the embodiment.

[FIG. 8] FIG. 8 is a schematic diagram illustrating parameters relating to calculation of the weight of sediment loaded on a bucket of the shovel according to the embodiment.

[FIG. 9] FIG. 9 is a diagram conceptually illustrating a correspondence relationship held by a center-of-gravity position holding table according to the embodiment.

[FIG. 10] FIG. 10 is a flowchart illustrating a processing procedure until the weight of a loaded material loaded in the bucket is determined in a controller according to the embodiment.

EMBODIMENT OF THE INVENTION

[0009] Hereinafter, embodiments of the present invention will be described with reference to the drawings. The embodiments described below are not intended to limit the invention but are merely examples, and all the features and combinations thereof described in the embodiments are not necessarily essential to the invention. In the drawings, the same or corresponding components are denoted by the same or corresponding reference numerals, and the description thereof may be omitted.

[Overview of Shovel]

[0010] First, an overview of the shovel 100 according to a present embodiment will be described with reference to FIG. 1. FIG. 1 is a side view illustrating a shovel 100 as a shovel according to the present embodiment.

[0011] In FIG. 1, the shovel 100 is illustrated as being located on a horizontal plane facing an upward inclined surface ES to be constructed, and an upward slope BS (that is, a slope shape after construction on the upward inclined surface ES), which is an example of a target construction surface to be described later, is also illustrated. Note that a cylindrical body (not illustrated) indicating a direction normal to the upward slope BS, which is a target construction surface, is provided on the upward inclined surface ES to be constructed.

[0012] The shovel 100 according to the present embodiment includes a lower traveling body 1, an upper turning body 3 turnably mounted via a turning mechanism 2 on the lower traveling body 1, a boom 4, an arm 5, and a bucket 6 that constitute an attachment (a working tool), and a cabin 10.

[0013] The lower traveling body 1 causes the shovel 100 to travel by a pair of left and right crawlers being hydraulically driven by traveling hydraulic motors 1L and 1R (see FIG. 2 described later). That is, a pair of traveling hydraulic motors 1L and 1R (an example of a traveling motor) drive the lower traveling body 1 (crawler) as a driven part.

[0014] The upper turning body 3 is driven by a turning hydraulic motor 2A (see FIG. 2 described later) to turn with respect to the lower traveling body 1. That is, the turning hydraulic motor 2A is a turning driving part that drives the upper turning body 3 as a driven part, and can change a direction of the upper turning body 3.

[0015] The upper turning body 3 may be electrically driven by a motor (hereinafter, referred to as a "turning motor") instead of the turning hydraulic motor 2A. That is, the turning motor is a turning driving part that drives the upper turning body 3 acting as a non-driving part, and can change the direction of the upper turning body 3, as in the turning hydraulic motor 2A.

[0016] The boom 4 is pivotally attached to the center of a front portion of the upper turning body 3 so as to be capable of being raised and lowered, the arm 5 is pivotally attached to a tip of the boom 4 so as to be capable of being vertically rotated, and a bucket 6 as an end attachment is pivotally attached to a tip of the arm 5 so as to be capable of being vertically rotated. The boom 4, the arm 5, and the bucket 6 are hydraulically driven by a boom cylinder 7, an arm cylinder 8, and a bucket cylinder 9, respectively, as hydraulic actuators which are examples of actuators.

[0017] The bucket 6 is an example of an end attachment, and another end attachment, for example, a slope bucket, a dredge bucket, a breaker, or the like may be attached to the tip of the arm 5 instead of the bucket 6, according to the work content or the like.

[0018] The cabin 10 is an operator's cabin, which is mounted on the front left side of the upper turning body 3.

[Configuration of Shovel]

[0019] Next, a specific configuration of the shovel 100 according to the present embodiment will be described with reference to FIG. 2 in addition to FIG. 1.

[0020] FIG. 2 is a diagram schematically illustrating an example of a configuration of the shovel 100 according to the present embodiment. In FIG. 2, a mechanical power system, a hydraulic fluid line, a pilot line, and an electric control system are indicated by a double line, a solid line, a broken line, and a dotted line, respectively.

[0021] The drive system of the shovel 100 according to the present embodiment includes an engine 11, a regulator 13, a main pump 14, and a control valve 17. As described above, a hydraulic drive system of the shovel 100 according

to the present embodiment includes the traveling hydraulic motors 1L and 1R, the turning hydraulic motor 2A, the boom cylinder 7, the arm cylinder 8, the bucket cylinder 9, and other hydraulic actuators that hydraulically drive the lower traveling body 1, the upper turning body 3, the boom 4, the arm 5, and the bucket 6, respectively.

[0022] The engine 11 is a main power source in the hydraulic drive system, and is mounted, for example, on a rear portion of the upper turning body 3. Specifically, the engine 11 rotates at a constant speed at a preset target speed, and drives the main pump 14 and a pilot pump 15, under direct or indirect control by a controller 30 described later. The engine 11 is, for example, a diesel engine using light oil as fuel.

[0023] The regulator 13 controls a discharge amount of the main pump 14. For example, the regulator 13 adjusts the angle (tilt angle) of the swash plate of the main pump 14 according to a control instruction from the controller 30. The regulators 13 include, for example, regulators 13L and 13R as described later.

[0024] The main pump 14 is mounted on, for example, a rear portion of the upper turning body 3 similarly to the engine 11, and supplies a hydraulic fluid to the control valve 17 through a high-pressure hydraulic line. The main pump 14 is driven by the engine 11 as described above. The main pump 14 is, for example, a variable displacement hydraulic pump, and as described above, the stroke length of the piston is adjusted by the tilt angle of the swash plate being adjusted by the regulator 13 under the control of the controller 30, and a discharge flow rate (discharge pressure) is thus controlled. The main pump 14 includes, for example, main pumps 14L and 14R as described later.

[0025] The control valve 17 is a hydraulic control device that controls a hydraulic system in the shovel 100. In the present embodiment, the control valve 17 includes control valves 171 to 176. The control valve 175 includes a control valve 175L and a control valve 175R, and the control valve 176 includes a control valve 176L and a control valve 176R. The control valve 17 is configured to be able to selectively supply the hydraulic fluid discharged by the main pump 14 to one or a plurality of hydraulic actuators through the control valves 171 to 176. The control valves 171 to 176 control, for example, the flow rate of the hydraulic fluid flowing from the main pump 14 to the hydraulic actuator and the flow rate of the hydraulic fluid flowing from the hydraulic actuator to the hydraulic fluid tank. The hydraulic actuators include a boom cylinder 7, an arm cylinder 8, a bucket cylinder 9, traveling hydraulic motors 1L and 1R, and a turning hydraulic motor 2A. The traveling hydraulic motors 1L and 1R include a left traveling hydraulic motor 1L and a right traveling hydraulic motor 1R. More specifically, the control valve 171 corresponds to the traveling hydraulic motor 1L, the control valve 172 corresponds to the traveling hydraulic motor 1R, and the control valve 173 corresponds to the turning hydraulic motor 2A. The control valve 174 corresponds to the bucket cylinder 9, the control valve 175 corresponds to the boom cylinder 7, and the control valve 176 corresponds to the arm cylinder 8. The control valve 175 includes, for example, control valves 175L and 175R as described later, and the control valve 176 includes, for example, control valves 176L and 176R as described later. The control valves 171 to 176 will be described in detail later.

[0026] The pilot pump 15 is an example of a pilot pressure generating device, and is configured to be able to supply the hydraulic fluid to the hydraulic control device via a pilot line. In the present embodiment, the pilot pump 15 is a fixed displacement hydraulic pump. However, the pilot pressure generating device may be implemented by the main pump 14. That is, the main pump 14 may have a function of supplying the hydraulic fluid to various hydraulic control devices via the pilot line in addition to a function of supplying the hydraulic fluid to the control valve 17 via the hydraulic fluid line. In this case, the pilot pump 15 may be omitted.

[0027] The operation device 26 is a device used by an operator to operate the actuator. The actuator includes at least one of a hydraulic actuator and an electric actuator.

[0028] The discharge pressure sensor 28 is configured to detect a discharge pressure of the main pump 14. In the present embodiment, the discharge pressure sensor 28 outputs a detected value to the controller 30.

[0029] The operation sensor 29 is configured to detect a content of an operation performed by the operator using the operation device 26. In the present embodiment, the operation sensor 29 detects an operation direction and an operation amount of the operation device 26 corresponding to each of the actuators, and outputs a corresponding detected value to the controller 30. In the present embodiment, the controller 30 controls an opening area of the proportional valve 31 according to an output of the operation sensor 29. The controller 30 supplies the hydraulic fluid discharged from the pilot pump 15 to a pilot port of a corresponding control valve in the control valve 17. The pressure of the hydraulic fluid supplied to each of the pilot ports (pilot pressure) is, in principle, a pressure corresponding to the operation direction and the operation amount of the operation device 26 corresponding to each of the hydraulic actuators. In this way, the operation device 26 is configured to be able to supply the hydraulic fluid discharged by the pilot pump 15 to the pilot port of the corresponding control valve in the control valve 17.

[0030] The proportional valve 31 functioning as a control valve for machine control is disposed in a conduit connecting the pilot pump 15 and pilot ports of control valves in the control valve 17, and is configured to be able to change a flow passage area of the conduit. In the present embodiment, the proportional valve 31 operates according to a control instruction output from the controller 30. Therefore, the controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the pilot ports of the control valves in the control valve 17 via the proportional valve 31, independently of the operation of the operation device 26 by the operator. The proportional valve 31 include, for example, proportional valves 31AL, 31AR, 31BL, 31BR, 31CL, and 31CR as described later.

[0031] With this configuration, even when an operation is not performed on a specific operation device 26, the controller 30 can operate the hydraulic actuator corresponding to the specific operation device 26.

[0032] The control system of the shovel 100 according to the present embodiment includes a controller 30, a display device 40, an input device 42, an audio output device 43, a storage device 47, a boom angle sensor S1, an arm angle sensor S2, a bucket angle sensor S3, a machine body inclination sensor S4, a turning state sensor S5, an imaging device S6, a positioning device PS, and a communication device T1.

[0033] The controller 30 (an example of a control device) is provided in the cabin 10, for example, and performs drive control of the shovel 100. The function of the controller 30 may be implemented by any hardware, software, or a combination thereof. For example, the controller 30 is mainly configured by a microcomputer including a central processing unit (CPU), a read only memory (ROM), a random access memory (RAM), a non-volatile auxiliary storage device, various input/output interfaces, and the like. The controller 30 may implement various functions by executing various programs stored in the ROM or the nonvolatile auxiliary storage device on the CPU, for example.

[0034] For example, the controller 30 sets a target rotation speed based on a work mode or the like set in advance by a predetermined operation of an operator or the like, and performs drive control for rotating the engine 11 at a constant speed.

[0035] Further, for example, the controller 30 outputs a control instruction to the regulator 13 as necessary to change the discharge amount of the main pump 14.

[0036] Further, for example, the controller 30 performs control relating to a machine guidance function of guiding (leading) a manual operation of the shovel 100 by the operator through the operation device 26. Further, the controller 30 performs control relating to a machine control function of automatically supporting manual operation of the shovel 100 by the operator through the operation device 26, for example. That is, the controller 30 includes the machine guidance part 50 as a functional part relating to the machine guidance function and the machine control function. The controller 30 includes a bucket shape setting part and a sediment weight processing part 60, which will be described later.

[0037] Note that some of the functions of the controller 30 may be implemented by another controller (control device). That is, the functions of the controller 30 may be implemented in a distributed manner by a plurality of controllers. For example, the machine guidance function and the machine control function may be implemented by a dedicated controller (control device).

[0038] The display device 40 is provided at a location in the cabin 10 that is easily visible to the seated operator, and displays various information images under the control of the controller 30. The display device 40 may be connected to the controller 30 via an in-vehicle communication network such as a controller area network (CAN) or may be connected to the controller 30 via a dedicated line in a one-to-one manner.

[0039] The input device 42 is provided within reach of an operator seated in the cabin 10, receives various operation inputs from the operator, and outputs a signal corresponding to the operation input to the controller 30. The input device 42 includes a touch panel mounted on a display of a display device that displays various information images, knob switches provided at the tips of lever portions of lever devices 26R, 26L, 26DR, and 26DL, button switches, levers, toggles, and rotary dials installed around the display device 40, and the like. A signal corresponding to the operation content on the input device 42 is input into the controller 30.

[0040] The audio output device 43 is provided in the cabin 10, for example, and is connected to the controller 30. The audio output device 43 outputs sound under the control of the controller 30. The audio output device 43 is, for example, a speaker, a buzzer, or the like. The audio output device 43 performs audio output of various kinds of information according to an audio output instruction from the controller 30.

[0041] The storage device 47 is provided in the cabin 10, for example, and stores various kinds of information under the control of the controller 30. The storage device 47 is, for example, a nonvolatile storage medium such as a semiconductor memory. The storage device 47 may store information output from various devices during the operation of the shovel 100, or may store information acquired via various devices before the operation of the shovel 100 is started. The storage device 47 may store, for example, information on the target construction surface acquired via the communication device T1 or the like or set through the input device 42 or the like. The target construction surface may be set (stored) by the operator of the shovel 100 or may be set by a construction manager or the like.

[0042] The boom angle sensor S1 is attached to the boom 4 and detects an elevation angle of the boom 4 with respect to the upper turning body 3 (hereinafter, referred to as a "boom angle"), for example, an angle formed by a straight line connecting fulcrums at both ends of the boom 4 with respect to a turning plane of the upper turning body 3 in a side view. The boom angle sensor S1 may include, for example, a rotary encoder, an acceleration sensor, a six-axis sensor, an inertial measurement unit (IMU), and the like. The boom angle sensor S1 may include potentiometers using variable resistors, cylinder sensors that detect the stroke amounts of the hydraulic cylinder (boom cylinder 7) corresponding to the boom angle, and the like. Hereinafter, the same applies to the arm angle sensor S2 and the bucket angle sensor S3. A detection signal corresponding to the boom angle by the boom angle sensor S1 is input into the controller 30.

[0043] The arm angle sensor S2 is attached to the arm 5 and detects a rotation angle of the arm 5 with respect to the boom 4 (hereinafter, referred to as an "arm angle"), for example, an angle formed by a straight line connecting fulcrums

at both ends of the arm 5 with respect to a straight line connecting fulcrums at both ends of the boom 4 in a side view. A detection signal corresponding to the arm angle by the arm angle sensor S2 is input into the controller 30.

[0044] The bucket angle sensor S3 is attached to the bucket 6 and detects a rotation angle of the bucket 6 with respect to the arm 5 (hereinafter, referred to as a "bucket angle"), for example, an angle formed by a straight line connecting a fulcrum and a tip (a blade edge) of the bucket 6 with respect to a straight line connecting fulcrums at both ends of the arm 5 in a side view. A detection signal corresponding to the bucket angle by the bucket angle sensor S3 is input into the controller 30.

[0045] The machine body inclination sensor S4 detects an inclination state of the machine body (the upper turning body 3 or the lower traveling body 1) with respect to a horizontal plane. The machine body inclination sensor S4 is attached to, for example, the upper turning body 3, and detects inclination angles (hereinafter, referred to as a "front-rear inclination angle" and a "left-right inclination angle") around two axes in the front-rear direction and the left-right direction of the shovel 100 (that is, the upper turning body 3). The machine body inclination sensor S4 may include, for example, a rotary encoder, an acceleration sensor, a six-axis sensor, an IMU, and the like. The controller 30 receives a detection signal corresponding to the inclination angle (the front-rear inclination angle and the left-right inclination angle) from the machine body inclination sensor S4.

[0046] The turning state sensor S5 outputs detection information relating to the turning state of the upper turning body 3. The turning state sensor S5 detects, for example, a turning angular speed and a turning angle of the upper turning body 3. The turning state sensor S5 may include, for example, a gyro sensor, a resolver, a rotary encoder, or the like. The detection signal corresponding to the turning angle and turning angular speed of the upper turning body 3 by the turning state sensor S5 is input into the controller 30.

[0047] The imaging device S6 as a space recognition device images the periphery of the shovel 100. The imaging device S6 includes a camera S6F that images the front of the shovel 100, a camera S6L that images the left side of the shovel 100, a camera S6R that images the right side of the shovel 100, and a camera S6B that images the rear of the shovel 100. The imaging device S6 may include an attachment camera attached to the attachment.

[0048] The camera S6F is mounted on, for example, the ceiling of the cabin 10, that is, inside the cabin 10. Alternatively, the camera S6F may be attached to the outside of the cabin 10, such as the roof of the cabin 10 or the side surface of the boom 4. The camera S6L is attached to the left end of the upper surface of the upper turning body 3, the camera S6R is attached to the right end of the upper surface of the upper turning body 3, and the camera S6B is attached to the rear end of the upper surface of the upper turning body 3.

[0049] Each of the imaging devices S6 (cameras S6F, S6B, S6L, and S6R) is, for example, a monocular wide-angle camera having a very wide angle of view. The imaging device S6 may be a stereo camera, a range image camera, or the like. The image captured by the imaging device S6 is input into the controller 30 via the display device 40.

[0050] The imaging device S6 as the space recognition device may function as an object detection device. In this case, the imaging device S6 may detect an object present around the shovel 100. The object to be detected may include, for example, a person, an animal, a vehicle, a construction machine, a building, a hole, or the like. The imaging device S6 may calculate distances from the imaging device S6 or the shovel 100 to the recognized objects. The imaging device S6 as the object detection device may include, for example, a stereo camera, a range image sensor, or the like. The space recognition device is, for example, a monocular camera having an imaging element such as a CCD or a CMOS, and outputs a captured image to the display device 40. The space recognition device may be configured to calculate a distance from the space recognition device or the shovel 100 to the recognized object. In addition to the imaging device S6, for example, another object detection device such as an ultrasonic sensor, a millimeter wave radar, a LIDAR, or an infrared sensor may be provided as the space recognition device. When a millimeter wave radar, an ultrasonic sensor, a laser radar, or the like is used as the spatial recognition device, a large number of signals (laser light or the like) may be transmitted to an object, and the reflected signals may be received so as to detect the distance and direction of the object according to the reflected signals. When the object detection device is provided, the imaging device S6 may be omitted.

