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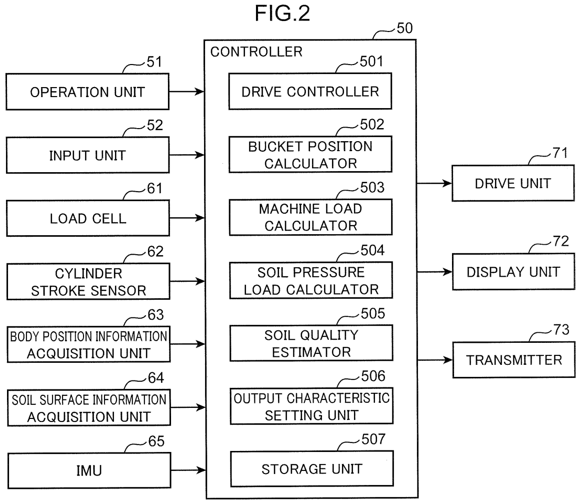
(54) **CONSTRUCTION MACHINE AND CONSTRUCTION MACHINE MANAGEMENT SYSTEM**

(57) The present invention acquires soil quality information of the ground while excavation work is performed at a work site. A hydraulic excavator (1) includes a work attachment (20), a drive unit (71), a load cell (61), a machine load calculator (503), a soil pressure load calculator (504), and a soil quality estimator (505). The machine load calculator (503) calculates, from orientation information of the work attachment (20) and information about a load that the drive unit (71) receives, a machine load, which is a load that a bucket (23) receives from earth and sand. The soil pressure load calculator (504) calculates, from a shape of a soil mass, the orientation information, the shape of the bucket (23), the density of the soil, a wall surface frictional angle, a soil pressure load.

FIG.2



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Description

Technical Field

[0001] The present invention relates to a construction machine including a bucket and relates to a construction machine management system.

Background Art

[0002] Conventionally, a hydraulic excavator (construction machine) including a bucket for excavating a ground surface of a work site has been known. The hydraulic excavator includes a lower travelling body capable of travelling on the ground surface, an upper body mounted on the lower travelling body, and a work attachment supported by the upper body. In the hydraulic excavator, a bucket is disposed at a distal end of the work attachment. The hydraulic excavator can excavate the ground surface while the bucket is in contact with the ground surface.

[0003] Patent Literature 1 discloses an excavator including a sensor attached to a work attachment and a hardness estimator that estimates the hardness of a ground based on a detection value of the sensor. The hardness estimator estimates the hardness of the ground based on a detection value of the sensor when a distal end (bucket) of the work attachment performs a predetermined operation of contacting a ground surface at a predetermined speed and at a predetermined angle and data stored in advance.

Citation List

Patent Literature

[0004] Patent Literature 1: JP 2019-163621 A

Summary of Invention

Problems to be Solved by the Invention

[0005] In the technique disclosed in Patent Literature 1, it is necessary to bring the work attachment into contact with the ground surface at a predetermined speed and at a predetermined angle in order to estimate the hardness of the ground. Therefore, there is a problem that the operation temporarily interrupts a work and reduces work efficiency.

Means for Solving the Problems

[0006] An object of the present invention is to provide a construction machine and a construction machine management system capable of acquiring soil quality information of a ground while performing excavation work at a work site.

[0007] The present invention is based on the technical idea of estimating the soil quality related to the soil pressure load from the machine load actually received by the bucket during the excavation work and the soil pressure load applied to the bucket by the soil mass formed by the bucket. A construction machine is provided by the present invention based on such a technical idea. The construction machine includes a machine body including a travelling unit capable of travelling on a ground surface, a work attachment including a rising and falling body supported by the machine body so as to be rotatable in a rising and falling direction with respect to the machine body, the work attachment including a bucket rotatably supported by a distal end of the rising and falling body, a drive unit that allows driving of the work attachment such that the bucket excavates the ground surface, an orientation information acquisition unit that acquires orientation information that is information regarding an orientation of the work attachment relative to the ground surface, a drive load information acquisition unit that acquires drive load information that is information regarding a load received by the drive unit as the bucket excavates the ground surface, a machine load calculator that calculates a machine load that is a load received by the bucket from earth and sand from the orientation information acquired by the orientation information acquisition unit and the drive load information acquired by the drive load information acquisition unit as the bucket excavates the ground surface, a soil pressure load calculator that calculates a soil pressure load that is a load applied to the bucket by a soil mass, based on a soil pressure theory from a shape of the soil mass constituted by a soil dammed by the bucket, the orientation information acquired by the orientation information acquisition unit, a shape of the bucket, a density of the soil, and a wall surface frictional angle between the soil and the bucket as the bucket excavates the ground surface, and a soil quality estimator that estimates a soil quality of the soil at a work site based on the machine load calculated by the machine load calculator and the soil pressure load calculated by the soil pressure load calculator.

[0008] The present invention provides a construction machine management system. The construction machine management system includes the construction machine according to any of the above descriptions, and a management device that is disposed at a position away from the construction machine and allows transmission and reception of information on the soil quality to and from the construction machine.

Brief Description of Drawings

[0009]

FIG. 1 is a side view of a construction machine according to an embodiment of the present invention.

FIG. 2 is a block diagram of a construction machine according to an embodiment of the present invention.

FIG. 3 is a schematic diagram for describing soil quality information acquisition processing executed in a construction machine according to an embodiment of the present invention.

FIG. 4 is a flowchart of soil quality information acquisition processing executed in a construction machine according to an embodiment of the present invention.

FIG. 5 is a schematic diagram illustrating a machine load acting on a bucket of a construction machine according to an embodiment of the present invention.

FIG. 6 is a schematic diagram for describing soil pressure load calculation processing executed in a construction machine according to an embodiment of the present invention.

FIG. 7 is a schematic diagram illustrating how a soil mass plastically collapses due to movement of a retaining wall.

FIG. 8 is a schematic diagram for describing a passive soil pressure based on soil mechanics.

FIG. 9 is a schematic diagram for describing excavation resistance acting on a bucket.

FIG. 10 is a schematic graph illustrating a relationship between a slip plane angle and excavation resistance.

FIG. 11 is a schematic diagram for describing a branch and bound method executed by a soil quality estimator according to an embodiment of the present invention.

FIG. 12 is a flowchart of output control processing executed in a construction machine according to a first modified embodiment of the present invention.

FIG. 13 is a flowchart of output control processing executed in a construction machine according to a second modified embodiment of the present invention.

FIG. 14 is a schematic diagram of the construction machine and a management device according to the second modified embodiment of the present invention.

FIG. 15 is a flowchart of another output control processing executed in the construction machine according to the second modified embodiment of the present invention.

FIG. 16 is a flowchart of soil quality information acquisition processing executed in a construction machine according to a third modified embodiment of the present invention.

FIG. 17 is a diagram illustrating appearance of a display unit in the soil quality information acquisition processing executed in the construction machine according to the third modified embodiment of the present invention.

FIG. 18 is a schematic diagram of calculation processing executed by a soil quality estimator or the like in a construction machine according to a fourth modified embodiment of the present invention.

FIG. 19 is a schematic diagram of calculation processing executed by a soil pressure load calculator in a construction machine according to a fifth modified embodiment of the present invention.

FIG. 20 is a flowchart of a part of soil quality information acquisition processing executed in the construction machine according to the fifth modified embodiment of the present invention.

FIG. 21 is a side view when the construction machine according to the fifth modified embodiment of the present invention executes the soil quality information acquisition processing.

FIG. 22 is a schematic diagram for describing a ground height in the soil quality information acquisition processing executed in the construction machine according to the fifth modified embodiment of the present invention.

Description of Embodiments

[0010] Hereinafter, preferred embodiments of the present invention will be described with reference to the drawings.

[0011] FIG. 1 is a side view of a hydraulic excavator 1 (construction machine) according to an embodiment of the present invention.

[0012] The hydraulic excavator 1 includes a lower travelling body 10 capable of travelling on a ground surface G (travelling surface), an upper slewing body 12 (upper body) slewably supported by the lower travelling body 10, and a work attachment 20 mounted on the upper slewing body 12. The lower travelling body 10 and the upper slewing body 12 constitute a machine body of the present invention.

[0013] The lower travelling body 10 can travel on the ground surface G. The lower travelling body 10 includes a crawler type travelling unit.

[0014] The upper slewing body 12 includes a slewing frame 121 supported by the lower travelling body 10 and a cab 13 mounted on the slewing frame 121. The cab 13 allows a worker to board, and various devices for operating the hydraulic excavator 1 are disposed in the cab 13.

[0015] The work attachment 20 is attached to the upper slewing body 12 so as to be movable relative to the upper slewing body 12, and performs a predetermined work on the ground surface G. The work attachment 20 includes a boom 21 connected to a front end of the slewing frame 121 so as to be rotatable in a rising and falling direction about a horizontal rotation center axis, an arm 22 connected to a distal end of the boom 21 so as to be rotatable about a horizontal rotation center axis, and a bucket 23 connected to a distal end of the arm 22 so as to be rotatable about a horizontal rotation center axis. In the present embodiment, the rotation center axes of the boom 21, the arm 22, and the bucket 23 are set to be parallel to each other. The boom 21 and the arm 22 constitute a rising and falling body of the present invention. The work attachment 20 further includes a boom cylinder 21S (rising and falling body cylinder) that expands and contracts so as to raise and lower (rotate) the boom 21, an arm cylinder 22S (rising and falling body cylinder) that expands and contracts so as to rotate the arm 22, and a bucket cylinder 23S that expands and contracts so as to rotate the bucket 23. Each of these cylinders includes a hydraulic cylinder.

[0016] The cab 13 is mounted on a front portion of the slewing frame 121, which is a portion (a left side of the boom 21 in the example illustrated in FIG. 1) adjacent to the boom 21 in a width direction of the slewing frame 121, and constitutes a cabin for operating the hydraulic excavator 1. That is, in the cab 13, the worker performs operations for travelling the lower travelling body 10, slewing the upper slewing body 12, and activating the work attachment 20.

[0017] FIG. 2 is a block diagram of the hydraulic excavator 1 according to the present embodiment. The hydraulic excavator 1 further includes an operation unit 51, an input unit 52, a load cell 61 (drive load information acquisition unit), a cylinder stroke sensor 62 (cylinder length detector), a body position information acquisition unit 63 (position information acquisition unit), a soil surface information acquisition unit 64, an inertial measurement unit (IMU) 65 (machine body inclination detector), a drive unit 71, a display unit 72, and a transmitter 73.

[0018] The operation unit 51 is disposed in the cab 13 and is operated by the worker. That is, the operation unit 51 receives an operation for operating the hydraulic excavator 1. The operation includes travelling the lower travelling body 10, slewing the upper slewing body 12, driving the work attachment 20 (the boom 21, the arm 22, and the bucket 23), and the like.

[0019] The input unit 52 is disposed in the cab 13 and receives input of various information. As an example, the input unit 52 includes various input buttons, switches, a touch panel included in the display unit 72 (described later), and the like. In particular, the input unit 52 can receive input of information to be referred to in a soil quality information acquisition operation (described later).

[0020] The load cell 61 includes two load cells provided in the bucket 23, and detects a load applied to a proximal end of the bucket 23. The load detected by the load cell 61 is referred to by a machine load calculator 503 (described later) and used for calculation of a machine load (see FIG. 3). In other words, the load cell 61 acquires drive load information that is information on a load received by the drive unit 71 as the bucket 23 excavates the ground surface. The drive load information is acquired by calculating a load received by the drive unit 71 based on a detection result of the load cell 61.

[0021] The cylinder stroke sensor 62 includes three sensors attached to the boom cylinder 21S, the arm cylinder 22S, and the bucket cylinder 23S described above, and detects a stroke (elongation amount and length) of each of the cylinders. The stroke of each cylinder detected by the cylinder stroke sensor 62 is used by a bucket position calculator 502, the machine load calculator 503, and a soil pressure load calculator 504 (described later) to calculate a position and orientation of the bucket 23.

[0022] The body position information acquisition unit 63 acquires position information of the hydraulic excavator 1 (machine body) at a work site. As an example, the body position information acquisition unit 63 can acquire body coordinate information that is information regarding absolute coordinates of a body reference point provided in the upper slewing body 12 in advance at the work site. The body position information acquisition unit 63 constituting the body reference point is disposed on an upper surface of the cab 13 and functions as a GNSS mobile station. On the other hand, a global navigation satellite system (GNSS) reference station is provided to acquire the body coordinate information (not shown). The GNSS reference station is a reference station disposed at a work site or disposed at a position closest to the work site. Note that, as the GNSS, in addition to a known global positioning system (GPS), a satellite positioning system such as a global navigation satellite system (GLONASS), Galileo, or a quasi-zenith satellite system (QZSS) may be adopted.

[0023] The soil surface information acquisition unit 64 is disposed at a front end of the upper surface of the cab 13. As an example, the soil surface information acquisition unit 64 includes a light detection and ranging (LiDAR) sensor. The soil surface information acquisition unit 64 acquires information regarding a shape and the like of a soil surface (soil surface information) in front of the cab 13. In the present embodiment, the shape of the soil surface is detected based on three-dimensional distance data detected by LiDAR. The soil surface information acquisition unit 64 may be a time of flight (TOF) sensor, a stereo camera, or the like. In another embodiment, the soil surface around the hydraulic excavator 1 may be regarded as horizontal.

[0024] The IMU 65 detects an angle (machine body angle) of a machine body (upper slewing body 12) of the hydraulic excavator 1 with respect to a horizontal plane. Note that the angle of the machine body with respect to the horizontal plane may be detected by an inclination sensor in addition to the IMU. As the inclination sensor, a sensor using a micro electro mechanical systems (MEMS) technology or a sensor using various types such as a liquid-sealed type can be adopted.

[0025] The drive unit 71 drives various structures of the hydraulic excavator 1, and drives the lower travelling body 10, the upper slewing body 12, the work attachment 20, and the like operated by the operation unit 51. In particular, the drive unit 71 can drive the work attachment 20 such that the bucket 23 excavates the ground surface. At this time, the drive unit 71 can receive a predetermined command signal and drive the work attachment 20 based on an output characteristic according to the command signal. The drive unit 71 includes a hydraulic circuit such as a hydraulic pump and a hydraulic motor.

[0026] The display unit 72 is disposed in the cab 13, receives a predetermined display command signal, and displays various information to be notified to the worker in accordance with the display command signal. The information includes soil quality information (described later), the position information of the hydraulic excavator 1, and the like. Specifically, the display unit 72 can display map information at the work site, and displays the soil quality estimated by the soil quality estimator 505 and the position information of the hydraulic excavator 1 acquired by the body position information acquisition unit 63 on the map information in association with each other.