[0051] Then, when a person is detected by the space recognition device within a range of a predetermined distance from the shovel 100 before the actuator operates, the controller 30 may set the actuator to an inoperable state or a slow speed state so that the shovel 100 does not excessively move even when the operator operates the operation device 26. Specifically, when a person is detected within a range of a predetermined distance from the shovel 100, the controller 30 can bring the actuator into an inoperable state by bringing a gate lock valve into a locked state. In a case of the operation device 26 being an electric type, the controller 30 can disable the actuator by invalidating a signal transmitted from the controller 30 to the operation control valve (proportional valve 31). The same applies to a case where the operation device 26 of another type is used (for example, a case where an operation control valve that outputs a pilot pressure corresponding to a control instruction from the controller 30 and causes the pilot pressure to act on a pilot port of a corresponding control valve in the control valve 17 is used). When the actuator is to be set to the slow speed state, the controller 30 can set the actuator to the slow speed state by reducing the output of the signal (for example, the current signal) transmitted from the controller 30 to the operation control valve. In this way, when an object is detected

within the range of the predetermined distance, the actuator is not driven even when the operation device 26 is operated, or the actuator is driven at a very low speed with an output smaller than the output of the signal when no object is detected within the range of the predetermined distance. Further, when a person is detected within a range of a predetermined distance from the shovel while the operator is operating the operation device 26, the controller 30 may stop or decelerate the actuator independently of the operation content of the operator. Specifically, when a person is detected within a range of a predetermined distance from the shovel 100, the controller 30 stops the actuator by setting the gate lock valve to the locked state. When an operation control valve is used which outputs a pilot pressure corresponding to a control instruction from the controller 30 and applies the pilot pressure to a pilot port of a corresponding control valve in the control valve 17, the controller 30 can disable the actuator or decelerate the actuator by invalidating a signal transmitted from the controller 30 to the operation control valve or outputting a deceleration instruction. In addition, when the detected object is a dump truck, the stop control may be omitted. In this case, the actuator may be controlled so as to avoid the detected dump truck. In this way, the actuator may be controlled based on the type of the detected object.

[0052] The imaging device S6 may be directly connected to the controller 30 so as to be able to communicate with the controller 30. The space recognition device may be disposed outside the shovel 100. In this case, the controller 30 may acquire information output by the space recognition device via the communication device T1. Specifically, the space recognition device may be attached to a multicopter for aerial photography, a steel tower installed at a work site, a dump truck DT, or the like. The controller 30 may determine a state of an earth and sand sediment that spills over and fall, based on the image viewed from any position around the shovel 100.

[0053] A boom rod pressure sensor S7R and a boom bottom pressure sensor S7B are attached to the boom cylinder 7. An arm rod pressure sensor S8R and an arm bottom pressure sensor S8B are attached to the arm cylinder 8. A bucket rod pressure sensor S9R and a bucket bottom pressure sensor S9B are attached to the bucket cylinder 9. The boom rod pressure sensor S7R, the boom bottom pressure sensor S7B, the arm rod pressure sensor S8R, the arm bottom pressure sensor S8B, the bucket rod pressure sensor S9R, and the bucket bottom pressure sensor S9B are collectively referred to as "cylinder pressure sensors".

[0054] The boom rod pressure sensor S7R detects the pressure in the rod side oil chamber of the boom cylinder 7 (hereinafter referred to as "boom rod pressure"). The boom bottom pressure sensor S7B detects the pressure in the bottom side oil chamber of the boom cylinder 7 (hereinafter referred to as "boom bottom pressure"). The arm rod pressure sensor S8R detects the pressure in the rod side oil chamber of the arm cylinder 8 (hereinafter referred to as "arm rod pressure"). The arm bottom pressure sensor S8B detects the pressure in the bottom side oil chamber of the arm cylinders 8 (hereinafter referred to as "arm bottom pressure"). The bucket rod pressure sensor S9R detects the pressure in the rod side oil chamber of the bucket cylinder 9 (hereinafter referred to as "bucket rod pressure"). The bucket bottom pressure sensor S9B detects the pressure in the bottom side oil chamber of the bucket cylinder 9 (hereinafter referred to as "bucket bottom pressure").

[0055] The positioning device PS measures the position and orientation of the upper turning body 3. The positioning device PS is, for example, a global navigation satellite system (GNSS) compass, and detects the position and orientation of the upper turning body 3. Detection signals corresponding to the position and orientation of the upper turning body 3 are input to the controller 30. Further, the function of detecting the orientation of the upper turning body 3 among the functions of the positioning device PS may be replaced by an orientation sensor attached to the upper turning body 3.

[0056] The communication device T1 communicates with external devices via predetermined networks including mobile communication networks that have base stations as terminals, satellite communications networks, Internet networks, and the like. The communication device T1 is, for example, a mobile communication module corresponding to a mobile communication standard such as Long Term Evolution (LTE), 4G (4th Generation), or 5G (5th Generation), a satellite communications module for connecting to a satellite communications network, or the like.

[0057] The machine guidance part 50 executes, for example, control of the shovel 100 relating to a machine guidance function. The machine guidance part 50 notifies the operator of work information, such as a distance between the target construction surface and a tip portion of the attachment, which is a working portion of the end attachment, through the display device 40, the audio output device 43, and the like. The data relating to the target construction surface is stored in advance in the storage device 47, for example, as described above. The data relating to the target construction surface is expressed by, for example, a reference coordinate system. The reference coordinate system is, for example, a world geodetic system. The world geodetic system is a three-dimensional orthogonal XYZ coordinate system with the origin at the center of gravity of the Earth, the X-axis in the direction of the intersection of the Greenwich meridian and the equator, the Y-axis in the direction of 90 degrees east longitude, and the Z-axis in the direction of the north pole. The operator may set any point of the construction site as a reference point, and set the target construction surface based on a relative positional relationship with the reference point through the input device 42. The working portion of the bucket 6 is, for example, a claw tip of the bucket 6, the back surface of the bucket 6, or the like. Further, when a breaker is employed as the end attachment instead of the bucket 6, for example, the tip portion of the breaker corresponds to a working portion. The machine guidance part 50 notifies the operator of the work information through the display device 40, the audio output device 43, and the like, and guides the operator to operate the shovel 100 through the operation

device 26.

[0058] The machine guidance part 50 executes, for example, control of the shovel 100 relating to the machine control function. For example, the machine guidance part 50 may automatically operate at least one of the boom 4, the arm 5, and the bucket 6 so that the target construction surface and the tip position of the bucket 6 match each other when the operator manually performs the excavation operation.

[0059] The machine guidance part 50 acquires information from the boom angle sensor S1, the arm angle sensor S2, the bucket angle sensor S3, the machine body inclination sensor S4, the turning state sensor S5, the imaging device S6, the positioning device PS, the communication device T1, the input device 42, and the like. The machine guidance part 50 then calculates, for example, the distance between the bucket 6 and the target construction surface based on the acquired information. The machine guidance part 50 notifies the operator of the length (degrees) of the distance between the bucket 6 and the target construction surface by sound from the audio output device 43 and images displayed on the display device 40, and automatically controls the operation of the attachment so that a tip portion of the attachment (specifically, a working portion such as the claw tip or the back surface of the bucket 6) matches the target construction surface. The machine guidance part 50 includes a position calculation part 51, a distance calculation part 52, an information transmission part 53, an automatic control part 54, a turning angle calculation part 55, and a relative angle calculation part 56, as detailed functional configurations relating to the machine guidance function and the machine control function.

[0060] The position calculation part 51 calculates a position of a predetermined positioning target. For example, the position calculation part 51 calculates a coordinate point of the tip portion of the attachment, specifically, the working portion such as the claw tip or the back surface of the bucket 6 in the reference coordinate system. Specifically, the position calculation part 51 calculates the coordinate point of the working portion of the bucket 6 from the elevation angles (the boom angle, the arm angle, and the bucket angle) of the boom 4, the arm 5, and the bucket 6.

[0061] The distance calculation part 52 calculates the distance between two positioning targets. For example, the distance calculation part 52 calculates the distance between the target construction surface and the tip portion of the attachment, specifically, the working portion such as the claw tip or the back surface of the bucket 6. The distance calculation part 52 may calculate an angle (relative angle) between the back surface as the working portion of the bucket 6 and the target construction surface.

[0062] The information transmission part 53 transmits (notifies) various kinds of information to the operator of the shovel 100 through a predetermined notification part such as the display device 40 or the audio output device 43. The information transmission part 53 notifies the operator of the shovel 100 of the length (extent) of the various distances and the like calculated by the distance calculation part 52. For example, the operator is notified of the distance (the length) between a tip portion of the bucket 6 and the target construction surface by using at least one of visual information by the display device 40 and auditory information by the audio output device 43. The information transmission part 53 may transmit (the magnitude of) the relative angle between the back surface as the working portion of the bucket 6 and the target construction surface to the operator using at least one of the visual information by the display device 40 and the auditory information by the audio output device 43.

[0063] Specifically, the information transmission part 53 transmits the length of the distance (for example, vertical distance) between the working portion of the bucket 6 and the target construction surface to the operator by using the intermittent sound by the audio output device 43. In this case, the information transmission part 53 may shorten the interval of the intermittent sound as the vertical distance decreases, and may lengthen the sense of the intermittent sound as the vertical distance increases. The information transmission part 53 may use a continuous sound or may represent a difference in the length of the vertical distance while changing the pitch, intensity, or the like of the sound. In addition, the information transmission part 53 may issue an alarm through the audio output device 43 in a case where the tip portion of the bucket 6 is positioned lower than the target construction surface, that is, exceeds the target construction surface. The alarm is, for example, a continuous sound that is significantly louder than the intermittent sound.

[0064] The information transmission part 53 may cause the display device 40 to display the tip portion of the attachment, specifically, the length of the distance between the working portion of the bucket 6 and the target construction surface, the magnitude of the relative angle between the back surface of the bucket 6 and the target construction surface, and the like as the work information. The display device 40 displays, for example, the work information received from the information transmission part 53 together with the image data received from the imaging device S6 under the control of the controller 30. The information transmission part 53 may transmit the length of the vertical distance to the operator using, for example, an image of an analog meter, an image of a bar graph indicator, or the like.

[0065] The automatic control part 54 automatically operates the actuator to automatically support the manual operation of the shovel 100 by the operator through the operation device 26. Specifically, as will be described later, the automatic control part 54 can individually and automatically adjust the pilot pressure applied to the control valves (specifically, the control valve 173, the control valves 174L and 175R, and the control valve 174) corresponding to the plurality of hydraulic actuators (specifically, the turning hydraulic motor 2A, the boom cylinder 7, and the bucket cylinder 9). Thus, the automatic control part 54 can automatically operate each hydraulic actuator. The control relating to the machine control function

by the automatic control part 54 may be executed, for example, when a predetermined switch included in the input device 42 is pressed. The predetermined switch is, for example, a machine control switch (hereinafter, referred to as an "MC (Machine Control) switch"), and may be disposed as a knob switch at the tip of a grip portion of the operation device 26 (for example, a lever device corresponding to the operation of the arm 5) gripped by the operator. The following description

will be given on the assumption that the machine control function is enabled when the MC switch is pressed.

[0066] For example, when the MC switch or the like is pressed, the automatic control part 54 automatically extends and contracts at least one of the boom cylinder 7 and the bucket cylinder 9 according to the operation of the arm cylinder 8 in order to support the excavation work or the shaping work. Specifically, when the operator manually performs the closing operation of the arm 5 (hereinafter, referred to as "arm closing operation"), the automatic control part 54 automatically extends and contracts at least one of the boom cylinder 7 and the bucket cylinder 9 so that the target construction surface and the position of the working portion such as the claw tip or the back surface of the bucket 6 match each other. In this case, the operator can close the arm 5 while making the claw tip or the like of the bucket 6 match the target construction surface, for example, only by performing an arm closing operation of the lever device corresponding to the operation of the arm 5.

[0067] Further, when the MC switch or the like is pressed, the automatic control part 54 may automatically rotate the turning hydraulic motors 2A (an example of actuators) in order to cause the upper turning body 3 to face the target construction surface. Hereinafter, the control of the controller 30 (automatic control part 54) to cause the upper turning body 3 to face the target construction surface will be referred to as "facing control". Thus, the operator or the like can cause the upper turning body 3 to face the target construction surface only by pressing a predetermined switch or only by operating a lever device 26C (described later) corresponding to the turning operation in a state in which the switch is pressed. Further, the operator can cause the upper turning body 3 to directly face the target construction surface and start the machine control function relating to the excavation work of the target construction surface and the like described above only by pressing the MC switch.

[0068] For example, a state in which the upper turning body 3 of the shovel 100 is directly facing the target construction surface is a state in which the tip portion of the attachment (for example, the claw tip, the back surface, or the like as the working portion of the bucket 6) can be moved along the inclination direction of the target construction surface (the upward slope BS) according to the operation of the attachment. Specifically, the state in which the upper turning body 3 of the shovel 100 is directly facing the target construction surface is a state in which the operation surface of the attachment (attachment operation surface) perpendicular to the turning plane of the shovel 100 includes the normal to the target construction surface corresponding to the cylindrical body (in other words, a state along the normal line).

[0069] When the attachment operation surface of the shovel 100 is not in a state of including the normal line to the target construction surface corresponding to the cylindrical body, the tip portion of the attachment cannot move the target construction surface in the inclination direction. Therefore, as a result, the shovel 100 cannot appropriately construct the target construction surface. In contrast, the automatic control part 54 can cause the upper turning body 3 to face the upper turning body 3 by automatically rotating the turning hydraulic motor 2A. Thus, the shovel 100 can appropriately construct the target construction surface.

[0070] In the facing control, the automatic control part 54 determines that the shovel faces the target construction surface, for example, when a left end vertical distance between the coordinate point of the left end of the claw tip of the bucket 6 and the target construction surface (hereinafter, simply referred to as "left end vertical distance") and a right end vertical distance between the coordinate point of the right end of the claw tip of the bucket 6 and the target construction surface (hereinafter, simply referred to as "right end vertical distance") are equal to each other. The automatic control part 54 may determine that the shovel 100 is directly facing the target construction surface when the difference between the left end vertical distance and the right end vertical distance is equal to or less than a predetermined value, instead of when the left end vertical distance and the right end vertical distance are equal to each other (that is, when the difference between the left end vertical distance and the right end vertical distance is zero).

[0071] Further, the automatic control part 54 may operate the turning hydraulic motor 2A based on, for example, the difference between the left end vertical distance and the right end vertical distance in the facing control. Specifically, when the lever device 26C corresponding to the turning operation is operated in a state in which a predetermined switch such as the MC switch is pressed, whether or not the lever device 26C is operated in a direction in which the upper turning body 3 is caused to face the target construction surface is determined. For example, when the lever device 26C is operated in a direction in which the vertical distance between the claw tip of the bucket 6 and the target construction surface (upward slope BS) increases, the automatic control part 54 does not execute the facing control. On the other hand, when the turning operation lever is operated in a direction in which the vertical distance between the claw tip of the bucket 6 and the target construction surface (upward slope BS) decreases, the automatic control part 54 executes the facing control. As a result, the automatic control part 54 can operate the turning hydraulic motor 2A so that the difference between the left end vertical distance and the right end vertical distance becomes small. Thereafter, when the difference becomes equal to or less than a predetermined value or zero, the automatic control part 54 stops the turning hydraulic motor 2A. The automatic control part 54 may set a turning angle at which the difference is equal to or

less than a predetermined value or zero as a target angle, and may control the operation of the turning hydraulic motor 2A so that the angle difference between the target angle and the current turning angle (specifically, a detection value based on the detection signal of the turning state sensor S5) becomes zero. In this case, the turning angle is, for example, an angle of the front-rear axis of the upper turning body 3 with respect to the reference direction.

[0072] As described above, when the shovel 100 is equipped with the turning motor instead of the turning hydraulic motor 2A, the automatic control part 54 performs the facing control on the turning motor (an example of the actuators) as a control target.

[0073] The turning angle calculation part 55 calculates the turning angle of the upper turning body 3. This enables the controller 30 to identify the current orientation of the upper turning body 3. The turning angle calculation part 55 calculates, for example, an angle of the longitudinal axis of the upper turning body 3 with respect to the reference direction as the turning angle based on an output signal of a GNSS compass included in the positioning device PS. The turning angle calculation part 55 may calculate the turning angle based on the detection signal of the turning state sensor S5. In addition, when a reference point is set in the construction site, the turning angle calculation part 55 may set a direction in which the reference point is viewed from the turning axis as the reference direction.

[0074] The turning angle indicates a direction in which the attachment operation surface extends with respect to the reference direction. The attachment operation surface is, for example, a virtual plane that longitudinally traverses the attachment, and is disposed so as to be perpendicular to the turning plane. The turning plane is, for example, a virtual plane including a bottom surface of a turning frame perpendicular to the turning axis. For example, when the controller 30 determines that the attachment operation surface includes the normal line to the target construction surface, the controller 30 (machine guidance part 50) determines that the upper turning body 3 is directly facing the target construction surface.

[0075] The relative angle calculation part 56 calculates a turning angle (relative angle) required to cause the upper turning body 3 to face the target construction surface. The relative angle is, for example, a relative angle formed between the direction of the longitudinal axis of the upper turning body 3 when the upper turning body 3 is made to face the target construction surface and the current direction of the longitudinal axis of the upper turning body 3. The relative angle calculation part 56 calculates the relative angle based on, for example, data relating to the target construction surface stored in the storage device 47 and the turning angle calculated by the turning angle calculation part 55.

[0076] When the lever device 26C corresponding to the turning operation is operated in a state in which a predetermined switch such as the MC switch is pressed, the automatic control part 54 determines whether the turning operation is performed in a direction in which the upper turning body 3 is caused to face the target construction surface. When determining that the upper turning body 3 is operated to turn in the direction in which the upper turning body 3 faces the target construction surface, the automatic control part 54 sets the relative angle calculated by the relative angle calculation part 56 as the target angle. Then, when the change in the turning angle after the lever device 26C is operated reaches the target angle, the automatic control part 54 may determine that the upper turning body 3 is directly facing the target construction surface and may stop the movement of the turning hydraulic motor 2A. Thus, the automatic control part 54 can cause the upper turning body 3 to face the target construction surface, on the assumption of the configuration illustrated in FIG. 2. In the above embodiment of the facing control, the facing control with respect to the target construction surface is described. For example, in the scooping operation when a temporarily placed sediment is loaded onto a dump truck, a target trajectory (target excavation trajectory) corresponding to the target volume may be generated, and the facing control of the turning operation may be performed such that the attachment faces the target excavation trajectory. In this case, the target excavation trajectory is changed every time the scooping operation is performed. Therefore, after the earth is discharged to the dump truck, the facing control is performed with respect to the newly changed target excavation trajectory.