[0027] The transmitter 73 transmits the position information of the hydraulic excavator 1 acquired by the body position information acquisition unit 63 and the soil quality information of the work site estimated by the soil quality estimator 505 to a data center, a remote management center, or the like disposed at a place away from the work site.

[0028] A controller 50 includes a central processing unit (CPU), a read only memory (ROM) that stores a control program, random access memory (RAM) used as a work area for the CPU, and the like. As illustrated in FIG. 2, the operation unit 51, the input unit 52, the load cell 61, the cylinder stroke sensor 62, the body position information acquisition unit 63, the soil surface information acquisition unit 64, the IMU 65, a drive unit 71, the display unit 72, and the transmitter 73 are connected to the controller 50.

[0029] The controller 50 functions so as to include a drive controller 501, the bucket position calculator 502 (orientation information acquisition unit), the machine load calculator 503, the soil pressure load calculator 504, the soil quality estimator 505, an output characteristic setting unit 506, and a storage unit 507 by the CPU executing the control program stored in the ROM. These functional units do not have substance and correspond to units of functions executed by the program. That is, it can be said that control executed by these functional units is substantially integrally executed by the controller 50. Note that each of the functional units may be divided into a plurality of controllers. In addition, an entire or a part of the controller 50 is not required to be provided in the hydraulic excavator 1, and may be disposed at a position different from the hydraulic excavator 1 in a case where the hydraulic excavator 1 is remotely controlled. Furthermore, the control program may be transmitted from a server (management device), a cloud, or the like at a remote location to the controller 50 in the hydraulic excavator 1 and executed, or the control program may be executed on the server or the cloud and various command signals generated may be transmitted to the hydraulic excavator 1.

[0030] The drive controller 501 inputs a drive command signal to the drive unit 71 in accordance with the content of the operation received by the operation unit 51. As a result, the operations of the lower travelling body 10, the upper slewing body 12, the work attachment 20, and the like are controlled.

[0031] The bucket position calculator 502 calculates and acquires, as orientation information, a current orientation of the work attachment 20, in particular, the position (coordinates) and orientation of the bucket 23 based on a stroke amount (cylinder length) of each cylinder detected by the cylinder stroke sensor 62, the machine body angle detected by the IMU 65, a mechanical specification of the hydraulic excavator 1, and the like. In other words, the bucket position calculator 502 acquires orientation information that is information regarding an orientation of the work attachment 20 relative to the ground surface G.

[0032] The machine load calculator 503 calculates an excavation resistance value P_A (machine load) (described later), which is a load received by the bucket 23 from earth and sand, based on the load (drive load information) detected by the load cell 61, the position and orientation (orientation information) of the bucket 23 calculated by the bucket position calculator 502, and the like as the bucket 23 excavates the ground surface.

[0033] The soil pressure load calculator 504 calculates an excavation resistance value P_B (described later) based on the stroke amount of each cylinder detected by the cylinder stroke sensor 62, the machine body angle detected by the IMU 65, the soil surface information detected by the soil surface information acquisition unit 64, a shape of the bucket 23 stored in the storage unit 507, the mechanical specification of the hydraulic excavator 1, and the like. Specifically, as the bucket 23 excavates the ground surface, the soil pressure load calculator 504 calculates a soil pressure load, which is a load applied to the bucket 23 by a soil mass, based on a soil pressure theory from a shape of the soil mass constituted by a soil dammed by the bucket 23, the orientation information acquired by the bucket position calculator 502, the shape of the bucket 23, a density γ_t of the soil, and a wall surface frictional angle δ between the soil and the bucket 23.

[0034] The soil quality estimator 505 estimates the soil quality information (the soil quality of the soil at the work site) around the hydraulic excavator 1 based on the excavation resistance value P_A (machine load) calculated by the machine load calculator 503 and the excavation resistance value P_B (soil pressure load) calculated by the soil pressure load calculator 504. Then, the soil quality estimator 505 inputs a display command signal corresponding to the estimated soil quality to the display unit 72 to display information corresponding to the soil quality. Furthermore, the soil quality estimator 505 inputs a display command signal in which the estimated soil quality and the position information acquired by the body position information acquisition unit 63 are associated with each other to the display unit 72.

[0035] In particular, in the present embodiment, the soil quality estimator 505 estimates an internal frictional angle ϕ of the soil and a cohesive force c of the soil at the work site as the soil quality on the assumption that the machine load applied to the bucket 23 and the soil pressure load coincide with each other. When the cohesive force c is 0, as illustrated in FIG. 8, the internal frictional angle ϕ corresponds to an angle between a direction of a slip plane load acting on a predetermined slip plane when the bucket 23 presses the soil mass and the soil mass moves along the slip plane and a normal line of the slip plane.

[0036] The output characteristic setting unit 506 sets (adjusts) an output characteristic of the drive unit 71 based on the soil quality information estimated by the soil quality estimator 505, and inputs a command signal corresponding to the characteristic to the drive unit 71.

[0037] The storage unit 507 stores in advance various threshold values, parameters, and the like referred to in the activation of the hydraulic excavator 1 and the soil quality information acquisition processing. The storage unit 507 stores the soil quality estimated by the soil quality estimator 505 and the position information acquired by the body position information acquisition unit 63 in association with each other.

[0038] Next, details of the soil quality information acquisition processing executed by the hydraulic excavator 1 according to the present embodiment will be described. FIG. 3 is a schematic diagram for describing the soil quality information acquisition processing executed in the hydraulic excavator 1 according to the present embodiment. The hydraulic excavator 1 can perform estimation while calculating soil quality information that is information regarding the soil quality of a surrounding ground during an arbitrary excavation work at the work site. At this time, the machine load calculator 503 calculates the load (machine load, excavation resistance value P_A) mechanically received by the bucket 23 (calculation 1 in FIG. 3), while the soil pressure load calculator 504 calculates the load (soil pressure load, excavation resistance value P_B) acting on the bucket 23 by the soil excavated by the bucket 23 based on the soil pressure theory (calculation 2 in FIG. 3). Then, the soil quality estimator 505 calculates the soil quality information included in the excavation resistance value P_B by assuming that the two loads are equal to each other (calculation 3 in FIG. 3).

[0039] As illustrated in FIG. 3, in the calculation 1, a bucket load detected by the load cell 61, a cylinder stroke detected by the cylinder stroke sensor 62, and the machine body angle detected by the IMU 65 are used. In the calculation 2, the cylinder stroke detected by the cylinder stroke sensor 62, the machine body angle detected by the IMU 65, the soil surface information detected by the soil surface information acquisition unit 64, the shape of the bucket 23 (bucket shape) stored in the storage unit 507 in advance, various mechanical specifications (such as a link length), and the like are mainly used.

[0040] In addition, in the calculation 3, the cohesive force c and the internal frictional angle ϕ are calculated and estimated as output information of the soil quality information acquisition processing of the present invention. Note that the cohesive force c and the internal frictional angle ϕ obtained by the calculation 3 are fed back and used as the cohesive force c for search and the internal frictional angle ϕ for search in the calculation 2.

[0041] Hereinafter, a flow of the soil quality information acquisition processing and a detailed calculation method will be further described. FIG. 4 is a flowchart of the soil quality information acquisition processing executed in the hydraulic excavator 1 according to the present embodiment.

[0042] When the worker presses a predetermined start switch through the input unit 52 disposed in the cab 13 of the hydraulic excavator 1, the soil quality information acquisition processing is started. After that, the worker can perform the excavation work of the ground surface in parallel by operating the operation unit 51.

[0043] When the soil quality information acquisition processing is started, the load cell 61, the cylinder stroke sensor 62, the soil surface information acquisition unit 64, and the IMU 65 acquire the load, the cylinder stroke, the soil surface information, and the machine body angle received by the proximal end of the bucket 23, respectively (step S1). Next, in the calculation 1, the excavation resistance value Pa is calculated (step S2).

[0044] FIG. 5 is a schematic diagram illustrating the machine load applied to the bucket 23 of the hydraulic excavator 1 according to the present embodiment. In the calculation 1, first, the bucket position calculator 502 calculates the position and orientation of the bucket 23. The cylinder stroke sensor 62 acquires the cylinder strokes (cylinder extension amounts) of the boom cylinder 21S, the arm cylinder 22S, and the bucket cylinder 23S. Thus, the bucket position calculator 502 can calculate the orientation of the work attachment 20 in FIG. 1. As a result, the bucket position calculator 502 can acquire information regarding the position and orientation of the bucket 23 in FIG. 5. Note that lengths, shapes, and the like of the boom 21, the arm 22, and the bucket 23 are stored in the storage unit 507 in advance. In addition, in the calculation of the position and orientation of the bucket 23, angles of the rising and falling body (the boom 21 and the arm 22) and the bucket 23 are calculated with reference to the machine body angle detected by the IMU 65.

[0045] The load cell 61 includes a first load cell 611 and a second load cell 612 (both of which are load sensors) illustrated in FIG. 5. The first load cell 611 is disposed at a connection portion CB1 between the arm 22 and the bucket 23, which is a rotation center axis of the bucket 23. On the other hand, the second load cell 612 is disposed at a connection portion CB2 between a link disposed at a distal end of the bucket cylinder 23S and the bucket 23. As illustrated in FIG. 5, the machine load calculator 503 can calculate the excavation resistance value P_A (resultant force F in FIG. 5) as a resultant force of a load F2 detected by the first load cell 611 and a load F1 detected by the second load cell 612. At this time, a direction (vector) in which the load F1 and the load F2 act is calculated based on the orientation of the bucket 23 calculated by the bucket position calculator 502. As described above, in the calculation 1, the excavation resistance value P_A received by the bucket 23 during excavation can be calculated based on the load detected by the load cell 61 (the first load cell 611 and the second load cell 612).

[0046] The excavation resistance value P_A is calculated in this way in step S2 in FIG. 4, and then, the soil pressure load calculator 504 assumes the cohesive force c and the internal frictional angle ϕ to be predetermined values (step S3). At this time, the soil pressure load calculator 504 may assume the above values from the result of the calculation 2 performed previously, or may assume the above values from an initial value for calculation stored in advance in the storage unit 507.

[0047] Next, the soil pressure load calculator 504 executes the calculation 2 to calculate the excavation resistance value P_B (step S4). FIG. 6 is a schematic diagram for describing the calculation 2 (soil pressure load calculation processing) executed in the hydraulic excavator 1 according to the present embodiment. As illustrated in FIG. 6, in the calculation of the excavation resistance value P_B in the calculation 2, the mechanical specifications (such as the link length) stored in the storage unit 507 in advance, the stroke of each cylinder detected by the cylinder stroke sensor 62, the soil surface information detected by the soil surface information acquisition unit 64, the machine body angle detected by the IMU 65, the shape of the bucket 23, the soil density γ_t, and the wall surface frictional angle δ stored in the storage unit 507 in advance, and the internal frictional angle ϕ and the cohesive force c assumed in step S3 are used.

[0048] In addition, in the calculation 2, the position and orientation (wall surface angle α) of the bucket 23 are calculated as needed by using the above parameters (bucket orientation calculation in FIG. 6), and a ground height H is calculated based on the calculation result (ground height calculation in FIG. 6). Then, the excavation resistance value P_B is calculated by using the wall surface angle α and the ground height H derived from these calculations (step S4 in FIG. 4). In this case as well, in the calculation of the position and orientation of the bucket 23, the angles of the rising and falling body (the boom 21 and the arm 22) and the bucket 23 are calculated with reference to the machine body angle detected by the IMU 65.

[0049] Referring to FIG. 4, next, the soil quality estimator 505 inputs the excavation resistance value P_A calculated in step S1 and the excavation resistance value P_B calculated in step S4 to the calculation 3 to estimate the soil quality (step S5). Furthermore, the soil quality estimator 505 calculates a residual Δ between the two excavation resistance values P_A and P_B (step S6). Then, when the residual Δ calculated in step S6 is less than a preset threshold value ε (YES in step S7), the soil quality estimator 505 outputs the obtained cohesive force c and internal frictional angle ϕ (step S8), and ends the soil quality information acquisition processing. The soil quality information output in step S8 is displayed on the display unit 72 together with a current position of the hydraulic excavator 1 acquired by the body position information acquisition unit 63. Furthermore, the information may be transmitted to the center described above through the transmitter 73.

[0050] On the other hand, the output characteristic setting unit 506 (FIG. 2) may input a predetermined characteristic command signal to the drive unit 71 in accordance with the soil quality information calculated by the soil quality estimator 505. For example, when the cohesive force c is great or the internal frictional angle ϕ is great, the output of the drive unit 71 may be increased by increasing a rotation speed of the hydraulic pump included in the drive unit 71.

[0051] In addition, as illustrated in FIG. 3, the soil quality information (the cohesive force c and the internal frictional angle ϕ) calculated by the soil quality estimator 505 is desirably fed back to the subsequent calculation 2 as search parameters to improve accuracy of the calculation 2. When the residual Δ is greater than or equal to the preset threshold value ε in step S7 (NO in step S7), step S3 and the subsequent steps are repeated.

[0052] Note that, in the flowchart illustrated in FIG. 4, an aspect has been described in which the cohesive force c and the internal frictional angle ϕ enabling reproduction of a single P_A are searched, but the present invention is not limited to this aspect. Since there are variations in the soil quality at an actual work site, an aspect may be employed in which the cohesive force c and the internal frictional angle ϕ are searched such that the residual (for example, the sum of squares of the residual) with respect to a plurality of P_A already acquired is minimized.

[0053] Next, the calculation 2 in step S4 described above will be described in more detail. FIG. 7 is a schematic diagram illustrating how a soil mass plastically collapses due to movement of a retaining wall. FIG. 8 is a schematic diagram for describing a passive soil pressure based on soil mechanics. In general, in the soil mechanics, a pressure received by a structure in contact with soil or a pressure generated in the soil is referred to as soil pressure. In particular, of forces received by the structure from the soil when the structure in contact with the soil moves, inclines, or the like, the soil pressure generated when the structure (retaining wall in FIG. 7) moves toward the soil is referred to as passive soil pressure. At this time, the forces received by the structure are calculated from a balance of forces generated when a soil mass moves along a slip plane (plastic collapse surface). As a plastic collapse condition of the slip plane, Mohr-Coulomb failure criterion shown in FIG. 8 and Equation 1 is used.

[Equation 1]

$$\tau = c + \sigma \tan \phi \quad \text{... (Equation 1)}$$

[0054] In Equation 1, τ is a shear strength, ϕ is the internal frictional angle, c is the cohesive force, and σ is a restraint pressure. The following parameters in FIG. 8 are important for the calculation of a passive soil pressure Qp (force received by the soil from the structure) in FIG. 8. W is a soil weight, R is a slip plane load, ω is a wall body angle, and β is a ground plane inclination angle. In addition, H is the ground height, δ is the wall surface frictional angle, and corresponds to a friction coefficient between the soil and the wall. θ is the slip plane angle. As illustrated in FIG. 8, the passive soil pressure Qp can be obtained by a vector sum of the own weight W of the soil and the slip plane load R. Here, an angle formed by Qp and W corresponds to π-ω+δ, and an angle formed by W and R corresponds to θ+ϕ.

[0055] The inventors of the present invention apply the idea of the soil mechanics (soil theory) to the bucket 23 of the hydraulic excavator 1. FIG. 9 is a schematic diagram for describing the excavation resistance value P_B acting on the bucket 23. In FIG. 9, a reaction force of a force P received by the soil mass corresponds to a force received by the bucket 23 from the soil mass, that is, the excavation resistance value P_B. In FIG. 9, W is a soil mass weight, T is the shear force on the slip plane, and N is a normal force on the slip plane. The square of the slip plane load R is equal to the sum of the square of the shear force T and the square of the normal force N. Also, as described above, H is the ground height and θ is the slip plane angle. FIG. 10 is a schematic graph illustrating a relationship between the slip plane angle θ and the excavation resistance value P (P_B). In the present embodiment, θ is obtained so as to satisfy dQp/dθ (obtained by differentiating the passive soil pressure Qp (P) with the slip plane angle θ) = 0. In addition, δ is the wall surface frictional angle (the friction coefficient between the bucket 23 and the soil), and α is the wall surface angle (an angle of a bottom plate surface of the bucket 23 with respect to a vertical plane).

[0056] Here, Equations 2 and 3 below are established when considering the balance of the forces to the soil mass that plastically collapses per unit width in a depth direction (width direction of the bucket 23) in FIG. 9.

[Equation 2]

$$T \sin\theta + P \sin(\delta - \alpha) + W = N \sin\left(\frac{\pi}{2} - \theta\right) \quad \text{... (Equation 2)}$$

[Equation 3]

$$T \cos\theta - P \cos(\delta - \alpha) + N \cos\left(\frac{\pi}{2} - \theta\right) = 0 \quad \text{... (Equation 3)}$$

[0057] In addition, Equation 4 below is established from the Mohr Coulomb failure criterion.

[Equation 4]

$$T = N \tan\phi \quad \text{... (Equation 4)}$$

[0058] In addition, Equation 5 below is established from a geometric condition of the soil mass that plastically collapses.

[Equation 5]

$$W = \frac{H^2}{2}(\tan\alpha + \cot\theta)\gamma_t$$

... (Equation 5)

[0059] By solving Equations 2 to 5 as simultaneous equations, Equation 6 below is obtained. Equation 6 corresponds to the case of c = 0 as an example.
[Equation 6]

$$P = -\frac{W(\tan\phi\cos\theta + \sin\theta)}{\tan\phi\sin(\theta+\delta-\alpha) - \cos(\theta+\delta-\alpha)}$$

... (Equation 6)

[0060] That is, a force that the soil mass receives from a wall surface, in other words, a force that the wall surface of the bucket receives from the soil mass is calculated as $P = P_B$. In Equations 5 and 6, the wall surface angle α and the ground height H can be obtained from measurement and calculation. In addition, a unit volume weight (density) γ_t of the soil and the wall surface frictional angle δ (friction coefficient between the bucket 23 and the soil) are stored in the storage unit 507 in advance as known values. As described above, the slip plane angle θ is $dP/d\theta = 0$, that is, an angle when P is positive and local minimum as illustrated in FIG. 10.

[0061] Next, the calculation 3 in step S7 in FIG. 4 will be described in more detail.

[0062] While the excavation resistance value P_A calculated in step S2 is obtained as a numerical value, the excavation resistance value P_B calculated in step S6 includes the cohesive force c and the internal frictional angle ϕ as variables as in Equations 5 and 6. Note that Equation 6 may include a correction term related to the cohesive force c. Therefore, the soil quality estimator 505 compares the input values of the excavation resistance values P_A and P_B, and calculates the internal frictional angle ϕ and the cohesive force c that minimize a difference between the values by using a known mathematical programming method or the like. As described above, initial values of the internal frictional angle ϕ and the cohesive force c have been desirably stored in the storage unit 507 in advance at a start of estimation. In addition, the excavation resistance values P_A and P_B, which change during the excavation work of the hydraulic excavator 1, are desirably calculated in consideration of a change on a time axis.

[0063] Here, examples of a method of searching for the internal frictional angle ϕ and the cohesive force c include the following methods. Note that the internal frictional angle ϕ and the cohesive force c have preset ranges such as $0 \leq \phi < \phi_{\_UPPER}$ (upper limit of ϕ) and $0 \leq c < c_{\_UPPER}$ (upper limit of c), respectively.

[0064] As a first search method, an enumeration method can be used. In this method, the soil quality estimator 505 enumerates combinations of all solutions for the internal frictional angle ϕ and the cohesive force c, and selects a combination that optimizes a predetermined objective function from the combinations.

[0065] As a second search method, a branch and bound method can be used. FIG. 11 is a schematic diagram for describing the branch and bound method executed by the soil quality estimator 505 according to the present embodiment. In this method, the soil quality estimator 505 decomposes an entire solution into some sub-problems and solves all the sub-problems to solve the original problem equivalently. In solving the sub-problems, it is possible to avoid solving all the sub-problems by preliminarily performing a test as to whether each of the sub-problems has an optimal solution or whether the optimal solution can be an optimal solution of the original problem. For example, in a case where the excavation resistance value at the time of substituting the internal frictional angle ϕ exceeds an excavation force of the mechanical specification as in the case of $\phi = 50$ in FIG. 11, or in a case where the difference between the two input values becomes greater than or equal to a certain value, it is possible not to calculate the combination of the solutions.

[0066] Furthermore, as a third search method, a known Newton Raphson method having the internal frictional angle ϕ and the cohesive force c as variables may be used.

[0067] As described above, the present embodiment is based on the technical idea of estimating the soil quality related to the soil pressure load from the machine load actually received by the bucket 23 during the excavation work and the soil pressure load applied to the bucket 23 by the soil mass formed by the bucket 23. While the machine load calculator 503 calculates the machine load during excavation by the bucket 23, the soil pressure load calculator 504 calculates the soil pressure load during the excavation, and the soil quality estimator 505 estimates the soil quality of the soil at the work site based on the machine load and the soil pressure load. Therefore, the soil quality information of the ground can be acquired while the excavation work is being performed at the work site.

[0068] In particular, in the present embodiment, the internal frictional angle ϕ as the soil quality and the cohesive force c of the soil can be estimated based on the technical idea that the machine load and the soil pressure load acting on the bucket 23 coincide with each other. At this time, since the information on various shapes of the bucket 23 has been stored in the storage unit 507 in advance for, the soil quality can be stably estimated regardless of the amount and distribution (shape) of the soil masses dammed by the bucket 23. Note that the present invention is not limited to the assumption that the machine load and the soil pressure load acting on the bucket 23 necessarily coincide with each other in order to acquire the soil quality information. It may be assumed that a value obtained by multiplying (or adding) the machine load acting on the bucket 23 by a predetermined constant and the soil pressure load coincide with each other in accordance with a strength of the bucket 23 and a work site environment.

[0069] In the present embodiment, the orientation of the work attachment 20 (bucket 23) can be calculated based on a length of each cylinder detected by the cylinder stroke sensor 62, and the machine load and the soil pressure load can be accurately calculated.

[0070] In the present embodiment, the load cell 61 detects the load of the proximal end of the bucket 23,and thus, the drive load information can be easily acquired.

[0071] In particular, in the present embodiment, the drive load information can be easily acquired by detecting the load acting on the bucket 23 by the first load cell 611 and the second load cell 612 (load sensor) disposed at the distal end of the arm 22.

[0072] In the present embodiment, information such as a strength of the ground is transmitted to the worker through the display unit 72, and thus, the worker can use the information as a guide for setting the output characteristics of the hydraulic excavator 1 (setting an engine rotation speed and an output mode). In addition, an amount of adjustment of the output characteristic can be quantitatively adjusted even when an unskilled person performs operation or the operation is performed remotely.

[0073] In the present embodiment, by combining the position information of the machine body and the soil quality information, the worker can know a portion where the strength of the ground is low. As a result, it is possible to predict a falling risk of the hydraulic excavator 1 due to insufficient ground strength.

[0074] In the present embodiment, the worker can visually and easily know the strength of the ground based on the map information displayed on the display unit 72.

[0075] In the present embodiment, the output characteristic setting unit 506 can adjust the output of the hydraulic excavator 1 in accordance with the strength of the surrounding ground and the like. It is therefore possible to improve workability of the excavation work perceived by the worker. In particular, as compared with a case where the worker sets the output characteristic of the hydraulic excavator 1 in accordance with the site environment, the output characteristic can be automatically adjusted even in a case where an unskilled person performs operation or the operation is performed remotely.

[0076] The hydraulic excavator 1 according to one embodiment of the present invention has been described above. Note that the present invention is not limited to these embodiments. The present invention can adopt the following modified embodiments, for example.

[0077] In the above embodiment, an aspect has been described in which the position and orientation of the work attachment 20 (bucket 23) are calculated in accordance with the length of each cylinder detected by the cylinder stroke sensor 62, but the present invention is not limited to this aspect. An angle detector (angle sensor) capable of detecting each of a relative angle of the boom 21 and the arm 22 (rising and falling body) with respect to the upper slewing body 12 and a relative angle of the bucket 23 with respect to the rising and falling body may be further provided. In this case, the bucket position calculator 502 (orientation information acquisition unit) is only required to acquire orientation information of the work attachment 20 (bucket 23) by calculating the orientation of the work attachment 20 based on the relative angle of the rising and falling body and the relative angle of the bucket 23 detected by the angle detector. At this time, the relative angle of the boom 21 and the arm 22 (rising and falling body) with respect to the upper slewing body 12 and the relative angle of the bucket 23 with respect to the rising and falling body are only required to be calculated with reference to the machine body angle detected by the IMU 65.

[0078] In such a configuration, the orientation of the work attachment 20 can be calculated based on the angle of the rising and falling body and the bucket 23, and the machine load and the soil pressure load can be accurately calculated. In particular, by using the detection result of the IMU 65, the orientation of the work attachment 20 can be accurately calculated and acquired even when the machine body is inclined with respect to the horizontal plane.

[0079] In the above embodiment, an aspect has been described in which the load of the proximal end of the bucket 23 is detected by using the load cell 61, and the excavation resistance value P_A is calculated based on the result. However, the present invention is not limited to this aspect. In FIG. 2, a cylinder pressure sensor (cylinder pressure detector) (not shown) may be provided instead of the load cell 61. The cylinder pressure sensor can detect a head pressure and a rod pressure of each of the boom cylinder 21S, the arm cylinder 22S, and the bucket cylinder 23S. On the other hand, the machine load calculator 503 can obtain a thrust (drive load information) of each actuator from the pressure detection result, and calculate an excavation reaction force (excavation resistance value P_A) received by the bucket 23 from the result and dimensional specifications and the orientation of the attachment.

<First Modified Embodiment>

[0080] As described above, in the above embodiment, the output characteristic setting unit 506 (FIG. 2) can set (adjusts) the output characteristic of the drive unit 71 based on the soil quality information estimated by the soil quality estimator 505, and input a command signal corresponding to the characteristic to the drive unit 71. Hereinafter, a plurality of modified embodiments will be described regarding output control processing executed by the output characteristic setting unit 506. FIG. 12 is a flowchart of the output control processing executed in the hydraulic excavator 1 according to a first modified embodiment of the present invention. Note that in each of the subsequent modified embodiments, the description will focus on the difference from the previous embodiment, and the description of common points will be omitted.

[0081] In the present modified embodiment, in the hydraulic excavator 1, when the output control processing is executed, the output characteristic setting unit 506 determines whether the soil quality information estimated by the soil quality estimator 505 has been input to the storage unit 507 (step S11). Here, in a case where the soil quality information estimated by the soil quality estimator 505 has been input to the storage unit 507 (YES in step S11), the output characteristic setting unit 506 acquires latest soil quality information I from the storage unit 507 (step S12). For example, the soil quality information I includes the cohesive force c and the internal frictional angle ϕ described above.

[0082] Next, the output characteristic setting unit 506 determines whether soil quality information I0 referred to when the output characteristic is previously adjusted coincides with the soil quality information I acquired this time (step S13). Here, when I 10 (NO in step S13), the output characteristic setting unit 506 acquires the output characteristic corresponding to the latest soil quality information I from the storage unit 507 to change the output characteristic of the hydraulic excavator 1 (step S14). Then, an output characteristic signal (command signal) corresponding to the changed output characteristic is input to the drive unit 71 (step S15).

[0083] When there is no input of soil quality information in step S11 (NO in step S11), and when I = 10 in step S13 (YES in step S13), the output characteristic setting unit 506 is only required to use the previous output characteristic (step S16) and input an output characteristic signal corresponding to the output characteristic to the drive unit 71 in step S15.

[0084] In general, in dry gravel or sand, the cohesive force $c \approx 0$, and the internal frictional angle ϕ is dominant. It is also said that the cohesive force c is dominant in terms of strength in clay. Therefore, in the present embodiment, as an example, a threshold value ca set in advance for the cohesive force c and a threshold value ϕa set in advance for the internal frictional angle ϕ are stored in the storage unit 507.

[0085] Four ranges of a first range ($\phi < \phi a$, $c < ca$), a second range ($\phi \geq \phi a$, $c < ca$), a third range ($\phi < \phi a$, $c \geq ca$), and a fourth range ($\phi \geq \phi a$, $c \geq ca$) are set by using each of the above threshold values, and the output characteristic setting unit 506 determines in step S14 in FIG. 16 which of the above four ranges the soil quality information I (ϕ, c) is included. Then, the output characteristic setting unit 506 acquires, from the storage unit 507, the output characteristic set in advance corresponding to each range and stored in the storage unit 507. For example, the output characteristic setting unit 506 sets the output to be greater as ϕ is greater. In addition, the output characteristic setting unit 506 sets the output to be greater as c is greater.

[0086] Note that the shear strength τ may be calculated from Equation 1 described above based on the soil quality information 1. In this case, three ranges of a first range ($\tau \leq \tau a$), a second range ($\tau a < \tau \leq \tau b$), and a third range ($\tau b < \tau$) may be set with reference to preset threshold values ra and ib, and the output characteristic may be determined corresponding to each range. In this case, the output characteristic setting unit 506 sets the output to be greater as τ is greater.

[0087] As described above, in the present modified embodiment, the output characteristic of the hydraulic excavator 1 can be changed in accordance with a work place while considering the soil quality information, the workability of the worker can be improved, and the work efficiency can be improved. In addition, since the output characteristic of the hydraulic excavator 1 is appropriately set in accordance with the softness and hardness of the ground, wasteful fuel consumption can be suppressed.