[Hydraulic System of Shovel]

[0077] Next, a hydraulic system of the shovel 100 according to the present embodiment will be described with reference to FIG. 3.

[0078] FIG. 3 is a diagram schematically illustrating an example of a configuration of a hydraulic system of the shovel 100 according to the present embodiment. In FIG. 3, the mechanical power system, the hydraulic fluid line, the pilot line, and the electric control system are indicated by a double line, a solid line, a broken line, and a dotted line, respectively, as in the case of FIG. 2 and the like.

[0079] The hydraulic system implemented by the hydraulic circuit circulates the hydraulic fluid from each of the main pumps 14L and 14R driven by the engine 11 to the hydraulic fluid tank via the center bypass oil passages C1L and C1R and the parallel oil passages C2L and C2R.

[0080] A center bypass oil passage C1L starts from the main pump 14L, passes through control valves 171, 173, 175L, and 176L disposed in the control valve 17 in order, and reaches the hydraulic fluid tank.

[0081] A center bypass oil passage C1R starts from the main pump 14R, sequentially passes through control valves

172, 174, 175R, and 176R disposed in the control valve 17, and reaches the hydraulic fluid tank.

[0082] The control valve 171 is a spool valve that supplies the hydraulic fluid discharged from the main pump 14L to the traveling hydraulic motor 1L and discharges the hydraulic fluid discharged from the traveling hydraulic motor 1L to the hydraulic fluid tank.

[0083] The control valve 172 is a spool valve that supplies the hydraulic fluid discharged from the main pump 14R to the traveling hydraulic motor 1R and discharges the hydraulic fluid discharged from the traveling hydraulic motor 1R to the hydraulic fluid tank.

[0084] The control valve 173 is a spool valve that supplies the hydraulic fluid discharged from the main pump 14L to the turning hydraulic motor 2A and discharges the hydraulic fluid discharged from the turning hydraulic motor 2A to the hydraulic fluid tank.

[0085] The control valve 174 is a spool valve that supplies the hydraulic fluid discharged from the main pump 14R to the bucket cylinder 9 and discharges the hydraulic fluid in the bucket cylinder 9 to the hydraulic fluid tank.

[0086] The control valves 175L and 175R are spool valves that supply the hydraulic fluid discharged from the main pumps 14L and 14R to the boom cylinder 7 and discharge the hydraulic fluid in the boom cylinder 7 to the hydraulic fluid tank.

[0087] The control valves 176L and 176R supply the hydraulic fluid discharged from the main pumps 14L and 14R to the arm cylinder 8 and discharge the hydraulic fluid in the arm cylinder 8 to the hydraulic fluid tank.

[0088] The control valves 171, 172, 173, 174, 175L, 175R, 176L, and 176R adjust the flow rate of the hydraulic fluid supplied to and discharged from the hydraulic actuator, and switch the flow direction of the hydraulic fluid according to the pilot pressure applied to the pilot port.

[0089] A parallel oil passage C2L supplies the hydraulic fluid of the main pump 14L to the control valves 171, 173, 175L, and 176L in parallel with the center bypass oil passage C1L. Specifically, the parallel oil passage C2L is configured to branch from the center bypass oil passage C1L on the upstream side of the control valve 171 and to be able to supply the hydraulic fluid from the main pump 14L in parallel to each of control valves 171, 173, 175L and 176R. Thus, when the flow of the hydraulic fluid passing through the center bypass oil passage C1L is restricted or blocked by any one of the control valves 171, 173, and 175L, the parallel oil passage C2L can supply the hydraulic fluid to the control valve on the further downstream side.

[0090] The parallel oil passage C2R supplies the hydraulic fluid of the main pump 14R to the control valves 172, 174, 175R, 176R in parallel with the center bypass oil passage C1R. Specifically, the parallel oil passage C2R is configured to branch from the center bypass oil passage C1R on the upstream side of the control valve 172 and to be able to supply the hydraulic fluid of the main pump 14R in parallel to each of the control valves 172, 174, 175R, and 176R. Thus, when the flow of the hydraulic fluid passing through the center bypass oil passage C1R is restricted or blocked by any one of the control valves 172, 174, and 175R, the parallel oil passage C2R can supply the hydraulic fluid to the control valve on a further downstream side.

[0091] The regulators 13L and 13R adjust the discharge amounts of the main pumps 14L and 14R by adjusting the tilt angles of the swash plates of the main pumps 14L and 14R under the control of the controller 30.

[0092] The discharge pressure sensor 28L detects the discharge pressure of the main pump 14L, and a detection signal corresponding to the detected discharge pressure is input to the controller 30. The same applies to the discharge pressure sensor 28R. Thus, the controller 30 can control the regulators 13L and 13R according to the discharge pressures of the main pumps 14L and 14R.

[0093] In the center bypass oil passages C1L and C1R, negative control throttles (hereinafter, referred to as "negative control throttles") 18L and 18R are provided between the control valves 176L and 176R on the most downstream side and the hydraulic fluid tank, respectively. Thus, the flow of the hydraulic fluid discharged by the main pumps 14L and 14R is restricted by the negative control throttles 18L and 18R. The negative control throttles 18L and 18R generate control pressures (hereinafter, referred to as "negative control pressures") for controlling the regulators 13L and 13R.

[0094] The negative control pressure sensors 19L and 19R detect the negative control pressures, and detection signals corresponding to the detected negative control pressures are input into the controller 30.

[0095] The controller 30 may control the regulators 13L and 13R according to the discharge pressures of the main pumps 14L and 14R detected by the discharge pressure sensors 28L and 28R, and adjust the discharge amounts of the main pumps 14L and 14R. For example, the controller 30 may control the regulator 13L according to an increase in the discharge pressure of the main pump 14L to adjust the swash plate tilt angle of the main pump 14L, thereby reducing the discharge amount. The same applies to the regulator 13R. Thus, the controller 30 can perform total horsepower control of the main pumps 14L and 14R so that the absorbed horsepower of the main pumps 14L and 14R, which is expressed by the product of the discharge pressure and the discharge amount, does not exceed the output horsepower of the engine 11.

[0096] The controller 30 may adjust the discharge amounts of the main pumps 14L and 14R by controlling the regulators 13L and 13R according to the negative control pressures detected by the negative control pressure sensors 19L and 19R. For example, the controller 30 decreases the discharge amounts of the main pumps 14L and 14R as the negative

control pressures increase, and increases the discharge amounts of the main pumps 14L and 14R as the negative control pressures decrease.

[0097] Specifically, in a case of a standby state (a state illustrated in FIG. 3) in which none of the hydraulic actuators in the shovel 100 is operated, the hydraulic fluid discharged from the main pumps 14L and 14R reaches the negative control throttles 18L and 18R through the center bypass oil passages C1L and C1R. The flow of the hydraulic fluid discharged from the main pumps 14L and 14R increases the negative control pressures generated upstream of the negative control throttles 18L and 18R. As a result, the controller 30 reduces the discharge amounts of the main pumps 14L and 14R to the minimum allowable discharge amounts, and prevents the pumping loss when the discharged hydraulic fluid passes through the center bypass oil passages C1L and C1R.

[0098] On the other hand, when any of the hydraulic actuators is operated through the operation device 26, the hydraulic fluid discharged from the main pumps 14L and 14R flows into the hydraulic actuators to be operated via the control valves corresponding to the hydraulic actuators to be operated. The flow of the hydraulic fluid discharged from the main pumps 14L and 14R reduces or eliminates the amount of the hydraulic fluid reaching the negative control throttles 18L and 18R, and reduces the negative control pressures generated upstream of the negative control throttles 18L and 18R. As a result, the controller 30 can increase the discharge amounts of the main pumps 14L and 14R, circulate sufficient hydraulic fluid to the hydraulic actuators to be operated, and reliably drive the hydraulic actuators to be operated.

[0099] The operation device 26 includes a left operation lever 26L, a right operation lever 26R, and a traveling lever 26D. The traveling lever 26D includes a left traveling lever 26DL and a right traveling lever 26DR.

[0100] The left operation lever 26L is used for a turning operation and an operation of the arm 5. When the left operation lever 26L is operated in the front-rear direction, the control pressure corresponding to the lever operation amount is introduced into the pilot port of the control valve 176 by using the hydraulic fluid discharged from the pilot pump 15. When the left operation lever 26L is operated in the left-right direction, the control pressure corresponding to the lever operation amount is introduced into the pilot port of the control valve 173 by using the hydraulic fluid discharged from the pilot pump 15.

[0101] More specifically, when the left operation lever 26L is operated in the arm closing direction, the hydraulic fluid is introduced into the right pilot port of the control valve 176L, and the hydraulic fluid is introduced into the left pilot port of the control valve 176R. Likewise, when the left operation lever 26L is operated in the arm opening direction, the hydraulic fluid is introduced into the left pilot port of the control valve 176L, and the hydraulic fluid is introduced into the right pilot port of the control valve 176R. Further, when the left operation lever 26L is operated in the left turning direction, the hydraulic fluid is introduced into the left pilot port of the control valve 173, and the hydraulic fluid is introduced into the right pilot port of the control valve 173.

[0102] The right operation lever 26R is used for operation of the boom 4 and operation of the bucket 6. When the right operation lever 26R is operated in the front-rear direction, a control pressure corresponding to the lever operation amount is introduced into the pilot port of the control valve 175 by using the hydraulic fluid discharged from the pilot pump 15. When the lever is operated in the left-right direction, a control pressure corresponding to the lever operation amount is introduced to the pilot port of the control valve 174 by using the hydraulic fluid discharged from the pilot pump 15.

[0103] More specifically, when the right operation lever 26R is operated in the boom lowering direction, the hydraulic fluid is introduced into the left pilot port of the control valve 175R. When the right operation lever 26R is operated in the boom raising direction, the hydraulic fluid is introduced into the right pilot port of the control valve 175L, and the hydraulic fluid is introduced into the left pilot port of the control valve 175R. Further, when the right operation lever 26R is operated in the bucket closing direction, the hydraulic fluid is introduced into the right pilot port of the control valve 174, and when the right operation lever 26R is operated in the bucket opening direction, the hydraulic fluid is introduced into the left pilot port of the control valve 174.

[0104] Hereinafter, the left operation lever 26L operated in the left-right direction may be referred to as a "turning operation lever", and the left operation lever 26L operated in the front-rear direction may be referred to as an "arm operation lever". The right operation lever 26R operated in the left-right direction may be referred to as a "bucket operation lever", and the right operation lever 26R operated in the front-rear direction may be referred to as a "boom operation lever".

[0105] The left traveling lever 26DL is used for operating the left crawler 1CL. The left traveling lever 26DL may be configured to be in conjunction with a left traveling pedal. When the left traveling lever 26DL is operated in the front-rear direction, a control pressure corresponding to the lever operation amount is introduced into the pilot port of the control valve 171 by using the hydraulic fluid discharged from the pilot pump 15. The right traveling lever 26DR is used for operating the right crawler 1CR. The right traveling lever 26DR may be configured to operate in conjunction with a right traveling pedal. When the right traveling lever 26DR is operated in the front-rear direction, a control pressure corresponding to the lever operation amount is introduced into the pilot port of the control valve 172 by using the hydraulic fluid discharged from the pilot pump 15.

[0106] The operation sensor 29 is configured to detect the content of the operation of the operation device 26 by the operator. In the present embodiment, the operation sensor 29 detects the operation direction and the operation amount of the operation device 26 corresponding to each of the actuators, and outputs the detected values to the controller 30.

[0107] The operation sensor 29 include operation sensors 29LA, 29LB, 29RA, 29RB, 29DL, and 29DR. The operation sensor 29LA detects the content of the operation of the left operation lever 26L in the front-rear direction by the operator, and outputs the detected value to the controller 30. The content of the operation is, for example, a lever operation direction, a lever operation amount (lever operation angle), or the like.

[0108] Similarly, the operation sensor 29LB detects the content of the operation of the left operation lever 26L in the left-right direction by the operator, and outputs the detected value to the controller 30. The operation sensor 29RA detects the content of the operation of the right operation lever 26R in the front-rear direction by the operator, and outputs the detected value to the controller 30. The operation sensor 29RB detects the content of the operation of the right operation lever 26R in the left-right direction by the operator, and outputs the detected value to the controller 30. The operation sensor 29DL detects the content of the operation of the left traveling lever 26DL in the front-rear direction by the operator, and outputs the detected value to the controller 30. The operation sensor 29DR detects the content of the operation of the right traveling lever 26DR in the front-rear direction by the operator, and outputs the detected value to the controller 30.

[0109] The controller 30 receives an output of the operation sensor 29, outputs a control instruction to the regulator 13 as necessary to change the discharge amount of the main pump 14. The controller 30 receives an output of a control pressure sensor 19 provided upstream of the throttle 18, and outputs a control instruction to the regulator 13 as necessary to change the discharge amount of the main pump 14. The throttle 18 includes a left throttle 18L and a right throttle 18R, and the control pressure sensor 19 includes negative control pressure sensors 19L and 19R.

[Details of Configuration of Shovel relating to Machine Control Function]

[0110] Next, the configuration of the shovel 100 relating to the machine control function will be described in detail with reference to FIGS. 4A to 4D in addition to FIG. 3.

[0111] FIGS. 4A to 4D are diagrams each illustrating a part of the hydraulic system. Specifically, FIG. 4A is a diagram illustrating a part of the hydraulic system relating to the operation of the arm cylinder 8, and FIG. 4B is a diagram illustrating a part of the hydraulic system relating to an operation of the boom cylinder 7. FIG. 4C is a diagram illustrating a part of the hydraulic system relating to the operation of the bucket cylinder 9, and FIG. 4D is a diagram illustrating a part of the hydraulic system relating to the operation of the turning hydraulic motor 2A.

[0112] As illustrated in FIGS. 4A to 4D, the hydraulic system includes a proportional valve 31. The proportional valve 31 includes proportional valves 31AL to 31DL and 31AR to 31DR.

[0113] The proportional valve 31 functions as a control valve for machine control. The proportional valve 31 is disposed in a conduit connecting the pilot pump 15 and a pilot port of a corresponding control valve in the control valve 17, and is configured to be able to change a flow passage area of the conduit. In the present embodiment, the proportional valve 31 operates according to a control instruction output from the controller 30. Therefore, the controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the pilot port of the corresponding control valve in the control valve 17 via the proportional valve 31, independently of the operation of the operation device 26 by the operator. The controller 30 can apply the pilot pressure generated by the proportional valve 31 to the pilot port of the corresponding control valve.

[0114] With this configuration, even when an operation is not performed on a specific operation device 26, the controller 30 can operate the hydraulic actuator corresponding to the specific operation device 26. Further, even when an operation is being performed on a specific operation device 26, the controller 30 can forcibly stop the operation of the hydraulic actuator corresponding to the specific operation device 26.

[0115] For example, as illustrated in FIG. 4A, the left operation lever 26L is used to operate the arm 5. Specifically, the left operation lever 26L uses the hydraulic fluid discharged by the pilot pump 15 to apply a pilot pressure corresponding to the operation in the front-rear direction to the pilot port of the control valve 176. More specifically, when the left operation lever 26L is operated in the arm closing direction (rearward direction), a pilot pressure corresponding to the operation amount is applied to the right pilot port of the control valve 176L and also to the left pilot port of the control valve 176R. When the left operation lever 26L is operated in the arm opening direction (forward direction), a pilot pressure corresponding to the operation amount is applied to the left pilot port of the control valve 176L and also to the right pilot port of the control valve 176R.

[0116] The operation device 26 is provided with a switch SW. In the present embodiment, the switch SW includes a switch SW1 and a switch SW2. The switch SW1 is a push button switch provided at the tip of the left operation lever 26L. The operator can operate the left operation lever 26L while pressing the switch SW1. The switch SW1 may be provided on the right operation lever 26R or may be provided at another position in the cabin 10. The switch SW2 is a push button switch provided at the tip of the left traveling lever 26DL. The operator can operate the left traveling lever 26DL while pressing the switch SW2. The switch SW2 may be provided on the right traveling lever 26DR or at another position in the cabin 10.

[0117] The operation sensor 29LA detects the content of the operation of the left operation lever 26L in the front-rear direction by the operator, and outputs the detected value to the controller 30.

[0118] The proportional valve 31AL operates according to a control instruction (electric current instruction) output from

the controller 30. The proportional valve 31AL adjusts the pilot pressure by the hydraulic fluid introduced from the pilot pump 15 to the right pilot port of the control valve 176L and the left pilot port of the control valve 176R via the proportional valve 31AL. The proportional valve 31AR operates according to a control instruction (electric current instruction) output from the controller 30. The proportional valve 31AR adjusts the pilot pressure by the hydraulic fluid introduced from the pilot pump 15 to the left pilot port of the control valve 176L and the right pilot port of the control valve 176R via the proportional valve 31AR. The proportional valve 31AL can adjust the pilot pressure so that the control valve 176L and the control valve 176R can be stopped at any positions. Similarly, the proportional valve 31AR can adjust the pilot pressure so that the control valve 176L and the control valve 176R can be stopped at any positions.

[0119] With this configuration, the controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the right pilot port of the control valve 176L and the left pilot port of the control valve 176R via the proportional valve 31AL, according to the arm closing operation by the operator. The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the right pilot port of the control valve 176L and the left pilot port of the control valve 176R via the proportional valve 31AL, independently of the arm closing operation by the operator. That is, the controller 30 can close the arm 5 according to the arm closing operation by the operator or independently of the arm closing operation by the operator.

[0120] The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the left pilot port of the control valve 176L and the right pilot port of the control valve 176R via the proportional valve 31AR, according to the arm opening operation by the operator. The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the left pilot port of the control valve 176L and the right pilot port of the control valve 176R via the proportional valve 31AR, independently of the arm opening operation by the operator. That is, the controller 30 can open the arm 5 according to the arm opening operation by the operator or independently of the arm opening operation by the operator.

[0121] Further, with this configuration, even when the arm closing operation is performed by the operator, the controller 30 can forcibly stop the closing operation of the arm 5 by reducing the pilot pressure applied to the pilot port on the closing side of the control valve 176 (the left pilot port of the control valve 176L and the right pilot port of the control valve 176R) as necessary. The same applies to a case where the opening operation of the arm 5 is forcibly stopped when the arm opening operation is performed by the operator.