[0088] Note that, in the above description, a mode has been described in which the output characteristic is set in accordance with the soil quality information I acquired in advance in step S14 in FIG. 12. However, the soil quality information I may be classified into a preset soil quality rank, and the output characteristic may be set in accordance with the soil quality rank.

<Second Modified Embodiment>

[0089] FIG. 13 is a flowchart of the output control processing executed in the hydraulic excavator 1 according to a second modified embodiment of the present invention. FIG. 14 is a schematic diagram of the hydraulic excavator 1 and a server 90 according to the present modified embodiment. The server 90 (management device) is disposed in a data center, a remote management center, or the like installed at a place away from the work site.

[0090] Referring to FIG. 14, the server 90 includes a server side receiver 901 (management device side receiver), a server side output characteristic setting unit 902 (management device side output characteristic setting unit), a server side storage unit 903 (management device side storage unit), and a server side transmitter 904 (management device side transmitter).

[0091] Referring to FIG. 13, in the present modified embodiment, the processing from steps S21 to S25 (including step S24A) is similar to the processing from steps S11 to S15 (including step S16) in FIG. 12. On the other hand, when the output characteristic setting unit 506 inputs the output characteristic signal to the drive unit 71 in step S25, the body position information acquisition unit 63 (FIG. 2) acquires the latest position information of the hydraulic excavator 1 (step S26). Note that an acquisition timing of the position information is not limited to a timing in step S26.

[0092] Next, the transmitter 73 (FIG. 2) transmits the position information of the hydraulic excavator 1 and the soil quality information estimated by the soil quality estimator 505 to the server 90 in association with each other (step S27). When the server side receiver 901 receives the information in the server 90 (step S28), the server side storage unit 903 stores the information in association with each other (step S29).

[0093] As described above, in the present embodiment, the server 90 can acquire and accumulate the position information and the soil quality information at the work site acquired by the hydraulic excavator 1. Therefore, as illustrated in FIG. 14, the information acquired by a hydraulic excavator 1A (one construction machine) is received by a receiver 74 of a hydraulic excavator 1B (another construction machine) via the server 90, and the output characteristic can be changed in accordance with the received soil quality information I.

[0094] In addition, by using the server side storage unit 903 of the server 90 in this manner, the information on a plurality of work sites and the ground can be accumulated by a storage unit having a larger capacity than the storage unit 507 of the hydraulic excavator 1.

[0095] FIG. 15 is a flowchart of another output control processing executed in the hydraulic excavator 1 according to the present modified embodiment. In the first modified embodiment described above, an aspect has been described in which the output characteristic setting unit 506 of the hydraulic excavator 1 sets the output characteristic. In the present modified embodiment, the server side output characteristic setting unit 902 in the server 90 sets the output characteristic of the hydraulic excavator 1.

[0096] That is, in step S31 in FIG. 15, in a case where the soil quality information acquired by the soil quality estimator 505 has been input to the storage unit 507 (YES in step S31), the body position information acquisition unit 63 acquires position information of the hydraulic excavator 1 (step S32). Next, the transmitter 73 transmits the position information of the hydraulic excavator 1 and the soil quality information estimated by the soil quality estimator 505 to the server 90 (step S33). Next, the server side output characteristic setting unit 902 selects the output characteristic information of the hydraulic excavator 1 with reference to the information stored in advance in the server side storage unit 903 based on the position information and the soil quality information received in step S34 (step S35). Then, the server side transmitter 904 transmits the selected output characteristic information to the hydraulic excavator 1 (step S36).

[0097] The hydraulic excavator 1 receives the output characteristic information, displays change contents of the output characteristic on the display unit 72 (FIG. 2) in the cab 13, and asks an approval of an operator (step S37). When the operator approves the change of the output characteristic through an approval button (not shown) (YES in step S37, step S38), the output characteristic setting unit 506 inputs an output characteristic signal (command signal) corresponding to the output characteristic to be changed to the drive unit 71 (step S39).

[0098] On the other hand, when there is no input of soil quality information in step S31 (NO in step S31), and when an approval of the operator cannot be obtained in step S37 (NO in step S37), the output characteristic setting unit 506 is only required to use the previous output characteristic (step S38A) and input an output characteristic signal corresponding to the output characteristic to the drive unit 71 in step S39.

[0099] In addition, in the present modified embodiment, an aspect has been described in which the soil quality information and the position information are transmitted to the server 90 in step S33 in FIG. 15, but only the position information of the hydraulic excavator 1 may be transmitted to the server 90. In this case, as described with reference to FIG. 13, the current soil quality information I around the hydraulic excavator 1 is only required to be acquired based on the soil quality information and the position information accumulated in the server 90 in advance, and the server side output characteristic setting unit 902 is only required to set the output characteristic corresponding to the soil quality information.

[0100] In step S31 in FIG. 15, in a case where the soil quality information estimated in advance by the soil quality estimator 505 has not been input to the storage unit 507, the output quality information may be received from the server 90 by transmitting the position information of the hydraulic excavator 1 to the server 90 without using the previous output characteristic in step S38A.

<Third Modified Embodiment>

[0101] FIG. 16 is a flowchart of soil quality information acquisition processing executed in a construction machine according to a third modified embodiment of the present invention. FIG. 17 is a diagram illustrating appearance of a display unit in the soil quality information acquisition processing executed in the construction machine according to the present modified embodiment.

[0102] The present modified embodiment has a feature in a condition for executing the soil quality information acquisition processing during work at the work site. Referring to FIG. 16, the operator tilts the work attachment 20 from the state illustrated in FIG. 1 and adjusts the orientation of the bucket 23 near the ground surface G (step S41). At this time, for the purpose of the bucket 23 stably excavating the soil of the ground surface G, the soil quality estimator 505 requests the operator to adjust the angle of the bucket 23 so that the angle of the bucket 23 is included in a preset estimation angle (angle range).

[0103] FIG. 17 is an example of a screen displayed on the display unit 72 (FIG. 2) in the cab 13 (FIG. 1). In a frame of a bucket angle on the left side in the drawing, Under (30 degrees in FIG. 17) means a lower limit of the estimation angle, and Over (120 degrees in FIG. 17) means an upper limit of the estimation angle. In addition, an angle (80 degrees in FIG. 17) shown between the two limits indicates a current bucket angle ψ. The bucket angle ψ is an angle formed by a straight line connecting the connection portion CB1 (fulcrum) between the arm 22 and the bucket 23 in FIG. 5 and a distal end of the bucket 23 with respect to the horizontal plane. As illustrated in FIG. 17, a current angle (orientation) of the bucket 23 is visually illustrated in the "bucket angle" field. Furthermore, a "scale" is disposed by which a relative position of the current bucket angle ψ with respect to Over and Under can be visually confirmed. A white triangle in the scale indicates a value of the current bucket angle ψ. A maximum value (180 degrees in FIG. 17) in the scale is set to a value greater than Over (120 degrees in FIG. 17), and a minimum value (0 degrees in FIG. 17) is set to a value less than Under (30 degrees in FIG. 17). As a result, when the operator adjusts the bucket angle ψ to fall within an appropriate range, the current bucket angle ψ can be recognized from a range wider than the upper limit (Over) and the lower limit (Under), and an angle adjustment operation can be easily performed.

[0104] In the present modified embodiment, since the display unit 72 (bucket angle display unit) can display the estimation angle and the current angle ψ of the bucket 23 as described above, the operator can easily adjust the angle of the bucket 23 while viewing the display unit 72.

[0105] The operator confirms that the angle ψ of the bucket 23 is included between the lower limit value and the upper limit value (YES in step S42 in FIG. 16), and then, the operator slightly lowers the work attachment 20 and causes the distal end of the bucket 23 to be in contact with the ground surface G (step S43).

[0106] Next, the operator presses an option button (not shown) disposed on a grip of an arm pulling lever (not shown) in the cab 13. This option button functions as a startup switch for bucket angle maintenance control. When the bucket angle maintenance control is in activation, the drive controller 501 (FIG. 2) automatically adjusts the angles of the boom 21 and the arm 22 to maintain the angle ψ of the bucket 23 constant when the arm is pulled by an operation of the operator. Therefore, the excavation work can be performed while the relative angle of the bucket 23 with respect to the ground surface G is kept constant. Then, when the operator presses the option button, the soil quality estimator 505 starts soil quality estimation processing (step S45). At this time, each data stored in the storage unit 507 (FIG. 2) in the previous soil quality information acquisition processing is reset.

[0107] The bucket 23 excavates the ground surface G while approaching the upper slewing body 12 by the operation of the operator, and then, the operator eventually presses the option button again. As a result, the bucket angle maintenance control is turned off, and the soil quality estimation processing (calculation) by the soil quality estimator 505 ends (step S46). Note that, while the soil quality estimator 505 is estimating the soil quality, a lamp "under estimation" is lit in a soil quality estimation region on the right side of a screen display in FIG. 17.

[0108] Here, in the present modified embodiment, the soil quality estimator 505 determines whether the soil quality information acquisition processing can be expected to be accurate (step S47). Specifically, the soil quality estimator 505 determines whether a soil volume V (m^3) calculated by the soil pressure load calculator 504 is greater than or equal to a preset soil volume threshold value Vmin. The soil volume V is a volume of soil included in the bucket 23 in the excavation work. In the present modified embodiment, the soil pressure load calculator 504 calculates the soil volume V based on the shape of the bucket 23 and the shape of the soil mass. The shape of the bucket 23 is known and stored in the storage unit 507. The shape of the soil mass is acquired by the soil surface information acquisition unit 64 (FIG. 1). When the soil volume V is less than the soil volume threshold value Vmin, a soil pressure load of a sufficient magnitude does not act on the bucket 23 from the soil mass, and thus, there is a possibility that the accuracy of the estimated soil quality is deteriorated. In the present modified embodiment, the magnitude of the soil volume V is determined from such a viewpoint.

[0109] Furthermore, in step S47 in FIG. 16, the soil quality estimator 505 determines whether the number M of data acquired from steps S44 to S46 is a predetermined threshold value Mmin or more. In the present modified embodiment, the soil quality estimator 505 sequentially estimates the soil quality at predetermined time intervals (ten times in 1 sec as an example) by using each parameter that changes from moment to moment during the excavation of the bucket 23. The number M of data corresponds to the number of soil quality data acquired in this process. The threshold value Mmin is set to 50, for example. In a case where the number M of data is smaller than the threshold value Mmin as in a case where the operator presses the option button at a short time interval, there is a possibility that the accuracy of the estimated soil quality is deteriorated. In the present modified embodiment, the number M of data is determined from such a viewpoint. Note that the number M of data may be the number of other parameters used for the soil quality information acquisition processing.

[0110] In step S47 in FIG. 16, when the above condition is satisfied (YES in step S47), a lamp of "success" is lit in the soil quality estimation region on the right side of the screen display in FIG. 17. The soil quality estimator 505 displays information on a finally estimated soil quality on the display unit 72 (FIG. 2). Specifically, in the soil quality estimation region in FIG. 17, information regarding the estimated soil quality is displayed in a portion indicated by "current value". The information may be a numerical value, a characteristic, or a message. In the present modified embodiment, soil quality information (past soil quality) estimated previously is displayed as "previous value" under "current value" (latest soil quality). Therefore, the operator can easily know a change in the soil quality at the work site. Note that the display of "current value" and "previous value" may be history information such as a graph.

[0111] In step S47 in FIG. 16, when the above condition is not satisfied (NO in step S47), a lamp of "failure" is lit in the soil quality estimation region on the right side of the screen display in FIG. 17. This display allows the operator to recognize the necessity of re-measurement (step S49). In this case, the operator is only required to repeat the steps after step S41 in FIG. 16 in the next excavation work.

[0112] As described above, in the present modified embodiment, the soil quality estimator 505 determines whether the soil quality can be estimated based on the soil volume V in the bucket 23. In such a configuration, it is possible to increase the estimation accuracy by displaying the final soil quality only when a certain volume of soil is in the bucket 23. Note that the estimation of the soil pressure means estimation of the final soil quality to be displayed on the display unit 72. When it is determined that estimation of the soil quality is impossible, any processing up to display of the soil quality is only required to be stopped.

[0113] In the present modified embodiment, since the soil quality estimator 505 calculates the soil volume based on the shape of the soil mass and the shape of the bucket 23, the soil volume V in the bucket 23 can be easily estimated.

[0114] In another embodiment, the soil quality estimator 505 may determine whether the soil quality can be estimated based on another characteristic value related to the magnitude of the soil pressure load. As an example, the characteristic value may be the ground height H in FIG. 9. Even in such a case, the estimation accuracy can be improved by executing soil pressure estimation processing only when the obtained soil pressure load is great to some extent. These features focus on the fact that the magnitude of the soil pressure load relates to the depth of the distal end of the bucket 23 with respect to the ground surface G.

[0115] In addition, in the present modified embodiment, the soil quality estimator 505 determines the soil quality on condition that the angle ψ of the bucket 23 is included in a preset estimation angle. In such a configuration, the estimation accuracy can be improved by executing the soil quality estimation processing after setting the angle of the bucket 23 to a predetermined estimation angle.

[0116] When the flowchart illustrated in FIG. 16 is executed, the input unit 52 in FIG. 2 may receive a command for switching between a valid state and an invalid state. In this case, the valid state is a state in which estimation of the soil quality by the soil quality estimator 505 is permitted, and the invalid state is a state in which estimation of the soil quality by the soil quality estimator 505 is prohibited. The above command may be input by the operator, or may be automatically input by the controller 50 including the soil quality estimator 505 based on a predetermined condition. In such a configuration, the soil quality estimation processing can be executed only when necessary, and useless calculation processing can be prevented.

[0117] In addition, the display unit 72 (FIG. 2) (state display unit) may be capable of displaying the valid state and the invalid state. In such a configuration, it is possible to notify the worker of a state in which the current soil quality can be estimated.

[0118] Furthermore, when the valid state and the invalid state are switched by the command input to the input unit 52, the storage unit 507 (soil quality storage unit) may store information regarding the soil quality estimated previously. In such a configuration, it is possible to reliably save necessary information on the soil quality at the time of switching the state. The functions of the input unit 52, the display unit 72, and the storage unit 507 as described above are also applicable to other embodiments.

[0119] Note that, in the present modified embodiment, an aspect has been described in which the soil quality estimation processing is executed in and after step S44 after the operator adjusts the orientation of the bucket 23 in steps S41 and S42 in FIG. 16. However, an aspect in which the soil quality estimation processing is not permitted may be adopted unless the angle condition in step S42 is satisfied. As an example, the soil quality estimator 505 (state switching unit) may input a command corresponding to the valid state to the input unit 52 on condition that the angle of the bucket 23 is included in a preset estimation angle. In such a configuration, the estimation accuracy can be improved by executing the soil quality estimation processing after setting the angle of the bucket 23 to a predetermined estimation angle. In addition, in a case where it is desired to estimate the soil quality with high accuracy, it is possible to avoid a result in which the operator starts the soil quality estimation processing outside the estimation angle and the soil quality with desired accuracy cannot be obtained.

[0120] As a condition for executing the estimation of the soil quality, the soil quality estimator 505 (angle request unit) may include a function of actively requesting the operator to set an angle as illustrated on the left side in FIG. 17. In such a configuration, the soil quality estimator 505 requests adjustment of the angle of the bucket 23, and thus, the soil quality estimation processing with high accuracy can be reliably executed.

[0121] In addition, in the present modified embodiment, the soil quality estimator 505 receives a predetermined estimation start signal (pressing of an option button), acquires a plurality of soil qualities by repeatedly estimating the soil qualities at predetermined time intervals, and estimates the final soil quality based on the plurality of soil qualities. On the other hand, after the input of the estimation start signal, when the number (M) of the plurality of soil qualities is less than the preset threshold value (Mmin), the soil quality estimator 505 does not execute estimation of the final soil quality (step S47 in FIG. 16). Such a configuration can prevent an erroneous estimation result from being output when the number of data necessary for estimation has not been obtained.

[0122] In addition, in the present modified embodiment, as illustrated on the right side in FIG. 17, the display unit 72 (completion display unit) displays information regarding whether estimation of the soil quality by the soil quality estimator 505 has been completed (success lamp, failure lamp). Such a configuration enables the worker to easily confirm completion or incomplete of the soil quality estimation processing by confirming the display unit 72.

<Fourth Modified Embodiment>

[0123] FIG. 18 is a schematic diagram of calculation processing executed by a soil quality estimator in a construction machine according to a fourth modified embodiment of the present invention. In the above embodiment, as illustrated in FIG. 3, an aspect has been described in which the machine load calculator 503 calculates the load (machine load, excavation resistance value PA) mechanically received by the bucket 23 (calculation 1 in FIG. 3), the soil pressure load calculator 504 calculates the load (soil pressure load, excavation resistance value PB) acting on the bucket 23 by the soil excavated by the bucket 23 based on the soil pressure theory (calculation 2 in FIG. 3), and the soil quality estimator 505 calculates the soil quality information included in the excavation resistance value PB on the assumption that the above two loads are equal to each other (calculation 3 in FIG. 3). Then, the three search methods have been described in detail as the method of the calculation 3. In the present modified embodiment, as described above, the machine load calculator 503 calculates the load (machine load, excavation resistance value PA) mechanically received by the bucket 23 (calculation 1 of FIGS. 3 and 18).

[0124] On the other hand, when the soil pressure load calculator 504 calculates the load (soil pressure load, excavation resistance value PB) acting on the bucket 23 by the soil excavated by the bucket 23 based on the soil pressure theory, the calculation 2 is executed by using three soil quality candidates (soil quality 1, soil quality 2, and soil quality 3) prepared in advance. The calculation with reference to each soil quality candidate is referred to as calculations 2-1, 2-2, and 2-3, and obtained excavation resistance values are referred to as PB1, PB2, and PB3, respectively. As described in the calculation 2 in the above embodiment, as an example, the soil quality information includes the internal frictional angle ϕ and the cohesive force c. Therefore, values having different magnitudes of the internal frictional angle ϕ and the cohesive force c are prepared for the respective information of the soil quality 1, the soil quality 2, and the soil quality 3. Here, the soil quality estimator 505 obtains an absolute value of a deviation between PA calculated in the calculation 1 and each PB, selects a soil quality having the smallest value, in other words, outputting PB closest to PA from among the soil quality 1, the soil quality 2, and the soil quality 3, and determines the selected soil quality as a final estimated soil quality X.

[0125] Note that, as in the third modified embodiment described above, in a case where data is acquired at predetermined time intervals while the bucket 23 is performing excavation, a plurality of calculation results can be obtained for each of PB1, PB2, and PB3 in FIG. 18. In this case, the soil quality estimator 505 may select a minimum soil quality from among the soil quality 1, the soil quality 2, and the soil quality 3 from among the integration of a plurality of |PA - PB1|, the integration of a plurality of |PA - PB2|, and the integration of a plurality of |PA - PB31, and determine the minimum soil quality as the final estimated soil quality X. At this time, a temporal integration range (integration section) may be set corresponding to the time during which the bucket angle maintenance control in FIG. 16 is executed, or may be set based on a magnitude relationship between a detection result of each sensor (detector) and a threshold value set corresponding to the detection result.

[0126] As described above, in the present modified embodiment, the soil quality estimator 505 refers to a plurality of soil quality candidates (soil quality 1, soil quality 2, and soil quality 3) prepared in advance, and determines one soil quality candidate among the plurality of soil quality candidates as the soil quality at the work site based on the machine load calculated by the machine load calculator 503 and the soil pressure load calculated by the soil pressure load calculator 504. Such a configuration can reduce a calculation load by limiting the soil quality to be a solution to a plurality of soil quality candidates.

[0127] In particular, in the present modified embodiment, the soil pressure load calculator 504 calculates a plurality of the soil pressure loads by using each of the plurality of soil quality candidates, and the soil quality estimator 505 determines, from among the plurality of soil pressure loads, the soil quality candidate corresponding to the soil pressure load closest to the machine load calculated by the machine load calculator 503 as the soil quality at the work site. Such a configuration allows an optimal soil quality to be accurately determined from a plurality of soil quality candidates.

<Fifth Modified Embodiment>

[0128] FIG. 19 is a schematic diagram of calculation processing executed by a soil pressure load calculator in a construction machine according to a fifth modified embodiment of the present invention. FIG. 20 is a flowchart of a part of soil quality information acquisition processing executed in the construction machine according to the present modified embodiment. FIG. 21 is a side view when the construction machine according to the present modified embodiment executes the soil quality information acquisition processing. FIG. 22 is a schematic diagram for describing a ground height in the soil quality information acquisition processing executed in the construction machine according to the present modified embodiment.

[0129] The present modified embodiment is characterized by a method of calculating the ground height H (distance in the vertical direction between a claw of the bucket 23 and the soil surface: see FIG. 9) referred to in the calculation 2. Specifically, even when the machine body of the hydraulic excavator 1 is inclined with respect to the horizontal plane as illustrated in FIG. 21, the ground height H can be accurately calculated.

[0130] When the calculation 2 is executed, the soil pressure load calculator 504 acquires each cylinder stroke, the machine body angle, the soil surface information, and the like as in step S1 in FIG. 4 (step S51 in FIG. 20). At this time, the acquired soil surface information does not depend on the machine body angle and is based on the soil surface. FIG. 22 shows the soil surface information acquired by the soil surface information acquisition unit 64 (FIG. 1) including LIDAR by a plurality of measurement points Dg.

[0131] Next, the bucket position calculator 502 calculates a position of the claw (bucket claw position) of the bucket 23 and a position of the distal end of the arm 22 (arm distal end position: the connection portion CB1 in FIG. 22) (step S52). Furthermore, the bucket position calculator 502 draws an arc RC passing through the claw of the bucket 23 with the position of the distal end of the arm 22 as a center (calculates an equation of the arc) (step S53). Then, the bucket position calculator 502 calculates a position of an intersection Pi of the arc RC and the soil surface (the plurality of Dg) (step S54). Furthermore, the bucket position calculator 502 calculates a distance between a horizontal line passing through the claw of the bucket 23 and the intersection point Pi as the ground height H (step S55).

[0132] As described above, in the present modified embodiment, even when the machine body of the hydraulic excavator 1 is inclined with respect to the horizontal plane, the ground height H can be accurately acquired by associating a relative positional relationship between the soil surface information and the bucket 23 by the arc RC.

<Other Modified Embodiments>

[0133] In each of the above embodiments, when the soil quality estimator 505 cannot temporarily estimate and acquire the soil quality information due to some circumstances, the output characteristic of the hydraulic excavator 1 may be set by using information regarding a ground hardness measured in advance by a penetration tester or the like at the work site. In this case, it is sufficient that the information regarding the ground hardness is stored in the storage unit 507, and the output characteristic setting unit 506 refers to the information. In such a configuration, it is possible to appropriately set the output characteristics of the hydraulic excavator 1 by utilizing a ground inspection result or the like performed in advance at the work site.

[0134] Furthermore, the storage unit 507 may store a plurality of ground materials in advance, information regarding the plurality of ground materials may be displayed on the display unit 72, and when the operator selects the ground material corresponding to the current work site, the output characteristic setting unit 506 may select and set the output characteristic of the hydraulic excavator 1 associated with the selected ground material. In such a configuration, it is possible to easily set output characteristic at a site where excavation work is started without performing a ground investigation, such as a mining site of a raw material. Examples of the ground materials include sand, sandy soil, gravel, and viscous soil.

[0135] When the soil surface information acquisition unit 64 (FIG. 2) includes a camera, the output characteristic setting unit 506 may recognize a surrounding ground material on the basis of an image or the like captured by the camera, and select and set the output characteristic of the hydraulic excavator 1 associated with the ground material. In this case, the ground material and the soil quality may be estimated in accordance with the size of soil particles included in the image, a water volume estimated from a soil color, and the like, or the ground material and the soil quality may be estimated from a similarity with a comparison image stored in advance in the storage unit 507. In such a configuration, it is possible to save time and effort for the operator to select the ground material, and also prevent erroneous setting of the output characteristic due to erroneous selection. In addition, the output characteristic of the hydraulic excavator 1 can be appropriately set even at a work site where the operator is absent, with an automatic operation of the hydraulic excavator 1.

[0136] Note that, as in the above embodiments, in a case where the soil quality information is stored in the storage unit 507 of the hydraulic excavator 1 or the server side storage unit 903 of the server 90, the output characteristic of the hydraulic excavator 1 may be set by using the information, or in a case where the soil quality information is temporally old information, the soil quality estimator 505 may estimate the latest soil quality information. When work is performed at a position not included in a relationship (map information) between the position information and the soil quality information stored in each storage unit, an appropriate output characteristic can be set by acquiring the latest soil quality information (adding map information).

[0137] The server side storage unit 903 of the server 90 may store different output characteristic information depending on a model and characteristic of the hydraulic excavator 1 even with the same soil quality information. In this case, when the soil quality information acquired by the hydraulic excavator 1A in FIG. 14 is transmitted to the server 90, the server 90 can select an output characteristic suitable for the hydraulic excavator 1B and transmit the output characteristic to the hydraulic excavator 1B while corresponding to the soil quality information. Therefore, even when a plurality of hydraulic excavator 1 of different models performs work at the same work site, it is possible to set an appropriate output characteristic for each hydraulic excavator 1 while sharing the soil quality information.

[0138] Note that the hydraulic excavator 1 and the server 90 as described above constitute a construction machine management system of the present invention. Here, the construction machine management system can include the following aspects.

[0139] First, the construction machine management system includes the hydraulic excavator 1 described above and the server 90 that is disposed at a position away from the hydraulic excavator 1 and can transmit and receive the information on the soil quality to and from the hydraulic excavator 1.

[0140] In such a configuration, the information on the soil quality acquired by the hydraulic excavator 1 is managed by the server 90, and thus, the information on the soil quality can be shared with another hydraulic excavator. At this time, even in a case where another hydraulic excavator does not have the soil quality estimator 505 as in the hydraulic excavator 1, the another hydraulic excavator can perform efficient work by utilizing the information on the soil quality.

[0141] Secondly, in the construction machine management system, the hydraulic excavator 1 further includes the body position information acquisition unit 63 that acquires position information of the machine body at the work site, and the transmitter 73 (machine body side transmitter) capable of transmitting the position information and the information on the soil quality to the server 90. The server 90 includes the server side receiver 901 capable of receiving the position information and the information on the soil quality transmitted by the transmitter 73, and the server side storage unit 903 that stores the position information and the information on the soil quality in association with each other.

[0142] In such a configuration, the server 90 manages the information on the soil quality and the position information acquired by the hydraulic excavator 1 in association with each other, and thus, another hydraulic excavator can share the information on the soil quality and the position information.

[0143] Thirdly, in the construction machine management system, the drive unit 71 can receive a predetermined command signal and drive the work attachment 20 based on an output characteristic according to the command signal. The hydraulic excavator 1 further includes the body position information acquisition unit 63 that acquires position information of the machine body at the work site, the transmitter 73 capable of transmitting the position information to the server 90, and the receiver 74 (machine body side receiver) capable of receiving the information transmitted from the server 90. The server 90 includes the server side storage unit 903 that stores the position information, the information on the soil quality, and the information on the output characteristic in association with each other, the server side receiver 901 that can receive the position information transmitted by the transmitter 73, the server side output characteristic setting unit 902 that sets a predetermined output characteristic from the server side storage unit 903 in accordance with the position information received by the server side receiver 901, and the server side transmitter 904 that transmits, to the hydraulic excavator 1, the command signal corresponding to the set output characteristic.

[0144] In such a configuration, when the hydraulic excavator 1 acquires the position information and the information on the soil quality during work, the server 90 can set a suitable output characteristic in accordance with the information and transmit a command signal to the hydraulic excavator 1. Therefore, the hydraulic excavator 1 is adjusted to have an appropriate output characteristic in accordance with the information on the surrounding soil quality while performing work at the work site.

[0145] Fourthly, in the construction machine management system, the drive unit 71 can receive a predetermined command signal and drive the work attachment 20 based on an output characteristic according to the command signal. The hydraulic excavator 1 further includes the transmitter 73 capable of transmitting the information on the soil quality to the server 90, and the receiver 74 capable of receiving the information transmitted from the server 90. The server 90 includes the server side storage unit 903 that stores the information on the soil quality and the information on the output characteristic in association with each other, the server side receiver 901 that can receive the information on the soil quality transmitted by the transmitter 73, the server side output characteristic setting unit 902 that sets a predetermined output characteristic from the server side storage unit 903 in accordance with the information on the soil quality received by the server side receiver 901, and the server side transmitter 904 that transmits, to the hydraulic excavator 1, the command signal corresponding to the set output characteristic.

[0146] In such a configuration, when the hydraulic excavator 1 acquires the information on the soil quality during work, the server 90 can set a suitable output characteristic in accordance with the information and transmit a command signal to the hydraulic excavator 1. Therefore, the hydraulic excavator 1 is adjusted to have an appropriate output characteristic in accordance with the information on the surrounding soil quality while performing work at the work site.

[0147] In the description of each of the above embodiments, the structure and function described in one embodiment are also applicable to the other embodiments.