[0122] Even when the arm closing operation is being performed, the controller 30 may control the proportional valve 31AR to increase the pilot pressure applied to the pilot port on the opening side of the control valves 176 (the right pilot port of the control valve 176L and the left pilot port of the control valve 176R) opposite to the pilot port on the closing side of the control valves 176, and forcibly return the control valves 176 to the neutral position, thereby forcibly stopping the closing operation of the arm 5. The same applies to a case where the opening operation of the arm 5 is forcibly stopped when the arm opening operation is performed by the operator.

[0123] Although description will be omitted with reference to FIGS. 4B to 4D, the same applies to a case where the operation of the boom 4 is forcibly stopped when the operator performs the boom raising operation or the boom lowering operation, a case where the operation of the bucket 6 is forcibly stopped when the operator performs the bucket closing operation or the bucket opening operation, and a case where the turning operation of the upper turning body 3 is forcibly stopped when the operator performs the turning operation.

[0124] The same applies to a case where the traveling operation of the lower traveling body 1 is forcibly stopped when the traveling operation is performed by the operator.

[0125] As illustrated in FIG. 4B, the right operation lever 26R is used to operate the boom 4. Specifically, the right operation lever 26R uses the hydraulic fluid discharged from the pilot pump 15 to apply a pilot pressure corresponding to the operation in the front-rear direction to the pilot port of the control valve 175. More specifically, when the right operation lever 26R is operated in the boom raising direction (rearward direction), a pilot pressure corresponding to the operation amount is applied to the right pilot port of the control valve 175L and the left pilot port of the control valve 175R. When the right operation lever 26R is operated in the boom lowering direction (forward direction), a pilot pressure corresponding to the operation amount is applied to the right pilot port of the control valve 175R.

[0126] The operation sensor 29RA detects the content of the operation of the right operation lever 26R in the front-rear direction by the operator, and outputs the detected value to the controller 30.

[0127] The proportional valve 31BL operates according to a control instruction (electric current instruction) output from the controller 30. The proportional valve 31BL adjusts the pilot pressure by the hydraulic fluid introduced from the pilot pump 15 to the right pilot port of the control valve 175L and the left pilot port of the control valve 175R via the proportional valve 31BL. The proportional valve 31BR operates according to a control instruction (electric current instruction) output from the controller 30. The proportional valve 31BR adjusts the pilot pressure by the hydraulic fluid introduced from the pilot pump 15 to the right pilot port of the control valve 175R via the proportional valve 31BR. The proportional valve 31BL can adjust the pilot pressure so that the control valve 175L and the control valve 175R can be stopped at any positions. The proportional valve 31BR can adjust the pilot pressure so that the control valve 175R can be stopped at any position.

[0128] With this configuration, the controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the

right pilot port of the control valve 175L and the left pilot port of the control valve 175R via the proportional valve 31BL, according to the boom raising operation by the operator. The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the right pilot port of the control valve 175L and the left pilot port of the control valve 175R via the proportional valve 31BL, independently of the boom raising operation by the operator. That is, the controller 30 can raise the boom 4 according to the boom raising operation by the operator or independently of the boom raising operation by the operator.

[0129] The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the right pilot port of the control valve 175R via the proportional valve 31BR, according to the boom lowering operation by the operator. The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the right pilot port of the control valve 175R via the proportional valve 31BR, independent of the boom lowering operation by the operator. That is, the controller 30 can lower the boom 4 according to the boom lowering operation by the operator or independently of the boom lowering operation by the operator.

[0130] Further, as illustrated in FIG. 4C, the right operation lever 26R is used to operate the bucket 6. Specifically, the right operation lever 26R uses the hydraulic fluid discharged from the pilot pump 15 to apply a pilot pressure corresponding to the operation in the right-left direction to the pilot port of the control valve 174. More specifically, when the right operation lever 26R is operated in the bucket closing direction (left direction), a pilot pressure corresponding to the operation amount is applied to the left pilot port of the control valve 174. When the right operation lever 26R is operated in the bucket opening direction (right direction), a pilot pressure corresponding to the operation amount is applied to the right pilot port of the control valve 174.

[0131] The operation sensor 29RB detects the content of the operation of the right operation lever 26R in the left-right direction by the operator, and outputs the detected value to the controller 30.

[0132] The proportional valve 31CL operates according to a control instruction (electric current instruction) output from the controller 30. The proportional valve 31CL adjusts the pilot pressure by the hydraulic fluid introduced from the pilot pump 15 to the left pilot port of the control valve 174 via the proportional valve 31CL. The proportional valve 31CR operates according to a control instruction (electric current instruction) output from the controller 30. The proportional valve 31CR adjusts the pilot pressure by the hydraulic fluid introduced from the pilot pump 15 to the right pilot port of the control valve 174 via the proportional valve 31CR. The proportional valve 31CL can adjust the pilot pressure so that the control valve 174 can be stopped at any position. Similarly, the proportional valve 31CR can adjust the pilot pressure so that the control valve 174 can be stopped at any position.

[0133] With this configuration, the controller 30 can supply the hydraulic fluid discharged by the pilot pump 15 to the left pilot port of the control valve 174 via the proportional valve 31CL, according to the bucket closing operation by the operator. The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the left pilot port of the control valve 174 via the proportional valve 31CL, independently of the bucket closing operation by the operator. That is, the controller 30 can close the bucket 6 according to the bucket closing operation by the operator or independently of the bucket closing operation by the operator.

[0134] The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the right pilot port of the control valve 174 via the proportional valve 31CR, according to the bucket opening operation by the operator. The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the right pilot port of the control valve 174 via the proportional valve 31CR, independently of the bucket opening operation by the operator. That is, the controller 30 can open the bucket 6 according to the bucket opening operation by the operator or independently of the bucket opening operation by the operator.

[0135] Further, as illustrated in FIG. 4D, the left operation lever 26L is used to operate the turning mechanism 2. Specifically, the left operation lever 26L uses the hydraulic fluid discharged by the pilot pump 15 to apply a pilot pressure corresponding to the operation in the left-right direction to the pilot port of the control valve 173. More specifically, when the left operation lever 26L is operated in the left turning direction (left direction), a pilot pressure corresponding to the operation amount is applied to the left pilot port of the control valve 173. When the left operation lever 26L is operated in the right turning direction (right direction), a pilot pressure corresponding to the operation amount is applied to the right pilot port of the control valve 173.

[0136] The operation sensor 29LB detects the content of the operation of the left operation lever 26L in the left-right direction by the operator, and outputs the detected value to the controller 30.

[0137] The proportional valve 31DL operates according to a control instruction (electric current instruction) output from the controller 30. The proportional valve 31DL adjusts the pilot pressure by the hydraulic fluid introduced from the pilot pump 15 to the left pilot port of the control valve 173 via the proportional valve 31DL. The proportional valve 31DR operates according to a control instruction (electric current instruction) output from the controller 30. The proportional valve 31DR adjusts the pilot pressure by the hydraulic fluid introduced from the pilot pump 15 to the right pilot port of the control valve 173 via the proportional valve 31DR. The proportional valve 31DL can adjust the pilot pressure so that the control valve 173 can be stopped at any position. Similarly, the proportional valve 31DR can adjust the pilot pressure so that the control valve 173 can be stopped at any position.

[0138] With this configuration, the controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the left pilot port of the control valve 173 via the proportional valve 31DL, according to the left turning operation by the operator. The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the left pilot port of the control valve 173 via the proportional valve 31DL, independently of the left turning operation by the operator. That is, the controller 30 can turn the turning mechanism 2 to the left according to the left turning operation by the operator or independently of the left turning operation by the operator.

[0139] Further, the controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the right pilot port of the control valve 173 via the proportional valve 31DR, according to the right turning operation by the operator. The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the right pilot port of the control valve 173 via the proportional valve 31DR, independently of the right turning operation by the operator. That is, the controller 30 can turn the turning mechanism 2 to the right according to the right turning operation by the operator or independently of the right turning operation by the operator.

[0140] The left traveling lever 26DL illustrated in FIG. 3 is used to operate the left crawler 1CL. More specifically, the left traveling lever 26DL uses the hydraulic fluid discharged from the pilot pump 15 to apply a pilot pressure corresponding to the operation in the front-rear direction to the pilot port of the control valve 171. The operation sensor 29DL electrically detects the content of the operation of the left traveling lever 26DL in the front-rear direction by the operator, and outputs an electric current instruction indicating the detected value to the controller 30. Thus, the controller 30 operates according to the electric current instruction.

[0141] Then, the controller 30 can supply the hydraulic fluid discharged by the pilot pump 15 to the left pilot port of the control valve 171 via a proportional valve (not illustrated), as in the above-described configuration. That is, the left crawler 1CL can be moved forward. The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the right pilot port of the control valve 171 via a proportional valve (not illustrated). That is, the left crawler 1CL can be moved backward.

[0142] Further, the right traveling lever 26DR illustrated in FIG. 3 is used to operate the right crawler 1CR. More specifically, the right traveling lever 26DR uses the hydraulic fluid discharged from the pilot pump 15 to apply a pilot pressure corresponding to the operation in the front-rear direction to the pilot port of the control valve 172. The operation sensor 29DR electrically detects the content of the operation of the right traveling lever 26DR in the front-rear direction by the operator, and outputs an electric current instruction indicating the detected value to the controller 30. Thus, the controller 30 operates according to the electric current instruction.

[0143] Then, the controller 30 can supply the hydraulic fluid discharged by the pilot pump 15 to the right pilot port of the control valve 172 via a proportional valve (not illustrated), as in the above-described configuration. That is, the right crawler 1CR can be moved forward. The controller 30 can supply the hydraulic fluid discharged from the pilot pump 15 to the left pilot port of the control valve 172 via a proportional valve (not illustrated). That is, the right crawler 1CR can be moved backward.

[0144] The shovel 100 may have a configuration in which a bucket tilt mechanism is automatically operated. In this case, a hydraulic system portion relating to a bucket tilt cylinder constituting the bucket tilt mechanism may be configured in the same manner as a hydraulic system portion relating to the operation of the boom cylinder 7.

[0145] Further, although an electric operation lever has been described as a form of the operation device 26, a hydraulic operation lever may be employed instead of the electric operation lever. In this case, the lever operation amount of the hydraulic operation lever may be detected in a form of pressure by a pressure sensor and input into the controller 30. Further, a solenoid valve may be disposed between the operation device 26 as the hydraulic operation lever and the pilot port of each control valve. The solenoid valve is configured to operate in response to an electrical signal from the controller 30. With this configuration, when a manual operation is performed using the operation device 26 as the hydraulic operation lever, the operation device 26 can move each control valve by increasing or decreasing the pilot pressure according to the lever operation amount. Further, each control valve may be formed by an electromagnetic spool valve. In this case, the electromagnetic spool valve operates in response to an electric signal from the controller 30 corresponding to the lever operation amount of the electric operation lever.

[Details of Configuration of Shovel Relating to Function of Detecting Sediment Weight]

[0146] Next, the configuration of the shovel 100 according to the present embodiment relating to a sediment weight detection function will be described in detail with reference to FIG. 5. FIG. 5 is a diagram schematically illustrating an example of a configuration portion relating to the sediment weight detection function of the shovel 100 according to the present embodiment.

[0147] The controller 30 according to the present embodiment calculates the weight of a sediment excavated by the bucket 6 based on the thrust of the boom cylinder 7. When the weight of the sediment is detected based on the thrust of the boom cylinder 7, a position of the center of gravity of an earth and sand sediment (hereinafter also referred to as "sediment center of gravity") is required. The position of the sediment center of gravity varies according to the shape of

the bucket 6. Therefore, the controller 30 according to the present embodiment includes a bucket shape setting part 70 as a functional part relating to setting of the shape of the bucket 6.

[0148] The bucket shape setting part 70 sets the shape of the bucket 6 mounted on the shovel 100. Information indicating the set shape of the bucket 6 is stored in the storage device 47, for example. Therefore, the shape is set every time the bucket 6 is mounted.

[0149] The bucket shape setting part 70 according to the present embodiment may perform the setting according to information that is input from the input device 42 (an example of the operation device) and that specifies the shape of the bucket 6. The input of the shape of the bucket 6 performed at the time of setting is not limited to the input performed by the input device 42. The bucket shape setting part 70 may perform the setting according to information for specifying the shape of the bucket 6, which is received from an external device via the communication device T1. The information for specifying the shape of the bucket may be any information, and may be, for example, the model number or the name of the bucket 6.

[0150] Further, the bucket shape setting part 70 may set the shape of the bucket 6 based on input captured image information. It is assumed that the captured image information depicts the bucket 6 attached to the shovel 100. Then, the bucket shape setting part 70 specifies the shape of the bucket 6 depicted in the captured image information and sets the specified shape of the bucket 6.

[0151] Further, when the bucket 6 is replaced, the bucket shape setting part 70 sets the shape of the bucket 6 and also sets the center of gravity of the bucket 6 and the weight of the bucket 6. The center of gravity of the bucket 6 and the weight of the bucket 6 may be stored in advance in the storage device 47 in association with the model number or the name of the bucket 6, or may be input from the input device 42 or the like.

[0152] The controller 30 includes a sediment weight processing part 60 as a functional part relating to a function of detecting the weight of a sediment excavated by the bucket 6 (hereinafter also referred to as "sediment weight").

[0153] In the present embodiment, the sediment weight processing part 60 recognizes the shape of the bucket 6, and thus can calculate the sediment weight in consideration of a position of the center of gravity of an earth and sand sediment (hereinafter also referred to as "sediment center of gravity") after specifying the position of the sediment center of gravity in consideration of the shape of the bucket 6. The center of gravity of an earth and sand sediment (an example of a loaded material) loaded on the bucket 6 is defined as Gs. The weight of a sediment (an example of loaded material) loaded on the bucket 6 is defined as Ws.

[0154] The position of the sediment center of gravity Gs changes according to not only the shape of the bucket 6 but also the amount of sediment excavated by the bucket 6, in other words, the sediment weight Ws. That is, when the sediment weight Ws increases or decreases, the position of the sediment center of gravity Gs changes according to the shape of the bucket 6 on which the sediment is loaded.

[0155] For example, in a bucket having a wide width and a flat bottom portion, the position of the sediment center of gravity Gs in the front-rear direction does not appreciably change according to the sediment weight Ws.

[0156] Therefore, the storage device 47 according to the present embodiment stores a center-of-gravity position holding table 47A in which the sediment weight Ws and the positional relationship information of the sediment center of gravity Gs are associated with each other, for each shape of the bucket 6 (type of bucket 6) connectable to the shovel 100. The positional relationship information of the sediment center of gravity Gs is information relating to the position of the sediment center of gravity Gs in order to specify the position of the sediment center of gravity Gs. Specific positional relationship information of the sediment center of gravity Gs will be described later.

[0157] Thus, when calculating the position of the sediment center of gravity Gs, the sediment weight processing part 60 refers to the center-of-gravity position holding table 47A.

[0158] For example, the sediment weight processing part 60 calculates the sediment weight Ws of the sediment excavated by the bucket 6 based on the thrust of the boom cylinder 7 and the position of the sediment center of gravity Gs set in advance. Then, the sediment weight processing part 60 calculates the position of the sediment center of gravity Gs from the positional relationship information of the sediment center of gravity Gs corresponding to the calculated sediment weight Ws by referring to the center-of-gravity position holding table 47A. Then, the sediment weight processing part 60 calculates the sediment weight Ws of the sediment excavated by the bucket 6 based on the calculated position of the sediment center of gravity Gs and the thrust of the boom cylinder 7.

[0159] The sediment weight processing part 60 according to the present embodiment alternately and repeatedly performs calculation of the position of the sediment center of gravity Gs based on the calculated sediment weight Ws, and calculation of the sediment weight Ws based on the calculated position of the sediment center of gravity Gs and the detection result of the thrust of the boom cylinder 7 (by the boom rod pressure sensor S7R or the boom bottom pressure sensor S7B) according to a cycle (for example, on a 0.1 second basis) executable by the controller 30. By repeatedly performing the processing from the completion of the excavation operation to the start of a sediment dumping operation, the calculation accuracy of the position of the sediment center of gravity Gs is improved, and thus the calculation accuracy of the sediment weight Ws can be improved. The repetition of the specific processing will be described later.

[0160] Next, the specific sediment weight processing part 60 will be described. The sediment weight processing part

60 includes a weight calculation part 61, a maximum load detection part 62, a load calculation part 63, a remaining load calculation part 64, and a center-of-gravity calculation part 65.

[0161] Here, an example of an operation of loading sediment (loaded material) onto a dump truck by the shovel 100 according to the present embodiment will be described.

[0162] First, the shovel 100 controls the attachment at the excavation position to excavate an earth and sand sediment by the bucket 6 (excavation operation). Next, the shovel 100 turns the upper turning body 3 to move the bucket 6 from the excavation position to the dumping position (turning operation). A loading bed of a dump truck is disposed below the dumping position. Next, the shovel 100 controls the attachment at the dumping position to dump the sediment in the bucket 6, thereby loading the sediment in the bucket 6 onto the loading bed of the dump truck (dumping operation). Next, the shovel 100 turns the upper turning body 3 to move the bucket 6 from the dumping position to the excavation position (turning operation). By repeating these operations, the shovel 100 loads the excavated sediment onto the loading bed of the dump truck.

[0163] The weight calculation part 61 calculates the weight W_s of sediment in the bucket 6. The weight calculation part 61 calculates the weight of sediment based on the thrust of the boom cylinder 7 and the distance from the pin for connecting the upper turning body 3 and the boom 4 to the sediment center of gravity G_s . For example, the weight calculation part 61 calculates the weight of sediment by substituting the thrust of the boom cylinder 7 and the distance from the pin for connecting the upper turning body 3 and the boom 4 to the sediment center of gravity G_s into the equation of the moment around the pin for connecting the upper turning body 3 and the boom 4.

[0164] The maximum load detection part 62 detects the maximum load of the dump truck on which sediment is to be loaded. For example, the maximum load detection part 62 specifies a dump truck on which sediment is to be loaded, based on the image captured by the imaging device S6. The expression "based on the image captured by the imaging device S6" means, for example, using information obtained by performing one or more image processing on the image captured by the imaging device S6. Next, the maximum load detection part 62 detects the maximum load of the dump truck based on the specified image of the dump truck. For example, the maximum load detection part 62 determines the vehicle type (size or the like) of the dump truck based on the image of the specified dump truck. The maximum load detection part 62 has a table in which the vehicle type and the maximum load are associated with each other, and obtains the maximum load of the dump truck based on the vehicle type determined from the image and the table. The maximum load, the vehicle type, and the like of the dump truck may be input by the input device 42, and the maximum load detection part 62 may obtain the maximum load of the dump truck based on the input information of the input device 42.