[0148] The present invention is based on the technical idea of estimating the soil quality related to the soil pressure load from the machine load actually received by the bucket during the excavation work and the soil pressure load applied to the bucket by the soil mass formed by the bucket. A construction machine is provided by the present invention based on such a technical idea. The construction machine includes a machine body including a travelling unit capable of travelling on a ground surface, a work attachment including a rising and falling body supported by the machine body so as to be rotatable in a rising and falling direction with respect to the machine body, the work attachment including a bucket rotatably supported by a distal end of the rising and falling body, a drive unit that allows driving of the work attachment such that the bucket excavates the ground surface, an orientation information acquisition unit that acquires orientation information that is information regarding an orientation of the work attachment relative to the ground surface, a drive load information acquisition unit that acquires drive load information that is information regarding a load received by the drive unit as the bucket excavates the ground surface, a machine load calculator that calculates a machine load that is a load received by the bucket from earth and sand from the orientation information acquired by the orientation information acquisition unit and the drive load information acquired by the drive load information acquisition unit as the bucket excavates the ground surface, a soil pressure load calculator that calculates a soil pressure load that is a load applied to the bucket by a soil mass, based on a soil pressure theory from a shape of the soil mass constituted by a soil dammed by the bucket, the orientation information acquired by the orientation information acquisition unit, a shape of the bucket, a density of the soil, and a wall surface frictional angle between the soil and the bucket as the bucket excavates the ground surface, and a soil quality estimator that estimates a soil quality of the soil at a work site based on the machine load calculated by the machine load calculator and the soil pressure load calculated by the soil pressure load calculator.

[0149] In this configuration, while the machine load calculator calculates the machine load received by the bucket during excavation by the bucket, and the soil pressure load calculator calculates the soil pressure load acting on the bucket by the soil mass during the excavation, and the soil quality estimator can estimate the soil quality of the soil at the work site based on the machine load and the soil pressure load. Therefore, the soil quality information of the soil can be acquired while the excavation work is being performed at the work site.

[0150] In the above configuration, the soil quality estimator may estimate an internal frictional angle of the soil and a cohesive force of the soil at the work site as the soil quality on the assumption that the machine load and the soil pressure load acting on the bucket coincide with each other.

[0151] In this configuration, the internal frictional angle as the soil quality and the cohesive force of the soil can be estimated based on the technical idea that the machine load and the soil pressure load acting on the bucket coincide with each other.

[0152] In the above configuration, the drive unit may include a rising and falling body cylinder that is hydraulic and expands and contracts so as to rotate the rising and falling body, and a bucket cylinder that is hydraulic and expands and contracts so as to rotate the bucket, the construction machine further may include a cylinder length detector that allows detection of a length of the rising and falling body cylinder and a length of the bucket cylinder, and the orientation information acquisition unit may acquire the orientation information by calculating the orientation of the work attachment based on the length of the rising and falling body cylinder and the length of the bucket cylinder detected by the cylinder length detector.

[0153] In this configuration, the orientation of the work attachment can be calculated based on the length of each cylinder, and the machine load and the soil pressure load can be calculated.

[0154] The above configuration may further include an angle detector that allows detection of each of a relative angle of the rising and falling body with respect to the machine body and a relative angle of the bucket with respect to the rising and falling body, in which the orientation information acquisition unit acquires the orientation information by calculating the orientation of the work attachment based on at least the relative angle of the rising and falling body and the relative angle of the bucket detected by the angle detector.

[0155] In this configuration, the orientation of the work attachment can be calculated based on the angle of the rising and falling body and the bucket, and the machine load and the soil pressure load can be accurately calculated.

[0156] The above configuration may further include a machine body inclination detector that allows detection of an inclination of the machine body with respect to a horizontal plane, in which the orientation information acquisition unit acquires the orientation information by calculating the orientation of the work attachment based on the relative angle of the rising and falling body and the relative angle of the bucket detected by the angle detector and the inclination of the machine body detected by the machine body inclination detector.

[0157] In this configuration, the orientation of the work attachment can be accurately calculated and acquired even when the machine body is inclined with respect to the horizontal plane.

[0158] In the above configuration, the drive unit may include a rising and falling body cylinder that is hydraulic and expands and contracts so as to rotate the rising and falling body, and a bucket cylinder that is hydraulic and expands and contracts so as to rotate the bucket, the construction machine may further include a cylinder pressure detector that allows detection of a pressure of the bucket cylinder, and the drive load information acquisition unit may acquire the drive load information by calculating the load received by the drive unit based on the pressure of the bucket cylinder detected by the cylinder pressure detector.

[0159] In this configuration, the drive load information can be easily acquired by detecting the pressure of each cylinder.

[0160] The above configuration may further include a load sensor that is disposed at a distal end of the rising and falling body and allows detection of a load acting on the bucket, in which the drive load information acquisition unit acquires the drive load information by calculating the load received by the drive unit based on the load acting on the bucket detected by the load sensor.

[0161] In this configuration, the drive load information can be easily acquired by detecting the load acting on the bucket by the load sensor disposed at the distal end of the rising and falling body.

[0162] The above configuration may further include a display unit that receives a predetermined display command signal and displays information to be notified to a worker in accordance with the display command signal, in which the soil quality estimator inputs, to the display unit, the display command signal corresponding to the soil quality having been estimated.

[0163] In this configuration, information such as a strength of the ground is transmitted to the worker through the display unit, and thus, the worker can use the information as a guide for setting the output characteristics of the construction machine.

[0164] In the above configuration, the display unit may allow displaying of a latest soil quality and a past soil quality estimated by the soil quality estimator.

[0165] In this configuration, the worker can easily know the change in the soil quality at the work site.

[0166] The above configuration may further include a position information acquisition unit that acquires position information of the machine body at the work site, in which the soil quality estimator inputs, to the display unit, the display command signal in which the soil quality having been estimated and the position information acquired by the position information acquisition unit are associated with each other.

[0167] In this configuration, by combining the position information of the machine body and the soil quality information, the worker can know a portion where the strength of the ground is low. As a result, it is possible to predict a falling risk of the machine due to insufficient ground strength.

[0168] In the above configuration, the display unit may further allow displaying of map information at the work site, and display the soil quality estimated by the soil quality estimator and the position information acquired by the position information acquisition unit on the map information in association with each other.

[0169] In this configuration, the worker can visually and easily know the strength of the ground based on the map information displayed on the display unit.

[0170] In the above configuration, the drive unit may allow reception of a predetermined command signal and driving of the work attachment based on an output characteristic according to the command signal, and the construction machine may further include an output characteristic setting unit that inputs a command signal to the drive unit so as to adjust the output characteristic in accordance with the soil quality acquired by the soil quality estimator.

[0171] In this configuration, since the output of the construction machine can be adjusted in accordance with the information on the soil quality such as the strength of the surrounding ground, the workability of the excavation work perceived by the worker can be improved, and the work efficiency can be improved. In addition, since the output characteristic of the construction machine is appropriately set in accordance with the softness and hardness of the ground, wasteful fuel consumption can be suppressed.

[0172] In the above configuration, the soil quality estimator may determine whether the soil quality can be estimated based on a characteristic value related to the magnitude of the soil pressure load.

[0173] In this configuration, the estimation accuracy can be improved by the executing soil pressure estimation processing only when the obtained soil pressure load is great to some extent.

[0174] In the above configuration, the characteristic value may be the soil volume in the bucket.

[0175] In this configuration, the estimation accuracy can be improved by executing the soil pressure estimation processing only when a certain volume of soil is in the bucket.

[0176] In the above configuration, the soil quality estimator may calculate the soil volume based on the shape of the soil mass and the shape of the bucket.

[0177] In this configuration, the soil volume can be easily estimated based on the shape of the soil mass and the shape of the bucket.

[0178] In the above configuration, the soil quality estimator may determine the soil quality on condition that an angle of the bucket is included in an estimation angle set in advance.

[0179] In this configuration, the estimation accuracy can be improved by executing the soil quality estimation processing after setting the angle of the bucket to a predetermined estimation angle.

[0180] In the above configuration, the soil quality estimator may refer to a plurality of soil quality candidates prepared in advance, and determine one of the plurality of soil quality candidates as the soil quality at the work site based on the machine load calculated by the machine load calculator and the soil pressure load calculated by the soil pressure load calculator.

[0181] This configuration can reduce a calculation load by limiting the soil quality to be a solution to a plurality of soil quality candidates.

[0182] In the above configuration, the soil pressure load calculator may calculate a plurality of the soil pressure loads by using each of the plurality of soil quality candidates, and the soil quality estimator may determine, as the soil quality at the work site, the soil quality candidate corresponding to the soil pressure load closest to the machine load calculated by the machine load calculator from among the plurality of soil pressure loads.

[0183] This configuration allows an optimal soil quality to be accurately determined from a plurality of soil quality candidates.

[0184] The above configuration may further include an input unit that receives a command for switching between a valid state and an invalid state, in which the valid state is a state in which the estimation of the soil quality by the soil quality estimator is permitted, and the invalid state is a state in which the estimation of the soil quality by the soil quality estimator is prohibited.

[0185] In this configuration, the soil quality estimation processing can be executed only when necessary, and useless calculation processing can be prevented.

[0186] The above configuration may further include a soil quality storage unit that stores information regarding the soil quality estimated previously when the valid state and the invalid state are switched by the command input to the input unit.

[0187] In this configuration, it is possible to reliably save necessary information on the soil quality.

[0188] The above configuration may further include a state display unit that allows displaying of the valid state and the invalid state.

[0189] In this configuration, it is possible to notify the worker of a state in which the current soil quality can be estimated.

[0190] The above configuration may further include a state switching unit that inputs a command corresponding to the valid state to the input unit on condition that the angle of the bucket is included in a preset estimation angle.

[0191] In this configuration, the estimation accuracy can be improved by executing the soil quality estimation processing after setting the angle of the bucket to a predetermined estimation angle.

[0192] The above configuration may further include an angle request unit that requests that the angle of the bucket is included in the estimation angle as a condition for the soil quality estimator to execute the estimation of the soil quality.

[0193] In this configuration, the angle request unit requests adjustment of the angle of the bucket, and thus, the soil quality estimation processing with high accuracy can be reliably executed.

[0194] The above configuration may further include a bucket angle display unit that allows displaying of the estimation angle and a current angle of the bucket.

[0195] In this configuration, the worker can easily adjust the angle of the bucket while viewing the bucket angle display unit.

[0196] In the above configuration, the soil quality estimator may receive a predetermined estimation start signal, acquire a plurality of soil qualities by repeatedly estimating the soil qualities at predetermined time intervals, and estimate a final soil quality based on the plurality of soil qualities, and the soil quality estimator does not necessarily estimate the final soil quality when a number of the plurality of soil qualities is less than a preset threshold value after the estimation start signal is input.

[0197] This configuration can prevent an erroneous estimation result from being output when the number of data necessary for estimation has not been obtained.

[0198] The above configuration may further include a completion display unit that displays information regarding whether the estimation of the soil quality by the soil quality estimator has been completed.

[0199] This configuration enables the worker to easily confirm completion or incomplete of the soil quality estimation processing by confirming the completion display unit.

[0200] The present invention provides a construction machine management system. The construction machine management system includes the construction machine according to any of the above descriptions, and a management device that is disposed at a position away from the construction machine and allows transmission and reception of information on the soil quality to and from the construction machine.

[0201] In this configuration, the information on the soil quality acquired by the construction machine is managed by the management device, and thus, the information on the soil quality can be shared with another construction machine. At this time, even in a case where another construction machine does not have the soil quality estimator, the another construction machine can perform efficient work by utilizing the information on the soil quality.

[0202] In the above configuration, the construction machine may further include a position information acquisition unit that acquires position information of the machine body at a work site, and a machine body side transmitter that allows transmission of the position information and the information on the soil quality to the management device, and the management device may include a management device side receiver that allows reception of the position information and the information on the soil quality transmitted by the machine body side transmitter, and a management device side storage unit that stores the position information and the information on the soil quality in association with each other.

[0203] In this configuration, the management device manages the information on the soil quality and the position information acquired by the construction machine in association with each other, and thus, another construction machine can share the information on the soil quality and the position information.

[0204] In the above configuration, the drive unit may allow reception of a predetermined command signal and driving of the work attachment based on an output characteristic according to the command signal, the construction machine may further include a position information acquisition unit that acquires position information of the machine body at a work site, a machine body side transmitter that allows transmission of the position information to the management device, and a machine body side receiver that allows reception of information transmitted from the management device, and the management device may include a management device side storage unit that stores the position information, the information on the soil quality, and information on the output characteristic in association with each other, a management device side receiver that allows reception of the position information transmitted by the machine body side transmitter, a management device side output characteristic setting unit that sets a predetermined output characteristic from the management device side storage unit in accordance with the position information received by the management device side receiver, and a management device side transmitter that transmits, to the construction machine, the command signal corresponding to the output characteristic having been set.

[0205] In this configuration, when the construction machine acquires the position information and the information on the soil quality during work, the management device can set a suitable output characteristic in accordance with the information and transmit a command signal to the construction machine. Therefore, the construction machine is adjusted to have an appropriate output characteristic in accordance with the information on the surrounding soil quality while performing work at the work site.

[0206] In the above configuration, the drive unit may allow reception of a predetermined command signal and driving of the work attachment based on an output characteristic according to the command signal, the construction machine may further include a machine body side transmitter that allows transmission of the information on the soil quality to the management device, and a machine body side receiver that allows reception of information transmitted from the management device, and the management device may include a management device side storage unit that stores the information on the soil quality and information on the output characteristic in association with each other, a management device side receiver that allows reception of the information on the soil quality transmitted by the machine body side transmitter, a management device side output characteristic setting unit that sets a predetermined output characteristic from the management device side storage unit in accordance with the information on the soil quality received by the management device side receiver, and a management device side transmitter that transmits, to the construction machine, the command signal corresponding to the output characteristic having been set.

[0207] In this configuration, when the construction machine acquires the information on the soil quality during work, the management device can set a suitable output characteristic in accordance with the information and transmit a command signal to the construction machine. Therefore, the construction machine is adjusted to have an appropriate output characteristic in accordance with the information on the surrounding soil quality while performing work at the work site.

[0208] The present invention provides a construction machine and a construction machine management system capable of acquiring soil quality information of a ground while performing excavation work at a work site.