[0165] The load calculation part 63 calculates the weight of the sediment loaded on the dump truck. That is, every time the sediment in the bucket 6 is discharged onto the loading bed of the dump truck, the load calculation part 63 adds the weight of the sediment in the bucket 6 calculated by the weight calculation part 61 to calculate the load (total weight) which is the total of the weight of the sediment loaded on the loading bed of the dump truck. The load is reset when a new dump truck becomes a target dump truck on which a sediment is loaded.

[0166] The remaining load calculation part 64 calculates the difference between the maximum load of the dump truck detected by the maximum load detection part 62 and the current load calculated by the load calculation part 63 as a remaining load. The remaining load is the remaining weight of the sediment that can be loaded on the dump truck.

[0167] The center-of-gravity calculation part 65 calculates the sediment center of gravity in the bucket 6. A method of calculating the sediment center of gravity will be described later.

[0168] The display device 40 may display the weight of the sediment in the bucket 6 calculated by the weight calculation part 61, the maximum load of the dump truck detected by the maximum load detection part 62, the load of the dump truck calculated by the load calculation part 63 (the total weight of the sediment loaded on the loading bed), and the remaining load of the dump truck calculated by the remaining load calculation part 64 (the remaining weight of loadable sediment).

[0169] Note that the display device 40 may be configured to issue a warning when the load exceeds the maximum load. Further, the display device 40 may be configured to issue a warning when the calculated weight of the sediment in the bucket 6 exceeds the remaining load. The warning is not limited to the case of being displayed on the display device 40, and may be an audio output by the audio output device 43. Thus, the earth and sand sediment may be prevented from being loaded in excess of the maximum load of the dump truck.

[0170] Here, a configuration example of a main screen 41V displayed on the display device 40 will be described with reference to FIG. 6. The information displayed on the main screen 41V of FIG. 6 includes, for example, information on the weight (current weight) of the sediment in the bucket 6, the load (cumulative weight) of the dump truck, the remaining load (remaining weight) of the dump truck, the maximum load (maximum load weight), and the like.

[0171] The main screen 41V includes a date and time display area 41a, a traveling mode display area 41b, an attachment display area 41c, a fuel efficiency display area 41d, an engine control state display area 41e, an engine operating time display area 41f, a cooling water temperature display area 41g, a remaining fuel level display area 41h, a rotational speed mode display area 41i, a remaining urea water amount display area 41j, a hydraulic fluid temperature display area 41k, a camera image display area 41m, a current weight display area 41p, a cumulative weight display area 41q,

a remaining weight display area 41s, and a maximum load weight display area 41t.

[0172] The traveling mode display area 41b, the attachment display area 41c, the engine control state display area 41e, and the rotational speed mode display area 41i are areas for displaying setting state information which is information relating to the setting state of the shovel 100. The fuel efficiency display area 41d, the engine operating time display area 41f, the cooling water temperature display area 41g, the remaining fuel level display area 41h, the remaining urea water amount display area 41j, the hydraulic fluid temperature display area 41k, the current weight display area 41p, and the cumulative weight display area 41q are areas for displaying operating state information that is information relating to the operating state of the shovel 100.

[0173] Specifically, the date and time display area 41a is an area for displaying the current date and time. The traveling mode display area 41b is an area for displaying the current traveling mode. The attachment display area 41c is an area for displaying an image representing the currently attached end attachment. FIG. 6 depicts a state in which an image representing the bucket 6 is displayed.

[0174] The fuel efficiency display area 41d is an area for displaying fuel efficiency information calculated by the controller 30. The fuel efficiency display area 41d includes a mean fuel efficiency display area 41d1 for displaying a lifetime mean fuel efficiency or a section mean fuel efficiency, and an instantaneous fuel efficiency display area 41d2 for displaying an instantaneous fuel efficiency.

[0175] The engine control state display area 41e is an area for displaying the control state of the engine 11. The engine operating time display area 41f is an area for displaying the cumulative operating time of the engine 11. The cooling water temperature display area 41g is an area for displaying the current temperature of the engine cooling water. The remaining fuel level display area 41h is an area for displaying the level of fuel stored in the fuel tank. The rotational speed mode display area 41i is an area for displaying the current rotational speed mode set by the engine rotational speed adjustment dial. The remaining urea water amount display area 41j is an area for displaying the remaining amount of the urea-water stored in the urea-water tank. The hydraulic fluid temperature display area 41k is an area for displaying the temperature state of the hydraulic fluid in the hydraulic fluid tank.

[0176] The camera image display area 41m is an area for displaying an image captured by the imaging device S6 acting as a space recognition device. In the example of FIG. 6, the camera image display area 41m displays an image captured by the camera S6B. The image captured by the camera S6B is a rear image displaying the space behind the shovel 100 and includes an image 3a of the counterweight.

[0177] The current weight display area 41p is an area for displaying the weight (current weight) of the earth and sand sediment in the bucket 6. FIG. 6 indicates that the current weight is 550 kg.

[0178] The cumulative weight display area 41q is an area for displaying the load (cumulative weight) of the dump truck. FIG. 6 indicates that the cumulative weight is 9500 kg.

[0179] The cumulative weight is reset every time the dump truck subject to loading the earth and sand sediment is replaced. In the present embodiment, the controller 30 is configured to automatically recognize the replacement of the dump truck and automatically reset the cumulative weight. Specifically, the controller 30 recognizes the replacement of the dump trucks by using the image captured by the imaging device S6. The controller 30 may recognize the replacement of the dump truck by using the communication device. Alternatively, the controller 30 may reset the cumulative weight when a reset button is pressed. The reset button may be a software button, or may be a hardware button disposed on the input device 42, the left operation lever, the right operation lever, or the like.

[0180] With this configuration, the shovel 100 can prevent a loaded material such as a sediment from being loaded on the loading bed of the dump truck in excess of the maximum load weight of the dump truck. When the loaded material is loaded in excess of the maximum load, which is detected by the weighbridge, the operator of the dump truck needs to return to the loading yard and perform an operation of unloading a part of the loaded material loaded on the loading bed. The shovel 100 can prevent the occurrence of such adjustment work of the load weight.

[0181] A predetermined period may be, for example, a period from the time when the work of one day is started to the time when the work of one day is ended. This is to allow the operator or the manager to easily recognize the total weight of the loaded material transported by the work of one day.

[0182] The controller 30 may be configured to integrate the current weight after recognizing that the sediment in the bucket 6 is loaded on the loading bed of the dump truck based on the image captured by the imaging device S6. This is to prevent the earth and sand sediment moved to a place other than the loading bed of the dump truck from being accumulated as the earth and sand sediment loaded on the dump truck.

[0183] The controller 30 may determine whether or not the sediment in the bucket 6 has been loaded onto the loading bed of the dump truck based on the posture of the attachment. Specifically, the controller 30 may determine that the sediment has been loaded onto the loading bed of the dump truck, for example, when the height of the bucket 6 exceeds a predetermined value (for example, the height of the loading bed of the dump truck) and the bucket 6 is opened.

[0184] The remaining weight display area 41s is an area for displaying the remaining weight. The maximum load weight display area 41t is an area for displaying the maximum load weight. FIG. 6 indicates that the cumulative weight is 9500 kg, the remaining load weight is 500 kg, and the maximum load weight is 10000 kg. However, the display device

40 may display the maximum load weight without displaying the remaining weight.

[0185] A message is displayed in the message display area 41m1. For example, a message is displayed when the cumulative weight exceeds the maximum load weight. Thus, the controller 30 can prompt the operator to perform the loading and unloading work, and can prevent the dump truck from being overloaded.

[Method for Calculating Sediment Weight in Weight Calculation Part 61]

[0186] Next, a method of calculating the weight of the sediment (loaded material) in the bucket 6 in the weight calculation part 61 of the shovel 100 according to the present embodiment will be described with reference to FIGS. 7 and 8 while referring to FIG. 5.

[0187] FIGS. 7 and 8 are schematic diagrams illustrating parameters relating to the calculation of the weight of sediment. FIG. 7 depicts the shovel 100, and FIG. 8 depicts the vicinity of the bucket 6.

[0188] Here, a pin for connecting the upper turning body 3 and the boom 4 is defined as a P1. A pin for connecting the upper turning body 3 and the boom cylinder 7 is defined as a P2. A pin for connecting the boom 4 and the boom cylinder 7 is defined as a P3. A pin for connecting the boom 4 and the arm cylinder 8 is defined as a P4. A pin for connecting the arm 5 and the arm cylinder 8 is defined as a P5. A pin for connecting the boom 4 and the arm 5 is defined as a P6. A pin for connecting the arm 5 and the bucket 6 is defined as a P7. The center of gravity of the boom 4 is defined as a G1. The center of gravity of the arm 5 is defined as a G2. The center of gravity of the bucket 6 is defined as a G3. A reference line L2 is a line that passes through the pin P7 and is parallel to the opening surface of the bucket 6. The distance between the pin P1 and the center of gravity G1 of the boom 4 is defined as D1. The distance between the pin P1 and the center of gravity G2 of the arm 5 is defined as D2. The distance between the pin P1 and the center of gravity G3 of the bucket 6 is defined as D3. The distance between the pin P1 and the sediment center of gravity Gs is defined as Ds. The distance between a straight line connecting the pin P2 and the pin P3 and the pin P1 is defined as Dc. Further, a force by the cylinder pressure of the boom cylinder 7 is defined as Fb. Further, of the boom weight (the gravity due to the self-weight of the boom 4), a vertical component in a direction perpendicular to a straight line connecting the pin P1 and the boom center of gravity G1 is defined as W1a. Of the arm weight (gravity due to the self-weight of the arm 5), a vertical component in the direction perpendicular to a straight line connecting the pin P1 and the arm center of gravity G2 is defined as W2a. The weight of bucket 6 is defined as W3.

[0189] As illustrated in FIG. 7, the position of the pin P7 is calculated by the boom angle and the arm angle. That is, the position of the pin P7 can be calculated based on the detection values of the boom angle sensor S1 and the arm angle sensor S2.

[0190] As illustrated in FIG. 8, the positional relationship between the pin P7 and the bucket center of gravity G3 (the angle $\theta 4$ between the reference line L2 of the bucket 6 and the straight line connecting the pin P7 and bucket center of gravity G3, and the distance D4 between the pin P7 and the bucket center of gravity G3) are values set according to types of the bucket 6. That is, the center-of-gravity calculation part 65 can estimate the position of the bucket center of gravity G3 based on the detection result of the bucket angle sensor S3.

[0191] The positional relationship between the pin P7 and the sediment center of gravity changes according to the shape of the bucket 6 and the amount of sediment loaded in the bucket 6.

[0192] The amount of sediment illustrated in FIG. 8 is assumed to be the sediment center of gravity Gs1 when the sediment is loaded in the bucket 6. In this case, the angle between the reference line L2 of the bucket 6 and a straight line connecting the pin P7 and the sediment center of gravity Gs1 is $\theta 51$, and the distance between the pin P7 and the sediment center of gravity Gs1 is D5.

[0193] As the amount of sediment, in other words, the sediment weight Ws decreases, the sediment center of gravity changes to Gs2 and to Gs3. As a result, the angle $\theta 52$ between the reference line L2 of the bucket 6 and a straight line connecting the pin P7 and the sediment center of gravity Gs2, and the angle $\theta 53$ between the reference line L2 of the bucket 6 and a straight line connecting the pin P7 and the sediment center of gravity Gs3 change. Similarly, the distance between the pin P7 and the sediment center of gravity Gs2, and the distance between the pin P7 and the sediment center of gravity Gs3 also change. The change in the sediment center of gravity Gs according to the change in the sediment weight Ws is based on the shape of the bucket 6.

[0194] Therefore, in the present embodiment, the center-of-gravity position holding table 47A stores the sediment weight Ws in association with the positional relationship information of the sediment center of gravity Gs for each shape of the bucket 6. The positional relationship information of the sediment center of gravity Gs includes, for example, an angle $\theta 5$ (not illustrated) between the reference line L2 of the bucket 6 and a straight line connecting the pin P7 and the sediment center of gravity Gs, and a distance D5 between the pin P7 and the sediment center of gravity Gs when the associated sediment weight Ws is loaded in the bucket 6. That is, when the sediment weight Ws has been estimated, the sediment center of gravity Gs can be estimated based on the current inclination of the bucket 6 and the positional relationship information.

[0195] FIG. 9 is a diagram conceptually illustrating the correspondence relationship held by the center-of-gravity

position holding table 47A according to the present embodiment. The horizontal axis represents the sediment weight W_s , and the vertical axis represents the distance D_5 from the pin P7 to the sediment center of gravity G_s .

[0196] As illustrated by a line 901 in FIG. 9, the distance D_5 from the pin P7 to the sediment center of gravity G_s can be specified from the sediment weight W_s . As illustrated in FIG. 9, when the sediment weight W_s is less than a reference weight value W_t , the distance D_5 to the sediment center of gravity G_s changes sharply. Therefore, the sediment may preferably be loaded in the bucket 6 so that the weight of the sediment is equal to or greater than the reference weight value W_t . Although FIG. 9 depicts only the correspondence relationship between the weight of the sediment and the distance D_5 from the pin P7 to the sediment center of gravity G_s , the angle Θ_5 is also specified in addition to the distance D_5 when the actual center-of-gravity position holding table 47A is referred to.

[0197] That is, when the center-of-gravity calculation part 65 calculates the sediment weight (an example of the weight of an object) in the bucket 6, the center-of-gravity calculation part 65 can estimate the position of the sediment center of gravity G_s (for example, the distance D_s between the pin P1 and the sediment center of gravity G_s) based on the calculated sediment weight W_s and the detection results of the respective angle sensors provided in the attachment of the shovel 100 by referring to the center-of-gravity position holding table 47A (an example of table information).

[0198] As described above, the center-of-gravity calculation part 65 can specify, from the sediment weight W_s , the distance D_5 from the pin P7 to the sediment center of gravity G_s and the angle Θ_5 , by referring to the center-of-gravity position holding table 47A (an example of table information). Since the distance D_s is a distance between the pin P1 and the sediment center of gravity G_s , a distance from the pin P1 to the pin P7 is required, in addition to the distance D_5 and the angle Θ_5 . The distance from the pin P1 to the pin P7 can be specified by the shapes of the boom 4 and the arm 5 and the detection results of the angle sensors (for example, the boom angle sensor S1, the arm angle sensor S2, and the bucket angle sensor S3). Since the shapes of the boom 4 and the arm 5 are predetermined, the distance from the pin P1 to the pin P7 can be calculated based on the detection results of the angle sensors. Therefore, the center-of-gravity calculation part 65 can estimate the distance D_s between the pin P1 and the sediment center of gravity G_s , based on the correspondence relationship in the center-of-gravity position holding table 47A, the calculated sediment weight W_s , and the detection results of the angle sensors provided in the attachment of the shovel 100.

[0199] Thus, when the sediment weight processing part 60 calculates the sediment weight W_s , the sediment weight W_s can be calculated with high accuracy by using the estimated distance D_s from the pin P1 to the sediment center of gravity G_s .

[0200] When the sediment weight W_s is calculated, the position of the sediment center of gravity G_s is required. However, before the sediment weight W_s is calculated for the first time, the position of the sediment center of gravity G_s may not be estimated.

[0201] Therefore, in the present embodiment, the storage device 47 stores, in advance, the initial values of the position of the sediment center of gravity G_s (for example, the initial value of the angle Θ_5 between the reference line L2 of the bucket 6 and a straight line connecting the pin P7 and the sediment center of gravity G_s and the initial value of the distance D_5 between the pin P7 and the sediment center of gravity G_s) corresponding to the bucket 6 mounted on the shovel 100. The initial values of the position of the sediment center of gravity G_s are values used for first calculation of the sediment weight W_s . In the present embodiment, the calculation of the sediment weight W_s is repeatedly performed. Among the repeatedly performed calculations of the sediment weight W_s , the initial values of the position of the sediment center of gravity G_s are used for the first calculation of the sediment weight W_s . In the repeated calculations of the sediment weight W_s , the position of the sediment center of gravity G_s estimated from the sediment weight calculated at the (n-1)-th time is used for the n-th (n is 2 or more) and subsequent calculations. Here, the center-of-gravity position holding table 47A may associate the height from the bottom surface of the bucket 6 to the position of the sediment center of gravity G_s with the sediment weight W_s . In this case, the center-of-gravity calculation part 65 can calculate the distance D_s from the pin P7 to the sediment center of gravity G_s using the shape of the bucket 6 set by the bucket shape setting part 70 and the positional relationship between the bucket 6 and the pin P1.

[0202] In this way, the sediment weight processing part 60 calculates a first sediment weight W_{s11} using the initial value of the position of the sediment center of gravity G_s . A specific method of calculating the sediment weight W_s using the position of the sediment center of gravity G_s will be described later. After the first sediment weight W_{s11} is calculated, the center-of-gravity calculation part 65 estimates the position of the first sediment center of gravity G_{s11} (distance D_s between the pin P1 and the sediment center of gravity G_s), based on the positional relationship information of the sediment center of gravity G_s associated with the calculated first sediment weight W_{s11} (the angle Θ_5 between the reference line L2 and a straight line connecting the pin P7 and the sediment center of gravity G_s , and the distance D_5 between the pin P7 and the sediment center of gravity G_s) and the detection values of the boom angle sensor S1, the arm angle sensor S2, and the bucket angle sensor S3. Thereafter, the sediment weight processing part 60 recalculates a second sediment weight W_{s12} , using the position of the first sediment center of gravity G_{s11} (the distance D_s from the pin P1 to the sediment center of gravity G_s).

[0203] The initial value of the position of the sediment center of gravity G_s may be different from the actual position of the sediment center of gravity G_s . Therefore, the first sediment weight W_{s11} calculated using the initial value of the

position of the sediment center of gravity G_s may be different from the actual sediment weight W_s . Thus, the center-of-gravity calculation part 65 according to the present embodiment estimates the position of the first sediment center of gravity G_{s11} corresponding to the calculated first sediment weight W_{s11} , by referring to the center-of-gravity position holding table 47A.

[0204] As illustrated in FIG. 9, the center-of-gravity position holding table 47A holds the correspondence relationship between the sediment weight W_s and the position of the sediment center of gravity G_s . The position of the first sediment center of gravity G_{s11} is a value estimated by referring to the center-of-gravity position holding table 47A using the calculated first sediment weight W_{s11} . Therefore, the position of the first sediment center of gravity G_{s11} is considered to be a value closer to the actual position of the sediment center of gravity G_s than the initial value.

[0205] Therefore, the sediment weight processing part 60 according to the present embodiment recalculates the second sediment weight W_{s12} , using the estimated position of the first sediment center of gravity G_{s11} . Since the calculated second sediment weight W_{s12} uses the estimated first sediment center of gravity G_{s11} , the calculated second sediment weight W_{s12} is considered to be closer to the actual sediment weight W_s than the first sediment weight W_{s11} . That is, in the present embodiment, the calculation accuracy of the estimated position of the sediment center of gravity G_s and the calculation accuracy of the sediment weight W_s may be improved by alternately repeating the calculation of the position of the sediment center of gravity G_s based on the sediment weight W_s , and the calculation of the sediment weight W_s based on the calculated position of the sediment center of gravity G_s and the detection result of the thrust of the boom cylinder 7. Therefore, in the present embodiment, the sediment weight W_s can be calculated with high accuracy. As described above, the specific repetition cycle may be determined according to the cycle (for example, on a 0.1 second basis) executable by the controller 30.

[0206] In this way, the center-of-gravity calculation part 65 estimates the distance D_s between the pin P1 and the sediment center of gravity G_s , based on the detection values of the sediment weight W_s , the boom angle sensor S1, the arm angle sensor S2, and the bucket angle sensor S3, by referring to the center-of-gravity position holding table 47A. Next, a method of calculating the sediment weight W_s will be described. First, parameters used for calculating the sediment weight W_s other than the sediment center of gravity G_s will be described.

[0207] The controller 30 according to the present embodiment calculates the sediment weight W_s of the bucket 6 based on information based on the shape of the bucket 6 in which the sediment is loaded (for example, the center of gravity of the bucket 6 and a bucket weight W_3), in addition to the outputs of the detection values of the various sensors whose detection results change according to the sediment weight W_s of the bucket 6. In the present embodiment, a case where detection values relating to the force F_b by the cylinder pressure of the boom cylinder 7 are used as examples of the detection values of the various sensors whose detection results change according to the sediment weight W_s of the bucket 6 will be described. The shovel 100 according to the present embodiment includes the boom 4 and the arm 5 as the attachment between the bucket 6 and the shovel 100 main body. Therefore, when the detection values relating to the force F_b by the cylinder pressure of the boom cylinder 7 are used as detection values of various sensors whose detection results change according to the sediment weight W_s , weights and shapes of the boom 4 and the arm 5 may need to be considered. The present embodiment is not limited to the method of using the detection values relating to the force F_b by the cylinder pressure of the boom cylinder 7 as the detection values of the various sensors whose detection results change according to the sediment weight W_s of the bucket 6, and other detection values (for example, detection values relating to the force by the cylinder pressure of the bucket cylinder 9) may be used.

[0208] Next, a balance equation in the case of using the force F_b by the cylinder pressure of the boom cylinder 7 will be described. The equation of the balance between each moment around the pin P1 and the boom cylinder 7 can be expressed by the following equation (A1).

$$W_s D_s + W_{1a} D_1 + W_{2a} D_2 + W_3 D_3 = F_b D_c \dots\dots (A1)$$

[0209] When the equation (A1) is expanded with respect to the sediment weight W_s , the following equation (A2) can be obtained.

$$W_s = (F_b D_c - (W_{1a} D_1 + W_{2a} D_2 + W_3 D_3)) / D_s \dots\dots (A2)$$

[0210] Here, the force F_b due to the cylinder pressure of the boom cylinder 7 is calculated from the detection values output from the boom rod pressure sensor S7R and the boom bottom pressure sensor S7B (examples of a detection part).

[0211] For example, the force F_b (thrust) by the cylinder pressure of the boom cylinder 7 is expressed by the following equation (A3) based on a pressure receiving area A_R of the rod side oil chamber of the boom cylinder 7, the boom rod pressure P_R , a pressure receiving area A_B of the bottom side oil chamber of the boom cylinder 7, and the boom bottom pressure P_B . The boom rod pressure P_R is a value detected by the boom rod pressure sensor S7R. The boom bottom

pressure PB is a value detected by the boom bottom pressure sensor S7B. The pressure receiving area AR of the rod side oil chamber and the pressure receiving area AB of the bottom side oil chamber are determined in advance. Note that the following equation (A3) indicates an example of a method of calculating the force Fb (thrust), and other calculation methods may be used.

$$F_b = AB \cdot PB - AR \cdot PR \dots\dots\dots (A3)$$

[0212] The force Fb due to the cylinder pressure is derived by substituting values detected by the boom rod pressure sensor S7R and the boom bottom pressure sensor S7B into equation (A3). In other words, the values detected (outputted) from the boom rod pressure sensor S7R and the boom bottom pressure sensor S7B can be regarded as detection values that change according to the sediment weight Ws in the bucket 6.

[0213] Among the variables represented by the equation (A2), the distance Dc and a vertical component W1a of the boom weight are calculated from the detection value of the boom angle sensor S1. A vertical component W2a and the distance D2 of the arm weight are calculated from the detection values of the boom angle sensor S1 and the arm angle sensor S2. The distance D1 is a known value. The bucket weight W3 (the gravity due to the self-weight of the bucket 6) is also a known value, and is set in correspondence with the shape of the bucket 6 by the bucket shape setting part 70. The distance D3 is calculated from the detection values of the boom angle sensor S1, the arm angle sensor S2, and the bucket angle sensor S3, and the bucket center of gravity G3 corresponding to the shape of the bucket 6 set by the bucket shape setting part 70, in addition to the shape of the attachment of the shovel 100.

[0214] Therefore, the sediment weight Ws can be calculated based on the estimated distance Ds between the pin P1 and the sediment center of gravity Gs, the detection value of the boom rod pressure sensor S7R, the detection value of the boom bottom pressure sensor S7B, the bucket angle (detection value of bucket angle sensor S3), the boom angle (detection value of the boom angle sensor S1), and the arm angle (detection value of the arm angle sensor S2) in addition to known values such as the bucket weight W3.

[0215] In other words, the weight calculation part 61 can calculate the sediment weight Ws based on the distance Ds to the sediment center of gravity Gs estimated by the center-of-gravity calculation part 65, the detection value of the cylinder pressure of the boom cylinder 7, and the detection values of the angle sensors.

[0216] The determination as to whether the shovel 100 is performing the predetermined operation using the attachment can be derived from the estimation result of the posture of the attachment based on the detection value of the cylinder pressure of the cylinder (for example, the boom cylinder 7, the arm cylinder 8, or the bucket cylinder 9) or the estimation result of the operation on the attachment based on the detection value of the pilot pressure on the boom 4, the arm 5, or the bucket 6. For example, when the detected value of the cylinder pressure changes, a change in the posture of the attachment can be estimated, and thus the operation of the attachment can be estimated from the change in the posture. As another example, when the detection value of the pilot pressure changes, the operation performed by the operator can be estimated, and thus the operation of the attachment performed according to the operation can be estimated. An example of the predetermined operation is an operation of closing the bucket 6. For example, whether or not the excavation operation is being performed may be estimated according to whether or not the operation of closing the bucket 6 is being performed. The determination of whether or not the predetermined operation is being performed is not limited to the method using the cylinder pressure or the pilot pressure, and may be performed based on a detection value of an angle sensor (for example, the boom angle sensor S1, the arm angle sensor S2, or the bucket angle sensor S3). The pilot pressure for the boom 4 is a pressure that changes according to the operation direction and operation amount of the boom operation lever of the operation device 26, and is a pressure of the hydraulic fluid that is applied to the pilot port of the control valve 175 corresponding to the boom cylinder 7. The same applies to the pilot pressure for the arm 5 and the pilot pressure for the bucket 6.

[0217] FIG. 10 is a flowchart illustrating a processing procedure until the weight of the loaded material loaded in the bucket 6 is determined in the controller 30 according to the present embodiment. In the example illustrated in FIG. 10, processing after the excavation operation by the shovel 100 is completed is illustrated.

[0218] First, after the excavation operation is completed, the weight calculation part 61 determines whether or not a weight calculation start condition is satisfied (S1001). If the weight calculation part 61 determines that the weight calculation start condition is not satisfied (S1001: NO), the processing of S1001 is repeated. The interval at which the S1001 processing is repeated may be any interval, and may be, for example, a cycle (for example, on a 0.1 second basis) that can be executed by the controller 30. The weight calculation start condition may be any condition, and for example, the weight calculation start condition may be that the lifting of the bucket 6 is started. Whether or not the lifting of the bucket 6 has been started can be estimated based on the detected value of the cylinder pressure of the boom cylinder 7 or the pilot pressure to the boom 4, or the like. Whether or not the bucket 6 starts to be lifted is not limited to the estimation based on the detection value of the cylinder pressure of the boom cylinder 7 or the pilot pressure to the boom 4, and

may be estimated based on, for example, the detection value of the boom angle sensor S1.

[0219] On the other hand, when the weight calculation part 61 determines that the weight calculation start condition is satisfied (S1001: YES), the weight calculation unit 61 calculates the sediment weight W_s (an example of the weight of an object) in the bucket 6 (S1002), based on the thrust of the boom cylinder 7 (force F_b due to cylinder pressure) and the initial value of the sediment center of gravity G_s (an example of the position of the center of gravity of an object set in advance) stored in the storage device 47, in addition to the detection values of various angle sensors on the attachment.

[0220] Then, the center-of-gravity calculation part 65 calculates the distance D_s from the pin P1 to the sediment center of gravity G_s in the bucket 6 corresponding to the calculated sediment weight W_s , by referring to the center-of-gravity position holding table 47A (S1003). More specifically, the center-of-gravity calculation part 65 calculates the distance D_s from the pin P1 to the sediment center of gravity G_s based on the positional relationship information (the angle Θ_5 between the reference line L2 of the bucket 6 and a straight line connecting the pin P7 and the sediment center of gravity G_s , and the distance D_5 between the pin P7 and the sediment center of gravity G_s) associated with the sediment weight W_s and the detection values of the boom angle sensor S1, the arm angle sensor S2, and the bucket angle sensor S3.

[0221] Thereafter, the weight calculation part 61 calculates the sediment weight (an example of the weight of the object) W_s in the bucket 6 based on the thrust (force F_b by the cylinder pressures) of the boom cylinder 7 and the distance D_s to the sediment center of gravity G_s calculated in the S1003, in addition to the detection values of the various angle sensors (S1004).

[0222] Thereafter, the weight calculation part 61 determines whether or not a condition for determining the weight (an example of a predetermined condition) is satisfied while the bucket 6 is lifted (S1005). When the weight calculation part 61 determines that the condition for determining the weight is not satisfied (S1005: NO), the processing is performed again from S1003. The condition for determining the weight may be any condition, and for example, the condition may be that the lifted height of the bucket 6 exceeds a predetermined reference value.

[0223] On the other hand, when the weight calculation part 61 determines that the condition for determining the weight is satisfied (S1005: YES), the processing is terminated. When the weight calculation part 61 determines that the condition for determining the weight is satisfied, the sediment weight W_s (an example of the weight of the object) to be determined may be, for example, the last calculated value or an average value of a plurality of sediment weights calculated close to the last calculated value.

[0224] In the present embodiment, the calculation of the sediment weight W_s and the calculation of the sediment center of gravity G_s are alternately repeated. By repeating this processing, the accuracy of the calculated position of the sediment center of gravity G_s and the sediment weight W_s can be improved. Therefore, the accuracy of the determined sediment weight W_s can be improved.

<Operation>

[0225] The shovel 100 (an example of a work machine) of the embodiment described above is configured to be capable of receiving an input of a shape of the bucket 6. Therefore, in the above-described embodiment, the position of the center of gravity of the sediment loaded in the bucket 6 is estimated in consideration of the shape of the bucket 6, and thus the estimation accuracy of the position of the sediment center of gravity can be improved.

[0226] In the above-described embodiment, the center-of-gravity position holding table 47A held for each shape of the bucket 6 is used as a method of considering the shape of the bucket 6. In other words, in the above-described embodiment, the position of the sediment center of gravity in consideration of the shape of the bucket 6 is implemented by referring to the center-of-gravity position holding table 47A. The method of estimating the sediment center of gravity G_s in consideration of the shape of the bucket 6 is not limited to the method using the center-of-gravity position holding table 47A, and other methods may be used.

[0227] In the above-described embodiment, the detection result of the force F_b due to the cylinder pressure of the boom cylinder 7 based on the detection values output from the boom rod pressure sensor S7R and the boom bottom pressure sensor S7B (examples of the detection part) changes according to the sediment weight.

[0228] Therefore, the weight calculation part 61 according to the above-described embodiment specifies the sediment center of gravity G_s by referring to the center-of-gravity position holding table 47A, and then calculates the sediment weight W_s based on the sediment center of gravity G_s and the detection value relating to the force F_b by the cylinder pressure of the boom cylinder 7. That is, in the above-described embodiment, the calculation accuracy of the sediment weight W_s can be improved by considering the shape of the bucket 6 by referring to the center-of-gravity position holding table 47A.

[0229] In the above-described embodiment, the example has been described in which the weight calculation part 61 specifies the sediment center of gravity G_s by referring to the center-of-gravity position holding table 47A, and then calculates the sediment weight W_s based on the sediment center of gravity G_s and the detection value relating to the force F_b by the cylinder pressure of the boom cylinder 7. However, the above-described embodiment is not limited to the method of considering the shape of the bucket 6 by referring to the center-of-gravity position holding table 47A. For

example, the sediment weight W_s may be calculated in consideration of the sediment center of gravity, which is determined according to the shape of the bucket 6.

[0230] Although the embodiment of the work machine according to the present invention has been described above, the present invention is not limited to the above-described embodiment, and the like. Various changes, modifications, substitutions, additions, deletions, and combinations are possible within the scope of the claims. Such changes, modifications, and the like are also included in the technical scope of the present invention.

DESCRIPTION OF THE REFERENCE NUMERALS

[0231]

- 100 shovel
- 1 lower traveling body
- 2 turning mechanism
- 3 upper turning body
- 4 boom (attachment)
- 5 arm (attachment)
- 6 bucket (work tool)
- 7 boom cylinder
- 8 arm cylinder
- 9 bucket cylinder
- 30 controller
- 47 storage device
- 47A center-of-gravity position holding table
- 50 machine guidance part
- 51 position calculation part
- 52 distance calculation part
- 53 information transmission part
- 54 automatic control part
- 55 turning angle calculation part
- 56 relative angle calculation part
- 60 sediment weight processing part
- 61 weight calculation part
- 62 maximum load detection part
- 63 load calculation part
- 64 remaining load calculation part
- 65 center-of-gravity calculation part
- 70 bucket shape setting part

Claims

1. A shovel control device configured to receive an input of a shape of a bucket provided at a tip of an attachment attached to a shovel, and calculate a weight of an object in the bucket, based on the input shape of the bucket and an output of a detection part whose detection result changes according to the weight of the object in the bucket.
2. The shovel control device according to claim 1, further comprising:
 - a storage device configured to store table information in which the weight of the object and a position of a center of gravity of the object are associated with each other according to the shape of the bucket, wherein when the weight of the object in the bucket is calculated, the shovel control device refers to the table information to specify the position of the center of gravity of the object based on the calculated weight of the object, and recalculates a weight of the object in the bucket, based on the specified position of the center of gravity of the object and the output of the detection part.
3. The shovel control device according to claim 2, wherein the shovel control device alternately performs
 - calculation of the weight of the object based on the specified position of the center of gravity of the object and

the output of the detection part, and
specification of the position of the center of gravity of the object based on the calculated weight of the object.

4. A shovel comprising:

a lower traveling body;
an upper turning body turnably mounted on the lower traveling body;
an attachment attached to the upper turning body;
a bucket provided at a tip of the attachment; and
a control device configured to receive an input of a shape of the bucket, and calculate a weight of an object in the bucket, based on the input shape of the bucket and an output of a detection part whose detection result changes according to the weight of the object in the bucket.

5. The shovel according to claim 4, further comprising:

a storage device configured to store table information in which the weight of the object and a position of a center of gravity of the object are associated with each other according to the shape of the bucket, wherein when the weight of the object in the bucket is calculated, the control device refers to the table information to specify the position of the center of gravity of the object based on the calculated weight of the object, and recalculates a weight of the object in the bucket, based on the specified position of the center of gravity of the object and the output of the detection part.

6. The shovel according to claim 5, wherein the control device alternately performs

calculation of the weight of the object based on the specified position of the center of gravity of the object and the output of the detection part, and
specification of the position of the center of gravity of the object based on the calculated weight of the object.

7. The shovel according to claim 6, wherein the control device calculates the weight of the object in the bucket based on the position of the center of gravity of the object set in advance and the output of the detection part when the lifting of the bucket is started.

8. The shovel according to claim 6, wherein the control device terminates the calculation of the weight of the object and the specification of the position of the center of gravity of the object when a predetermined condition is satisfied while the bucket is being lifted.

9. The shovel according to claim 4, wherein the control device receives an input from an operation device, an input from an external device, or an input from an imaging device, as the input of the shape of the bucket.