Claims

1. A construction machine comprising:

a machine body including a travelling unit capable of travelling on a ground surface;
a work attachment including a rising and falling body supported by the machine body so as to be rotatable in a rising and falling direction with respect to the machine body, the work attachment including a bucket rotatably supported by a distal end of the rising and falling body;
a drive unit that allows driving of the work attachment such that the bucket excavates the ground surface;
an orientation information acquisition unit that acquires orientation information that is information regarding an orientation of the work attachment relative to the ground surface;
a drive load information acquisition unit that acquires drive load information that is information regarding a load received by the drive unit as the bucket excavates the ground surface;

a machine load calculator that calculates a machine load that is a load received by the bucket from earth and sand from the orientation information acquired by the orientation information acquisition unit and the drive load information acquired by the drive load information acquisition unit as the bucket excavates the ground surface;
a soil pressure load calculator that calculates a soil pressure load that is a load applied to the bucket by a soil mass, based on a soil pressure theory from a shape of the soil mass constituted by a soil dammed by the bucket, the orientation information acquired by the orientation information acquisition unit, a shape of the bucket, a density of the soil, and a wall surface frictional angle between the soil and the bucket as the bucket excavates the ground surface; and
a soil quality estimator that estimates a soil quality of the soil at a work site based on the machine load calculated by the machine load calculator and the soil pressure load calculated by the soil pressure load calculator.

2. The construction machine according to claim 1, wherein the soil quality estimator estimates an internal frictional angle of the soil and a cohesive force of the soil at the work site as the soil quality on an assumption that the machine load and the soil pressure load acting on the bucket coincide with each other.

3. The construction machine according to claim 1 or 2, wherein

the drive unit includes
a rising and falling body cylinder that is hydraulic and expands and contracts so as to rotate the rising and falling body, and
a bucket cylinder that is hydraulic and expands and contracts so as to rotate the bucket,
the construction machine further includes a cylinder length detector that allows detection of a length of the rising and falling body cylinder and a length of the bucket cylinder, and
the orientation information acquisition unit acquires the orientation information by calculating the orientation of the work attachment based on the length of the rising and falling body cylinder and the length of the bucket cylinder detected by the cylinder length detector.

4. The construction machine according to claim 1 or 2, further comprising

an angle detector that allows detection of each of a relative angle of the rising and falling body with respect to the machine body and a relative angle of the bucket with respect to the rising and falling body,
wherein the orientation information acquisition unit acquires the orientation information by calculating the orientation of the work attachment based on at least the relative angle of the rising and falling body and the relative angle of the bucket detected by the angle detector.

5. The construction machine according to claim 4, further comprising

a machine body inclination detector that allows detection of an inclination of the machine body with respect to a horizontal plane,
wherein the orientation information acquisition unit acquires the orientation information by calculating the orientation of the work attachment based on the relative angle of the rising and falling body and the relative angle of the bucket detected by the angle detector and the inclination of the machine body detected by the machine body inclination detector.

6. The construction machine according to any one of claims 1 to 5, wherein

the drive unit includes
a rising and falling body cylinder that is hydraulic and expands and contracts so as to rotate the rising and falling body, and
a bucket cylinder that is hydraulic and expands and contracts so as to rotate the bucket,
the construction machine further includes a cylinder pressure detector that allows detection of a pressure of the bucket cylinder, and
the drive load information acquisition unit acquires the drive load information by calculating the load received by the drive unit based on the pressure of the bucket cylinder detected by the cylinder pressure detector.

7. The construction machine according to any one of claims 1 to 5, further comprising

a load sensor that is disposed at a distal end of the rising and falling body and allows detection of a load acting

on the bucket,
wherein the drive load information acquisition unit acquires the drive load information by calculating the load received by the drive unit based on the load acting on the bucket detected by the load sensor.

8. The construction machine according to any one of claims 1 to 7, further comprising

a display unit that receives a predetermined display command signal and displays information to be notified to a worker in accordance with the display command signal,
wherein the soil quality estimator inputs, to the display unit, the display command signal corresponding to the soil quality having been estimated.

9. The construction machine according to claim 8, wherein the display unit allows displaying of a latest soil quality and a past soil quality estimated by the soil quality estimator.

10. The construction machine according to claim 8 or 9, further comprising

a position information acquisition unit that acquires position information of the machine body at the work site,
wherein the soil quality estimator inputs, to the display unit, the display command signal in which the soil quality having been estimated and the position information acquired by the position information acquisition unit are associated with each other.

11. The construction machine according to claim 10, wherein
the display unit further allows displaying of map information at the work site, and displays the soil quality estimated by the soil quality estimator and the position information acquired by the position information acquisition unit on the map information in association with each other.

12. The construction machine according to any one of claims 1 to 11, wherein

the drive unit allows reception of a predetermined command signal and driving of the work attachment based on an output characteristic according to the command signal, and
the construction machine further includes an output characteristic setting unit that inputs a command signal to the drive unit so as to adjust the output characteristic in accordance with the soil quality acquired by the soil quality estimator.

13. The construction machine according to any one of claims 1 to 12, wherein the soil quality estimator determines whether estimation of the soil quality is allowed based on a characteristic value related to a magnitude of the soil pressure load.

14. The construction machine according to claim 13, wherein the characteristic value is a soil volume in the bucket.

15. The construction machine according to claim 14, wherein the soil quality estimator calculates the soil volume based on the shape of the soil mass and the shape of the bucket.

16. The construction machine according to any one of claims 1 to 15, wherein the soil quality estimator determines the soil quality on condition that an angle of the bucket is included in an estimation angle set in advance.

17. The construction machine according to any one of claims 1 to 16, wherein the soil quality estimator refers to a plurality of soil quality candidates prepared in advance, and determines one of the plurality of soil quality candidates as the soil quality at the work site based on the machine load calculated by the machine load calculator and the soil pressure load calculated by the soil pressure load calculator.

18. The construction machine according to claim 17, wherein

the soil pressure load calculator calculates a plurality of the soil pressure loads by using each of the plurality of soil quality candidates, and
the soil quality estimator determines, as the soil quality at the work site, the soil quality candidate corresponding to the soil pressure load closest to the machine load calculated by the machine load calculator from among the plurality of soil pressure loads.

19. The construction machine according to any one of claims 1 to 18, further comprising

an input unit that receives a command for switching between a valid state and an invalid state,
wherein the valid state is a state in which the estimation of the soil quality by the soil quality estimator is permitted, and
the invalid state is a state in which the estimation of the soil quality by the soil quality estimator is prohibited.

20. The construction machine according to claim 19, wherein a soil quality storage unit that stores information regarding the soil quality estimated previously when the valid state and the invalid state are switched by the command input to the input unit.

21. The construction machine according to claim 19 or 20, further comprising a state display unit that allows displaying of the valid state and the invalid state.

22. The construction machine according to any one of claims 19 to 21, further comprising a state switching unit that inputs a command corresponding to the valid state to the input unit on condition that an angle of the bucket is included in an estimation angle set in advance.

23. The construction machine according to claim 22, further comprising an angle request unit that requests that the angle of the bucket is included in the estimation angle as a condition for the soil quality estimator to execute the estimation of the soil quality.

24. The construction machine according to claim 22 or 23, further comprising a bucket angle display unit that allows displaying of the estimation angle and a current angle of the bucket.

25. The construction machine according to any one of claims 1 to 24, wherein

the soil quality estimator receives a predetermined estimation start signal, acquires a plurality of soil qualities by repeatedly estimating the soil qualities at predetermined time intervals, and estimates a final soil quality based on the plurality of soil qualities, and
the soil quality estimator does not estimate the final soil quality when a number of the plurality of soil qualities is less than a preset threshold value after the estimation start signal is input.

26. The construction machine according to any one of claims 1 to 25, further comprising a completion display unit that displays information regarding whether the estimation of the soil quality by the soil quality estimator has been completed.

27. A construction machine management system comprising:

the construction machine according to any one of claims 1 to 26; and
a management device that is disposed at a position away from the construction machine and allows transmission and reception of information on the soil quality to and from the construction machine.

28. The construction machine management system according to claim 27, wherein

the construction machine further includes
a position information acquisition unit that acquires position information of the machine body at a work site, and
a machine body side transmitter that allows transmission of the position information and the information on the soil quality to the management device, and
the management device includes
a management device side receiver that allows reception of the position information and the information on the soil quality transmitted by the machine body side transmitter, and
a management device side storage unit that stores the position information and the information on the soil quality in association with each other.

29. The construction machine management system according to claim 27, wherein

the drive unit allows reception of a predetermined command signal and driving of the work attachment based

on an output characteristic according to the command signal,
the construction machine further includes
a position information acquisition unit that acquires position information of the machine body at a work site,
a machine body side transmitter that allows transmission of the position information to the management device, and
a machine body side receiver that allows reception of information transmitted from the management device, and
the management device includes
a management device side storage unit that stores the position information, the information on the soil quality, and information on the output characteristic in association with each other,
a management device side receiver that allows reception of the position information transmitted by the machine body side transmitter,
a management device side output characteristic setting unit that sets a predetermined output characteristic from the management device side storage unit in accordance with the position information received by the management device side receiver, and
a management device side transmitter that transmits, to the construction machine, the command signal corresponding to the output characteristic having been set.

30. The construction machine management system according to claim 27, wherein

the drive unit allows reception of a predetermined command signal and driving of the work attachment based on an output characteristic according to the command signal,
the construction machine further includes
a machine body side transmitter that allows transmission of the information on the soil quality to the management device, and
a machine body side receiver that allows reception of information transmitted from the management device, and
the management device includes
a management device side storage unit that stores the information on the soil quality and information on the output characteristic in association with each other,
a management device side receiver that allows reception of the information on the soil quality transmitted by the machine body side transmitter,
a management device side output characteristic setting unit that sets a predetermined output characteristic from the management device side storage unit in accordance with the information on the soil quality received by the management device side receiver, and
a management device side transmitter that transmits, to the construction machine, the command signal corresponding to the output characteristic having been set.