FIG.1

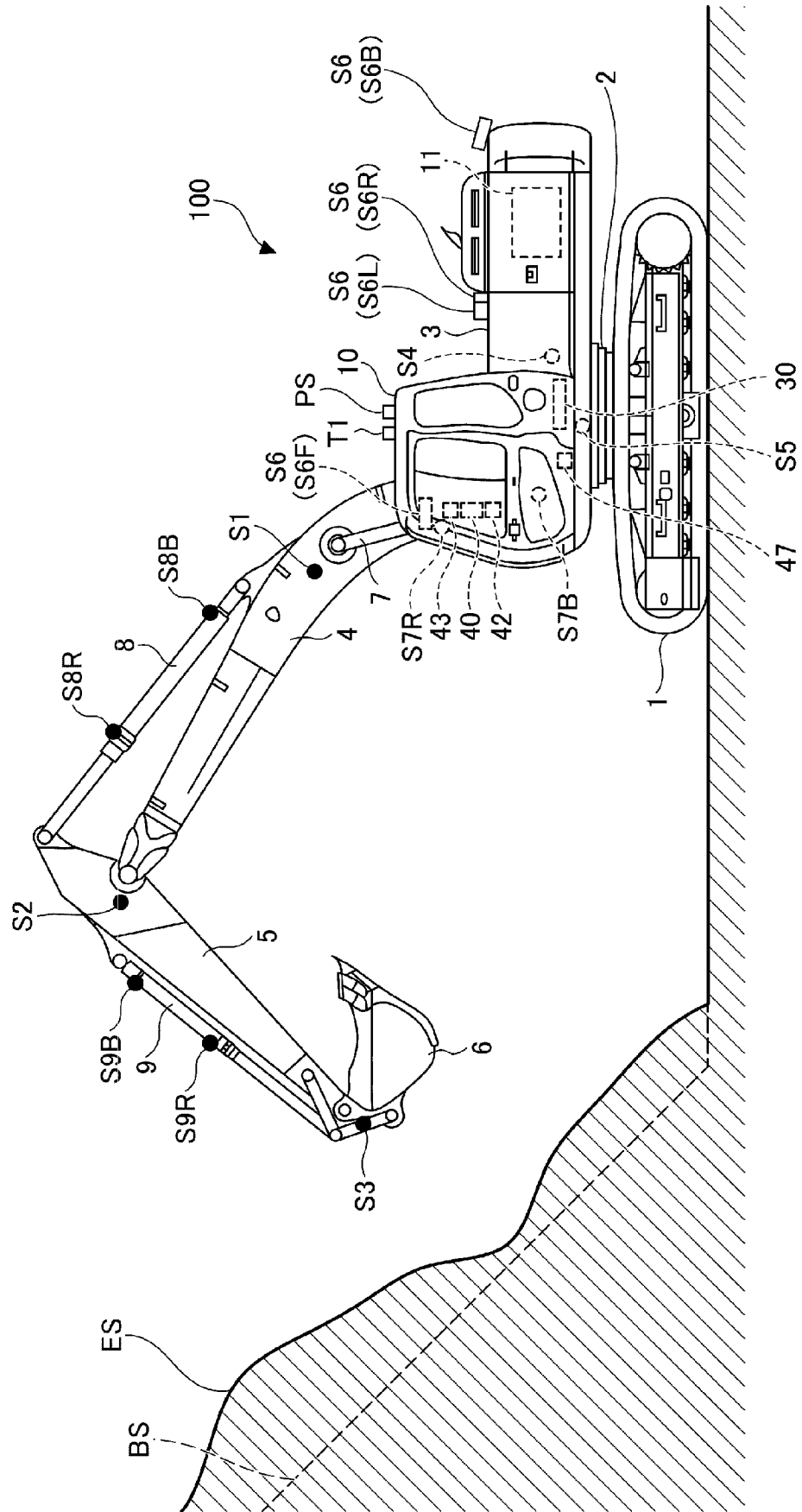


FIG.2

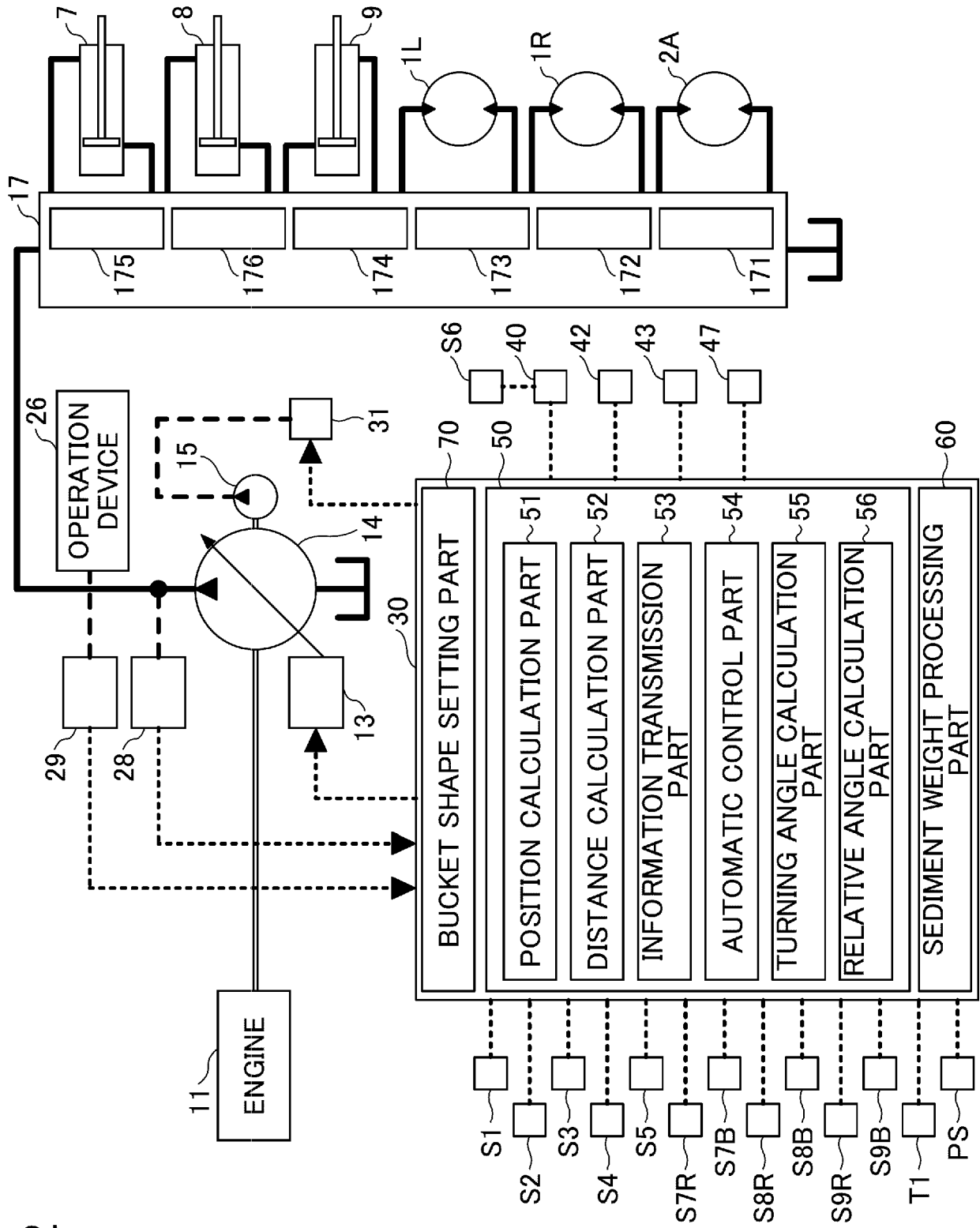


FIG.3

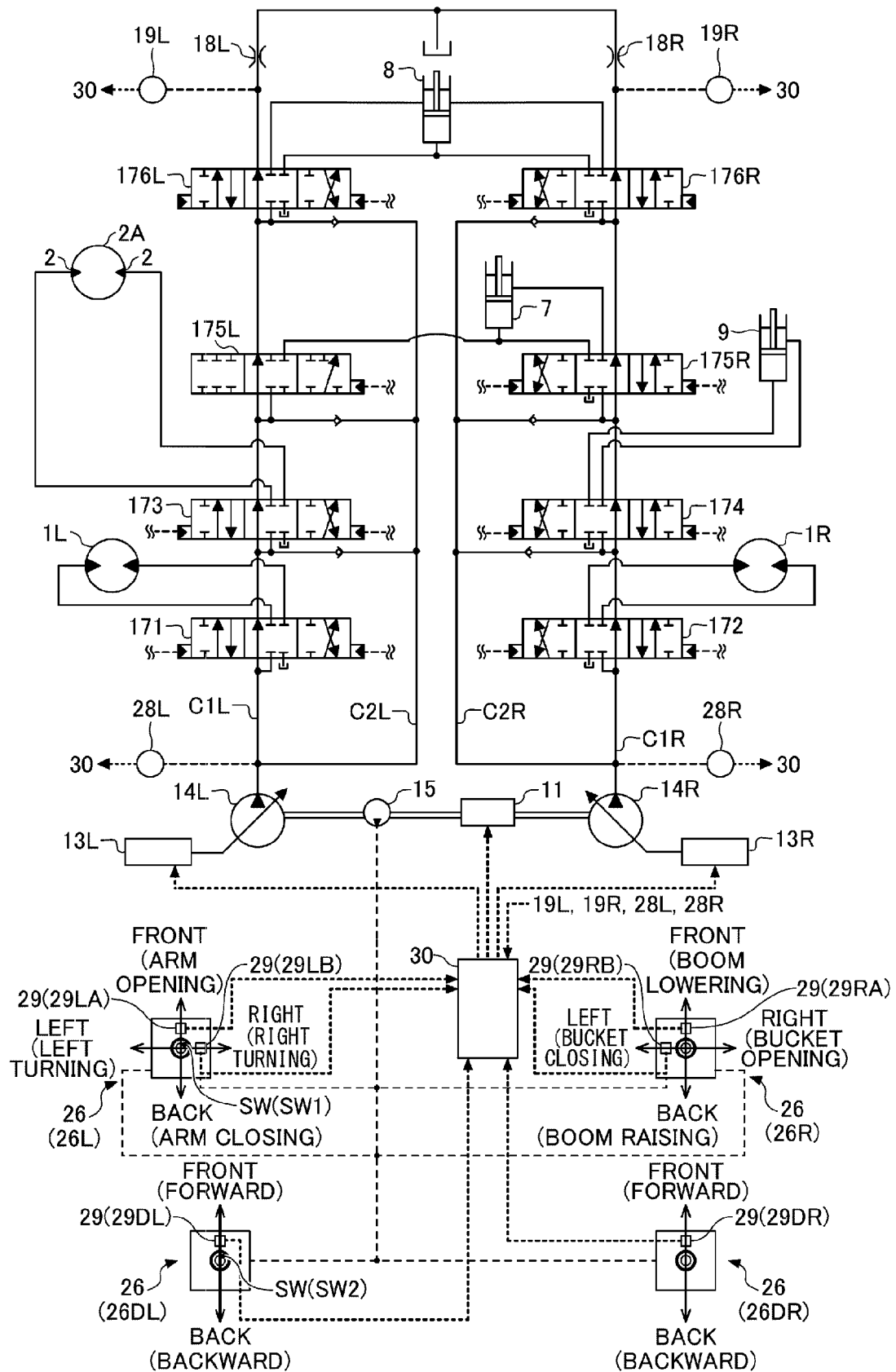


FIG.4A

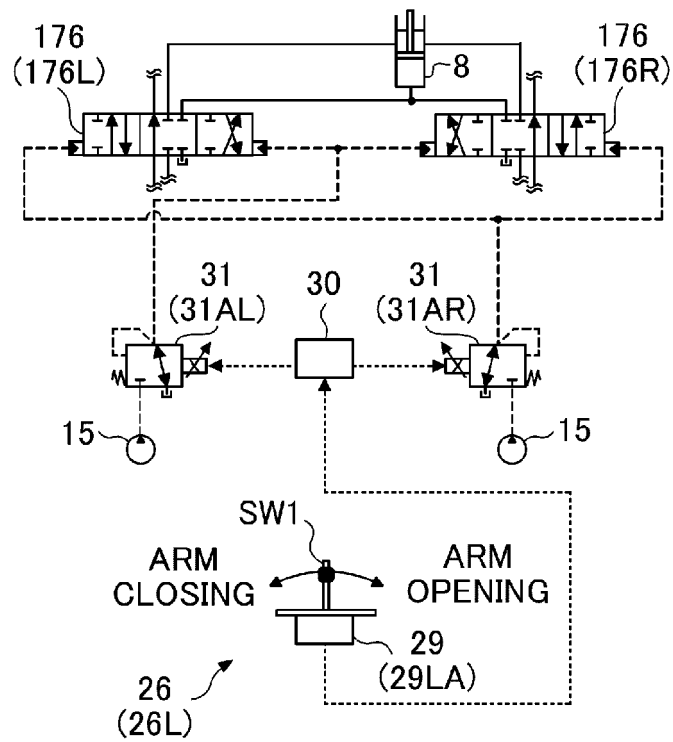


FIG.4B

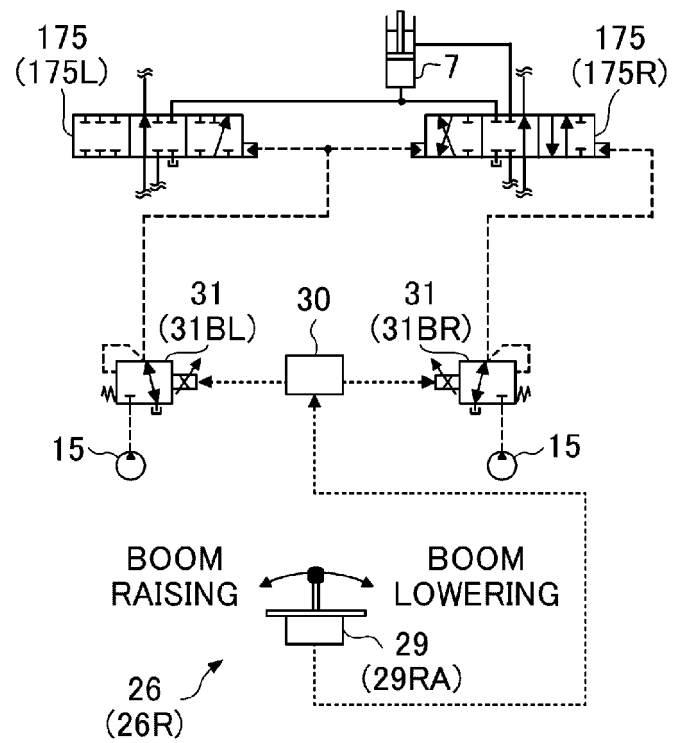


FIG.4C

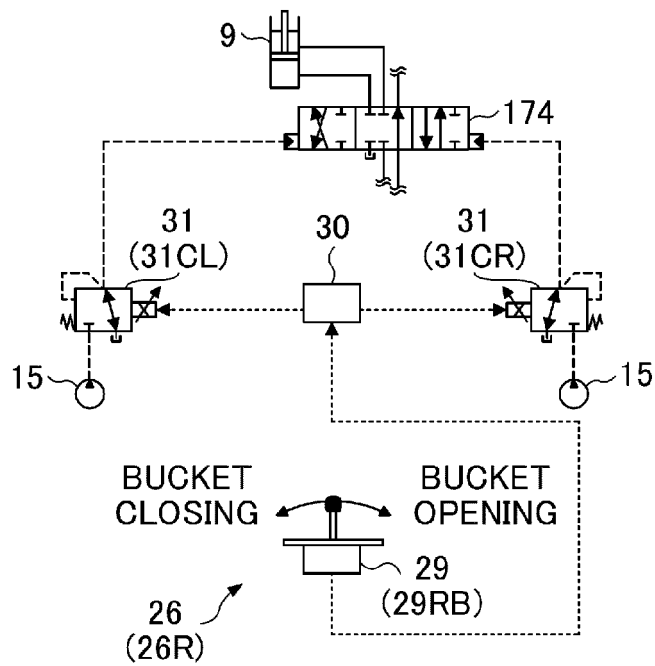


FIG.4D

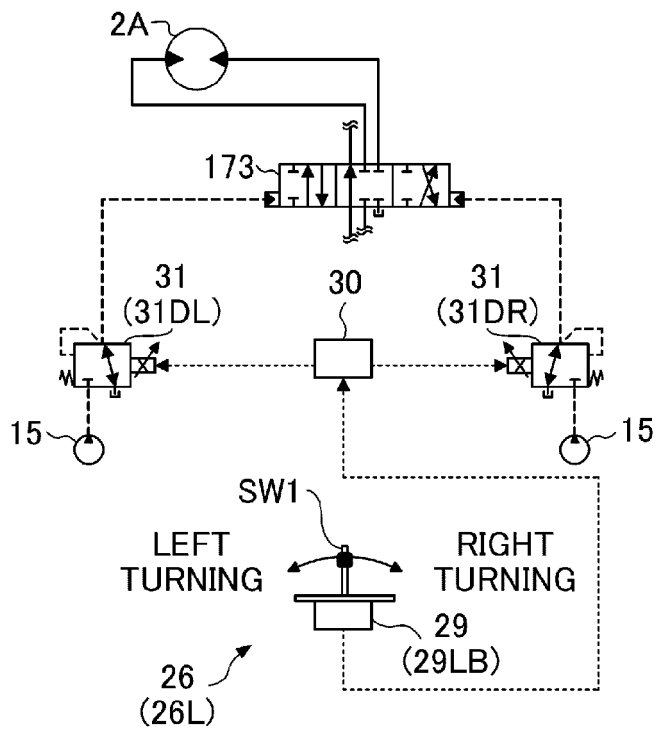


FIG.5

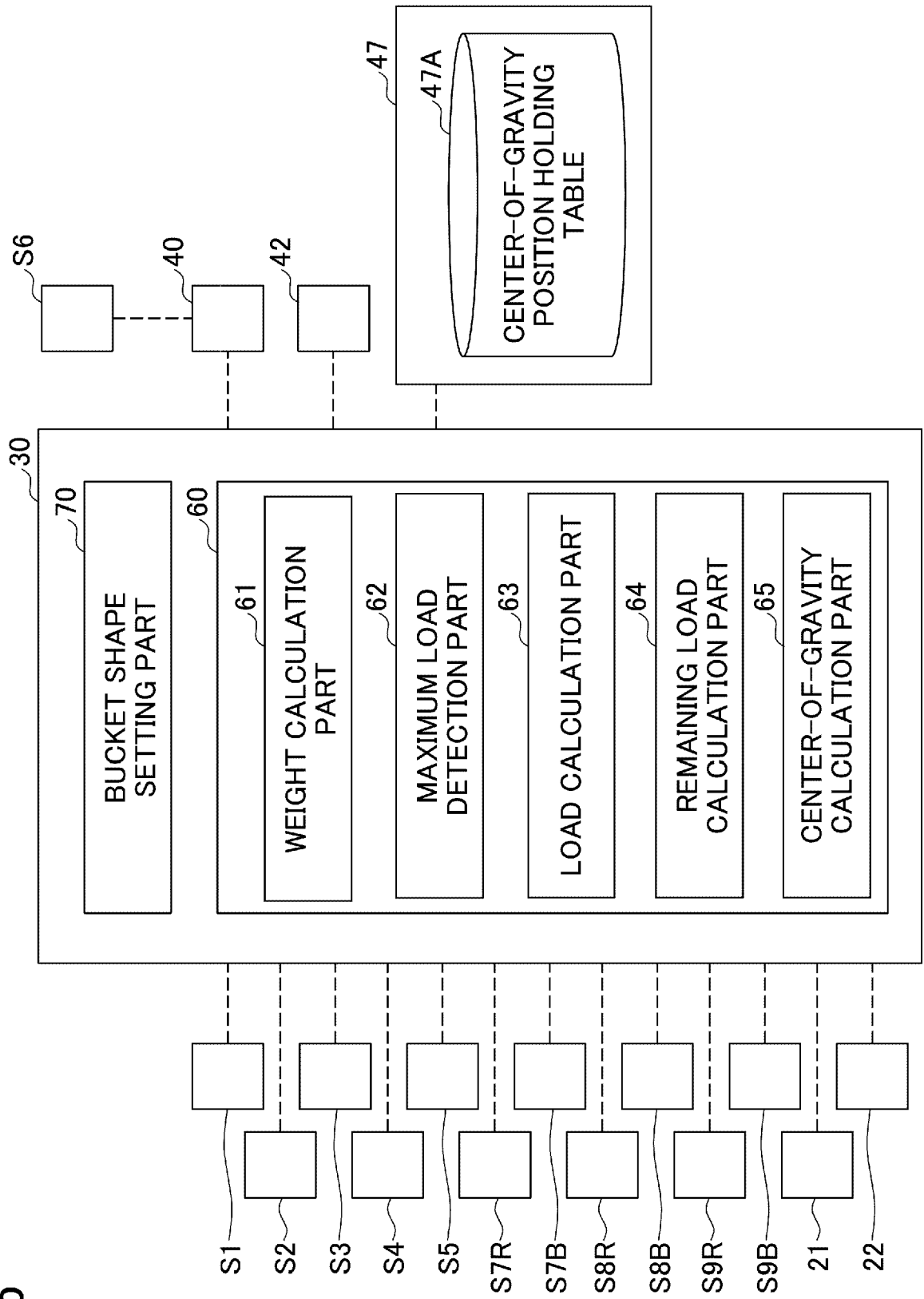


FIG.6

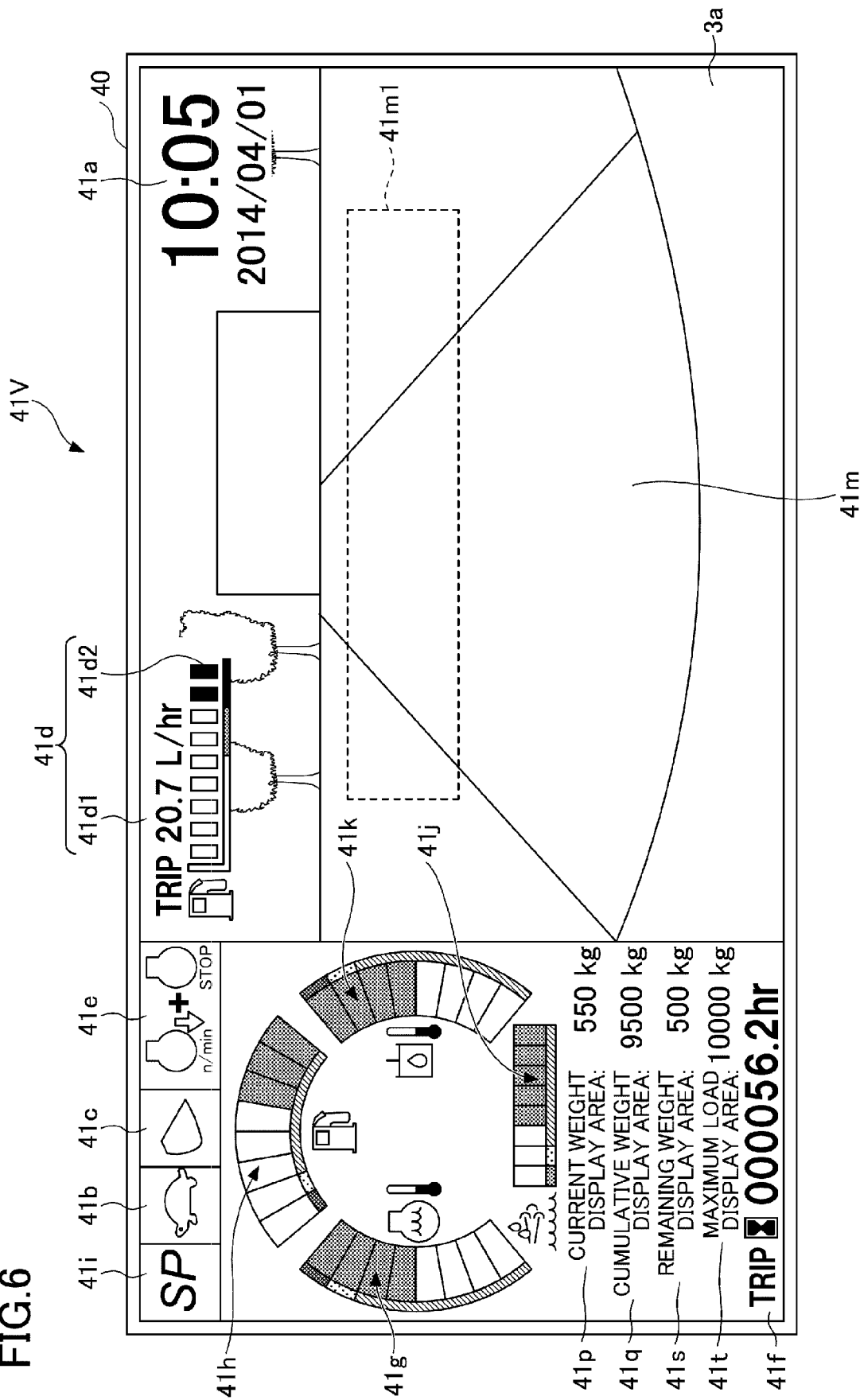


FIG.7

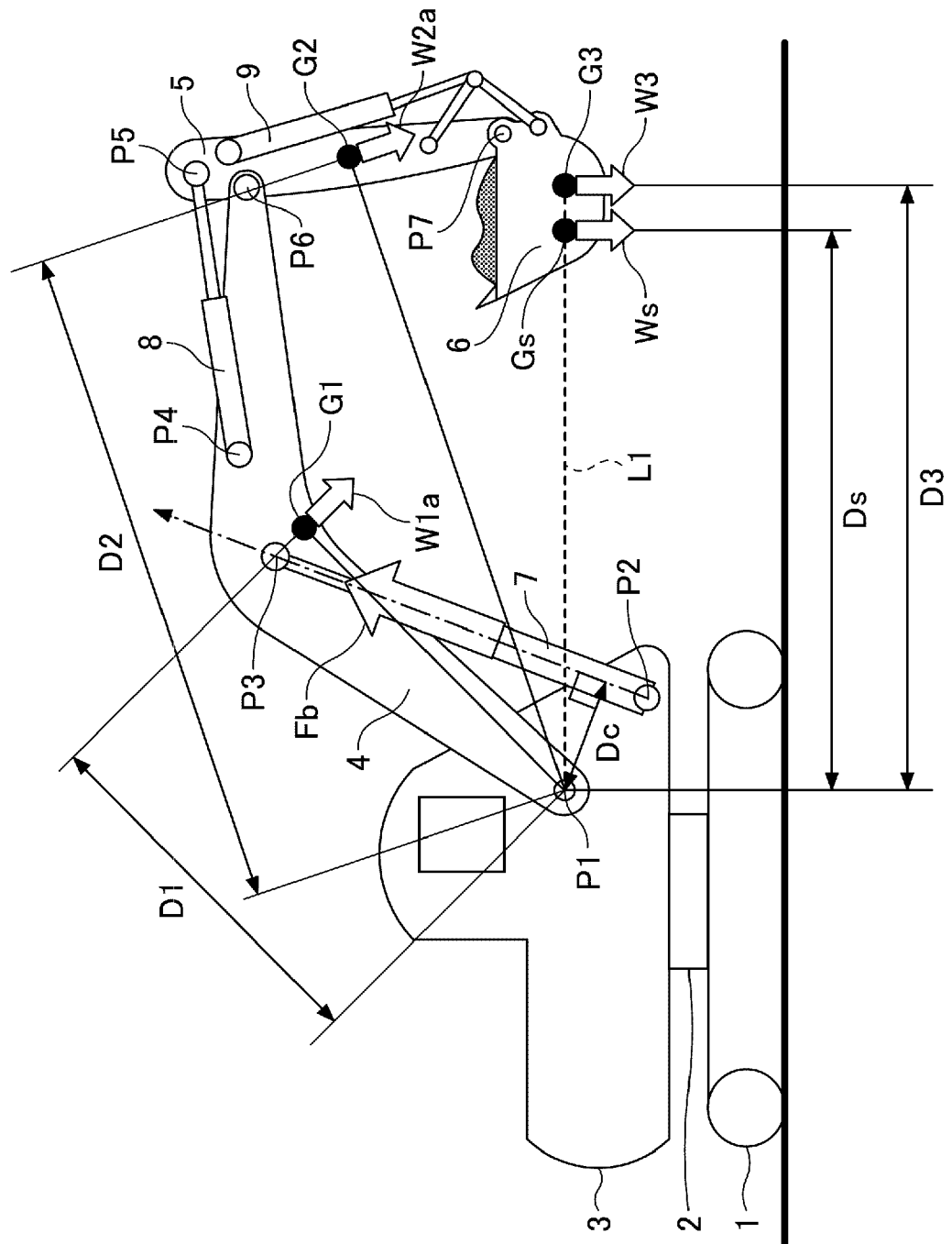


FIG.8

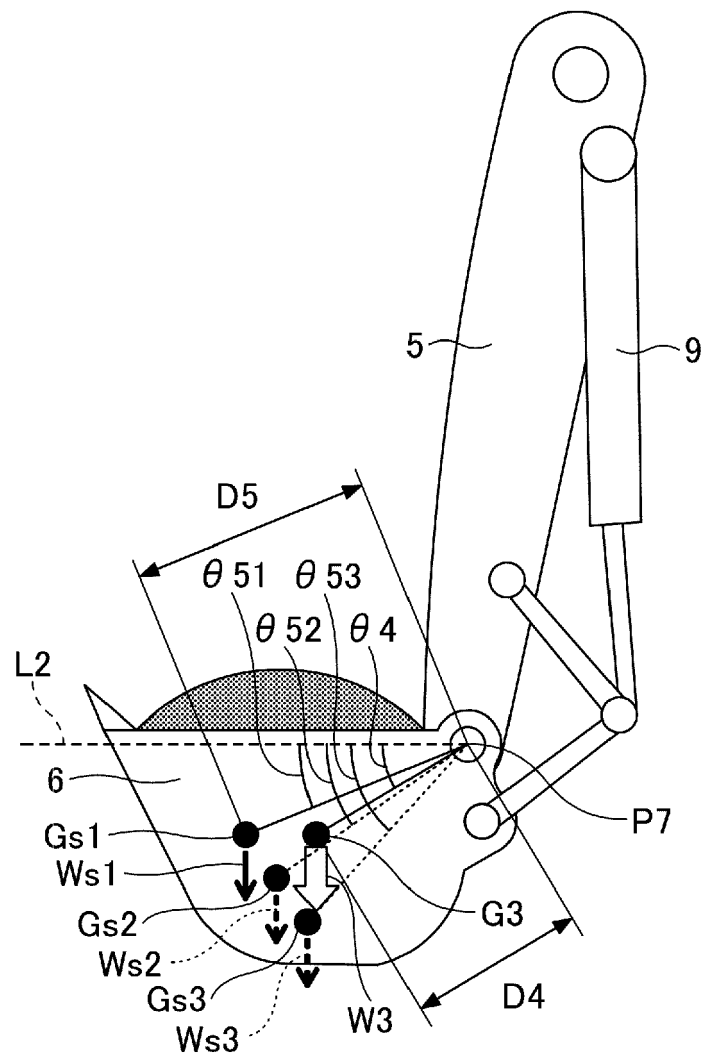


FIG.9

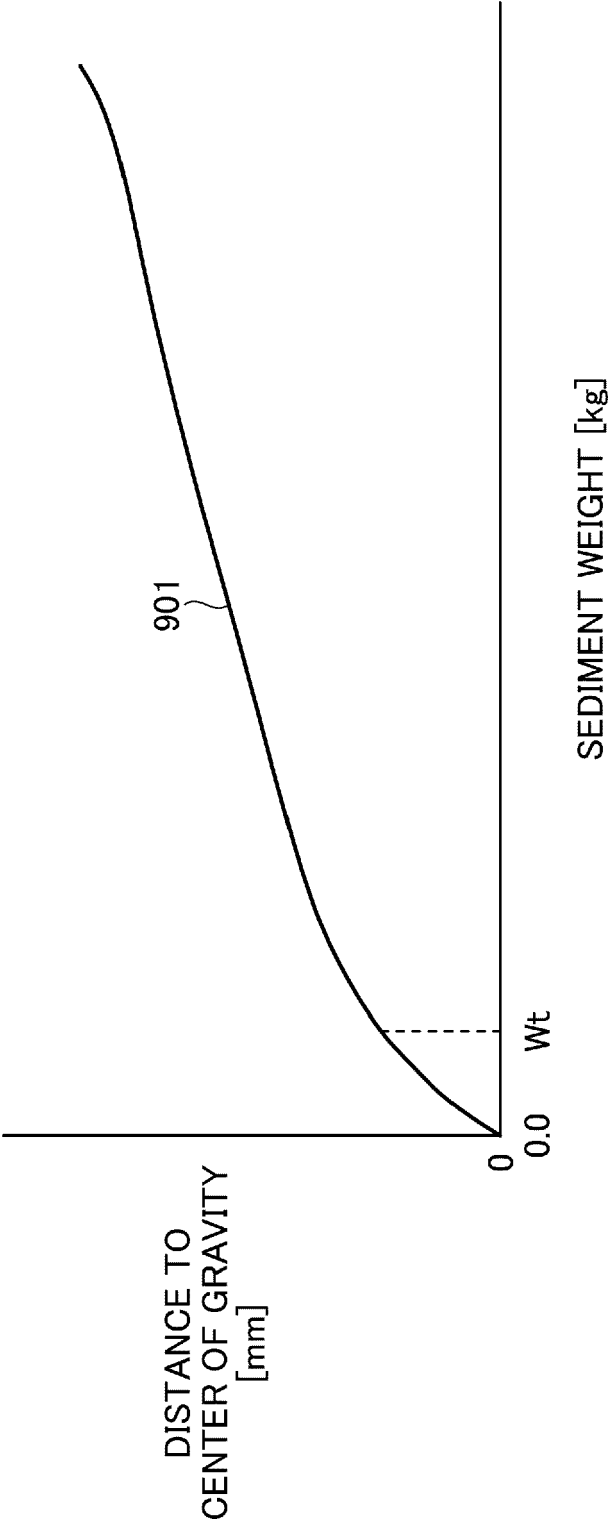
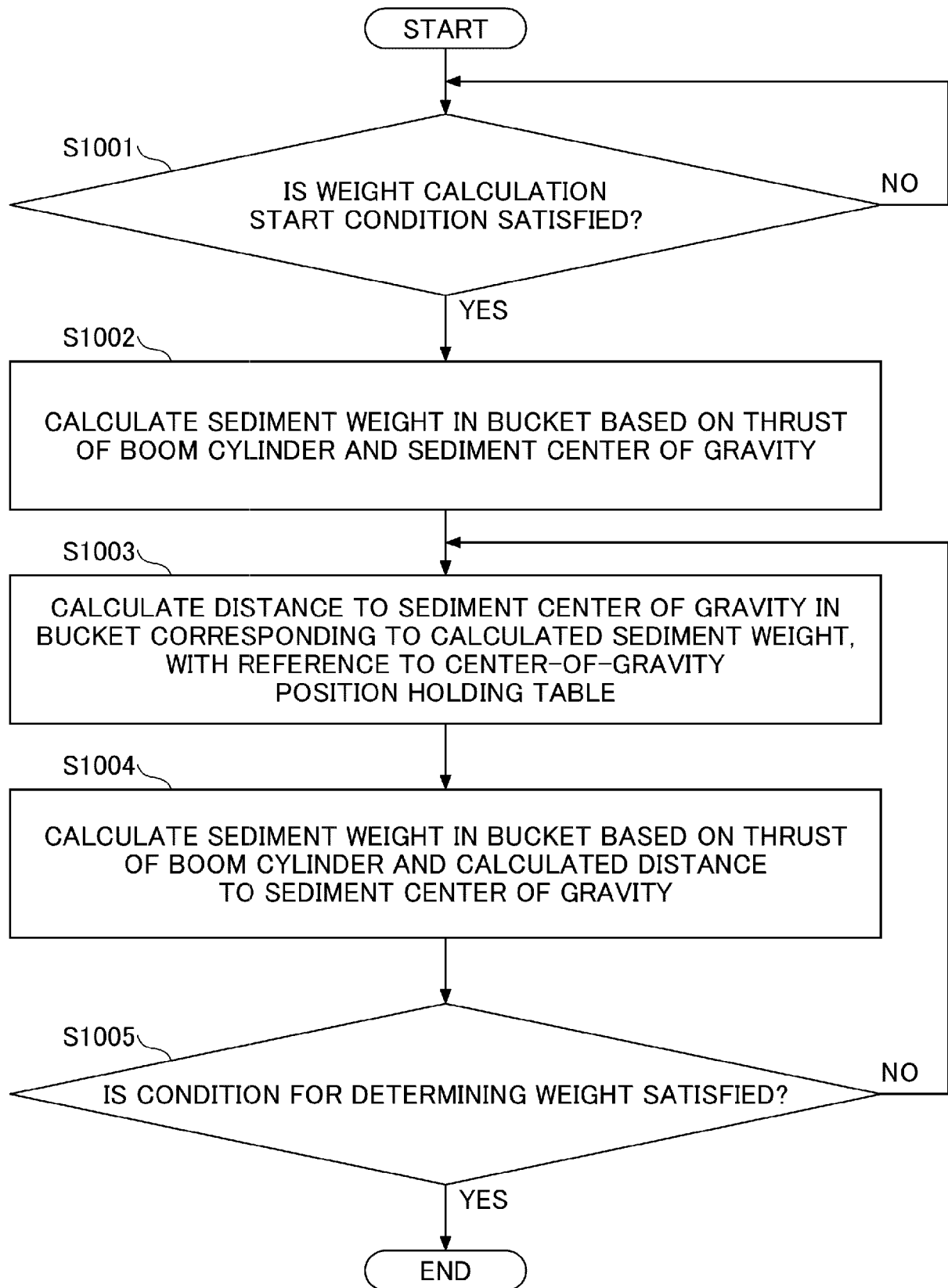


FIG.10





EUROPEAN SEARCH REPORT

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