FIG.1

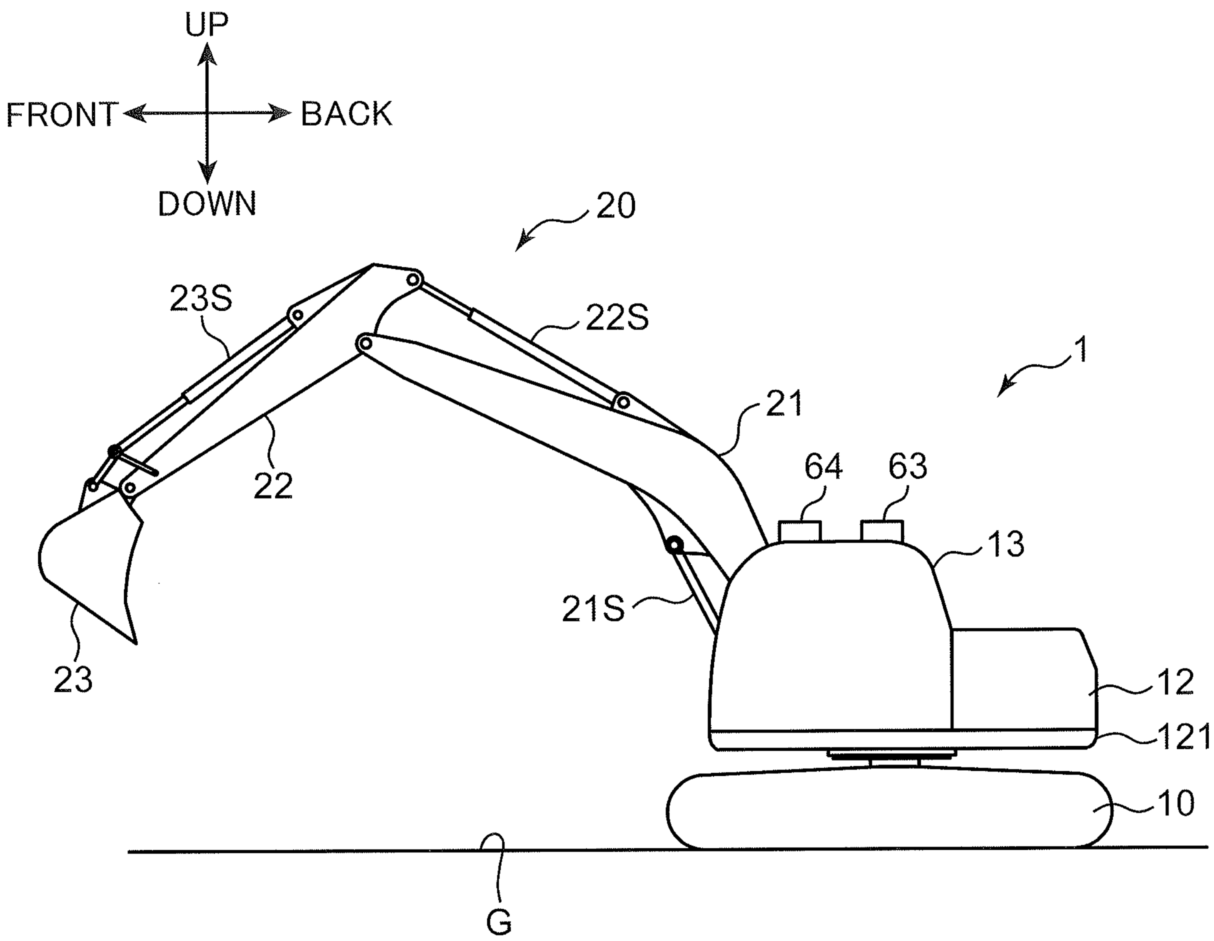


FIG.2

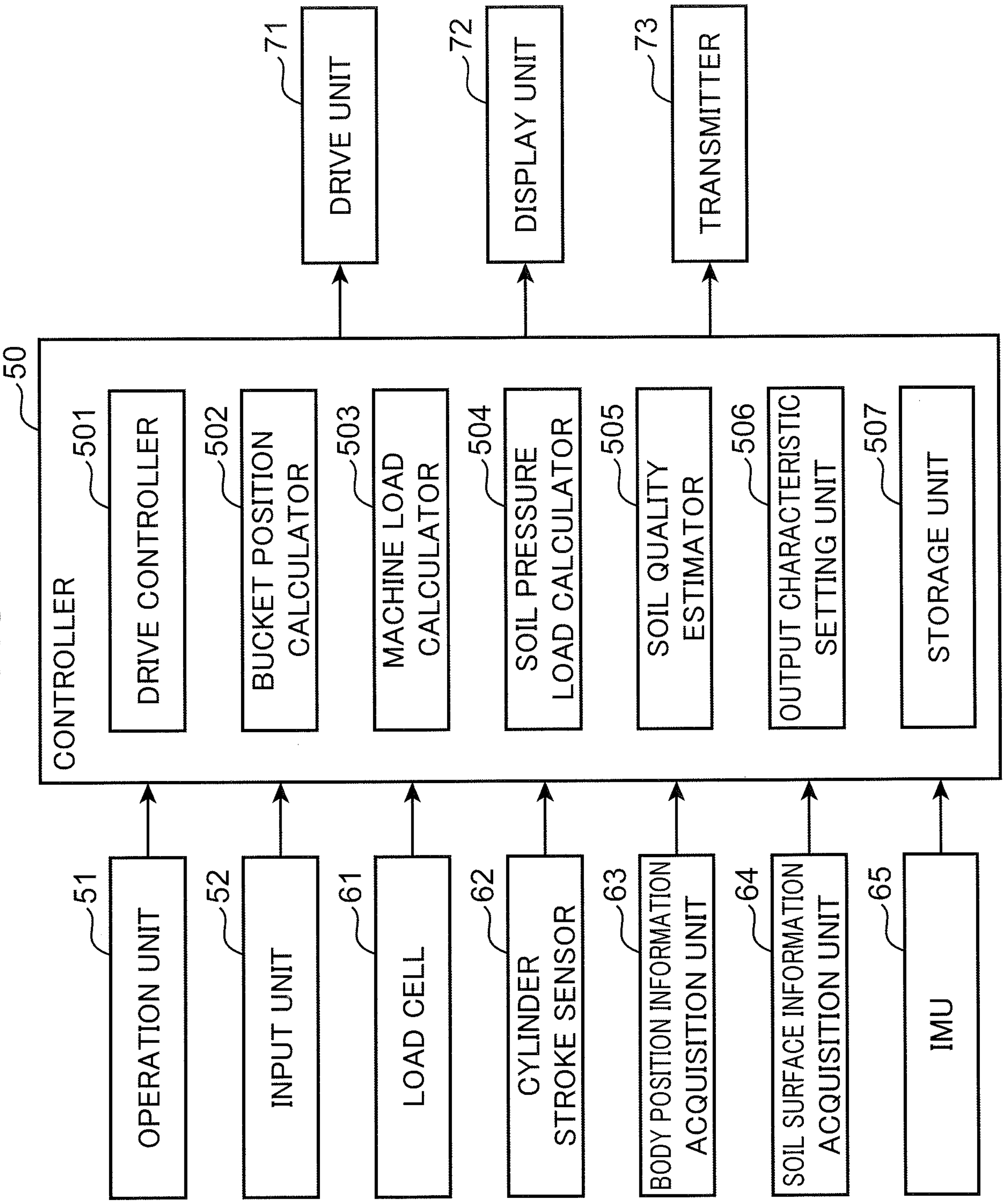

CONTROLLER
50
DRIVE CONTROLLER
501
BUCKET POSITION CALCULATOR
502
MACHINE LOAD CALCULATOR
503
SOIL PRESSURE LOAD CALCULATOR
504
SOIL QUALITY ESTIMATOR
505
OUTPUT CHARACTERISTIC SETTING UNIT
506
STORAGE UNIT
507
DRIVE UNIT
71
DISPLAY UNIT
72
TRANSMITTER
73
OPERATION UNIT
51
INPUT UNIT
52
LOAD CELL
61
CYLINDER STROKE SENSOR
62
BODY POSITION INFORMATION ACQUISITION UNIT
63
SOIL SURFACE INFORMATION ACQUISITION UNIT
64
IMU
65

FIG.3

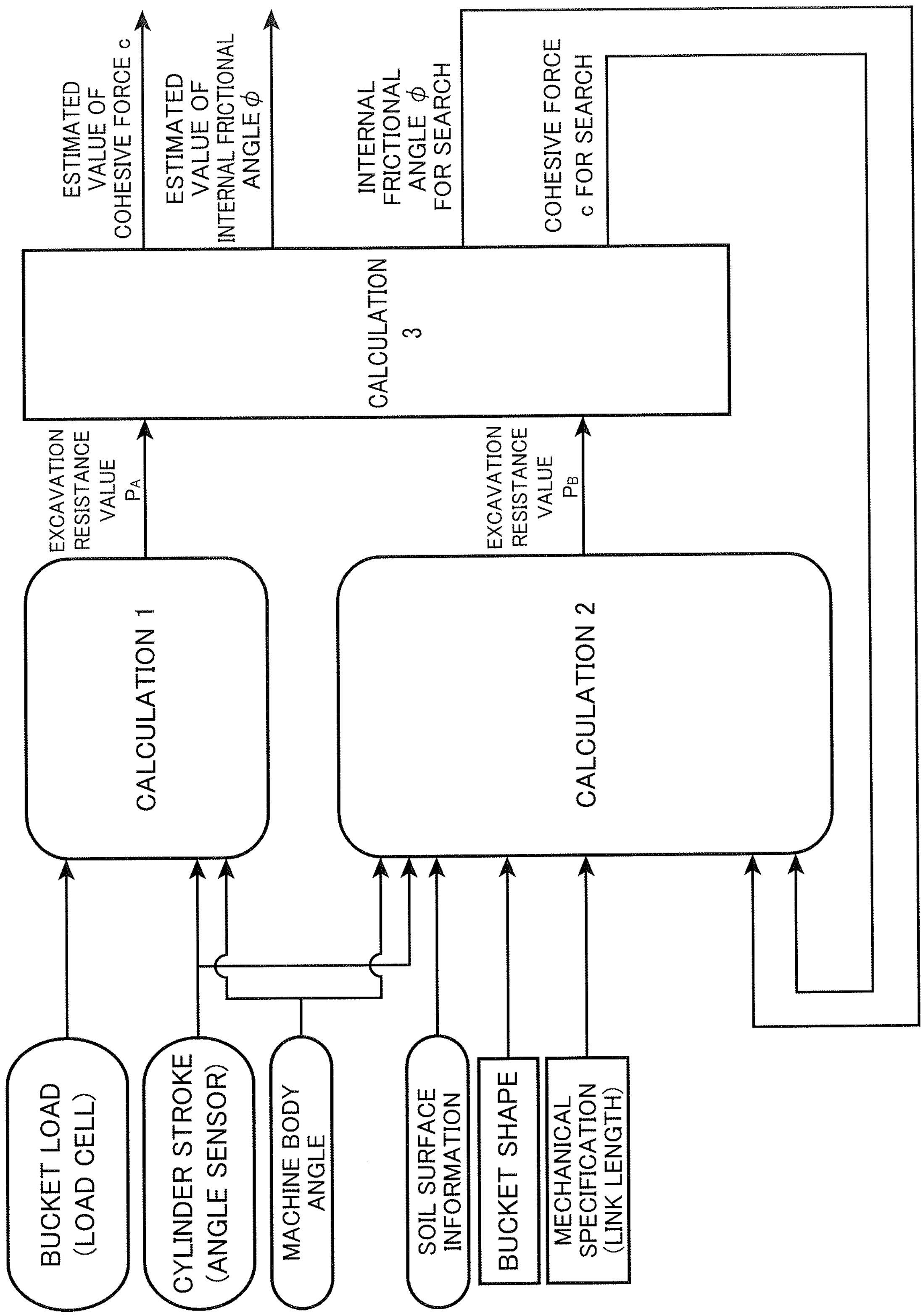

BUCKET LOAD (LOAD CELL)
CYLINDER STROKE (ANGLE SENSOR)
MACHINE BODY ANGLE
SOIL SURFACE INFORMATION
BUCKET SHAPE
MECHANICAL SPECIFICATION (LINK LENGTH)
CALCULATION 1
CALCULATION 2
EXCAVATION RESISTANCE VALUE P_A
EXCAVATION RESISTANCE VALUE P_B
CALCULATION 3
ESTIMATED VALUE OF COHESIVE FORCE c
ESTIMATED VALUE OF INTERNAL FRICTIONAL ANGLE φ
INTERNAL FRICTIONAL ANGLE φ FOR SEARCH
COHESIVE FORCE c FOR SEARCH

FIG.4

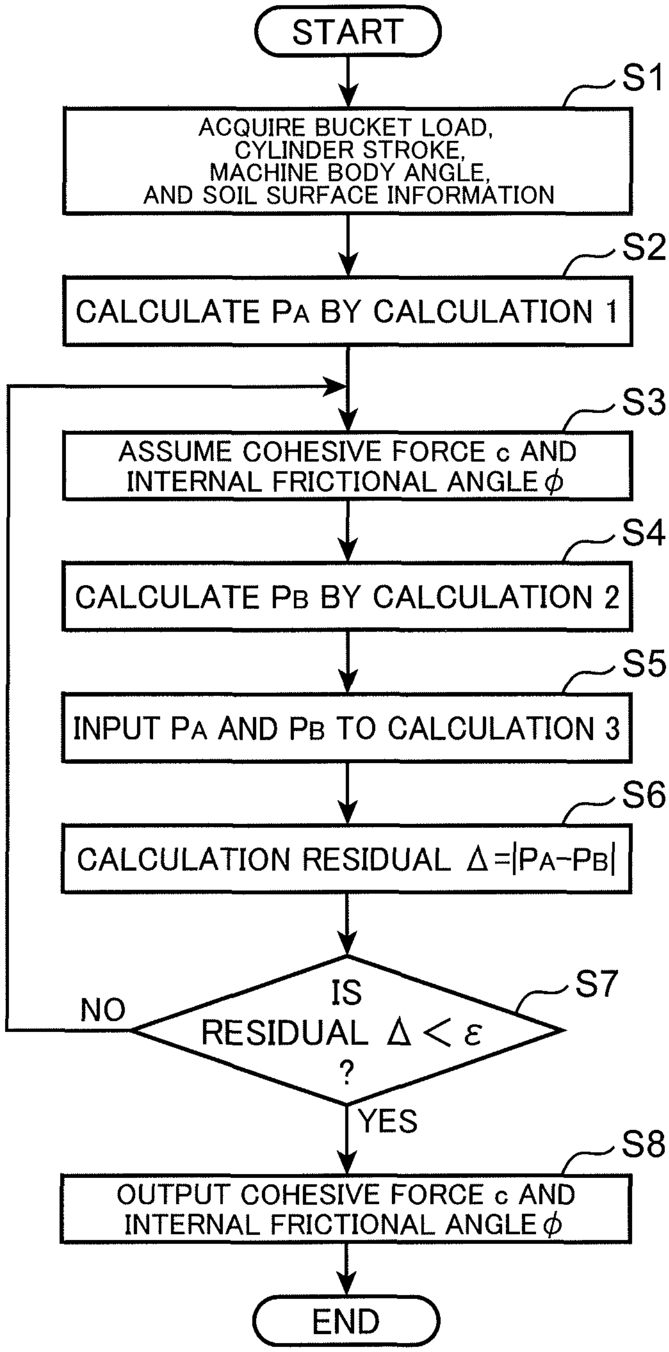

START
S1
ACQUIRE BUCKET LOAD, CYLINDER STROKE, MACHINE BODY ANGLE, AND SOIL SURFACE INFORMATION
S2
CALCULATE PA BY CALCULATION 1
S3
ASSUME COHESIVE FORCE c AND INTERNAL FRICTIONAL ANGLE ϕ
S4
CALCULATE PB BY CALCULATION 2
S5
INPUT PA AND PB TO CALCULATION 3
S6
CALCULATION RESIDUAL Δ=|PA−PB|
S7
IS RESIDUAL Δ < ε ?
NO
YES
S8
OUTPUT COHESIVE FORCE c AND INTERNAL FRICTIONAL ANGLE ϕ
END

FIG.5

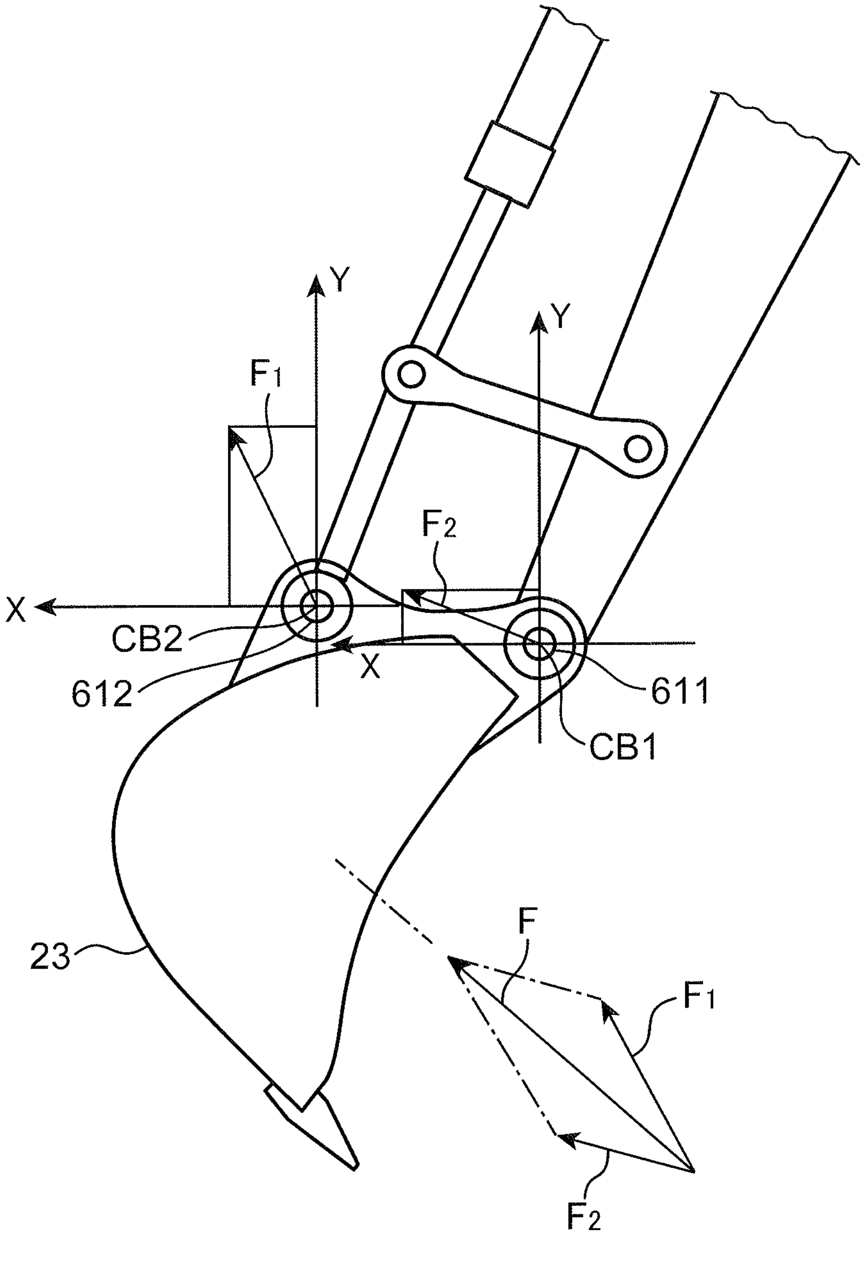


FIG.6

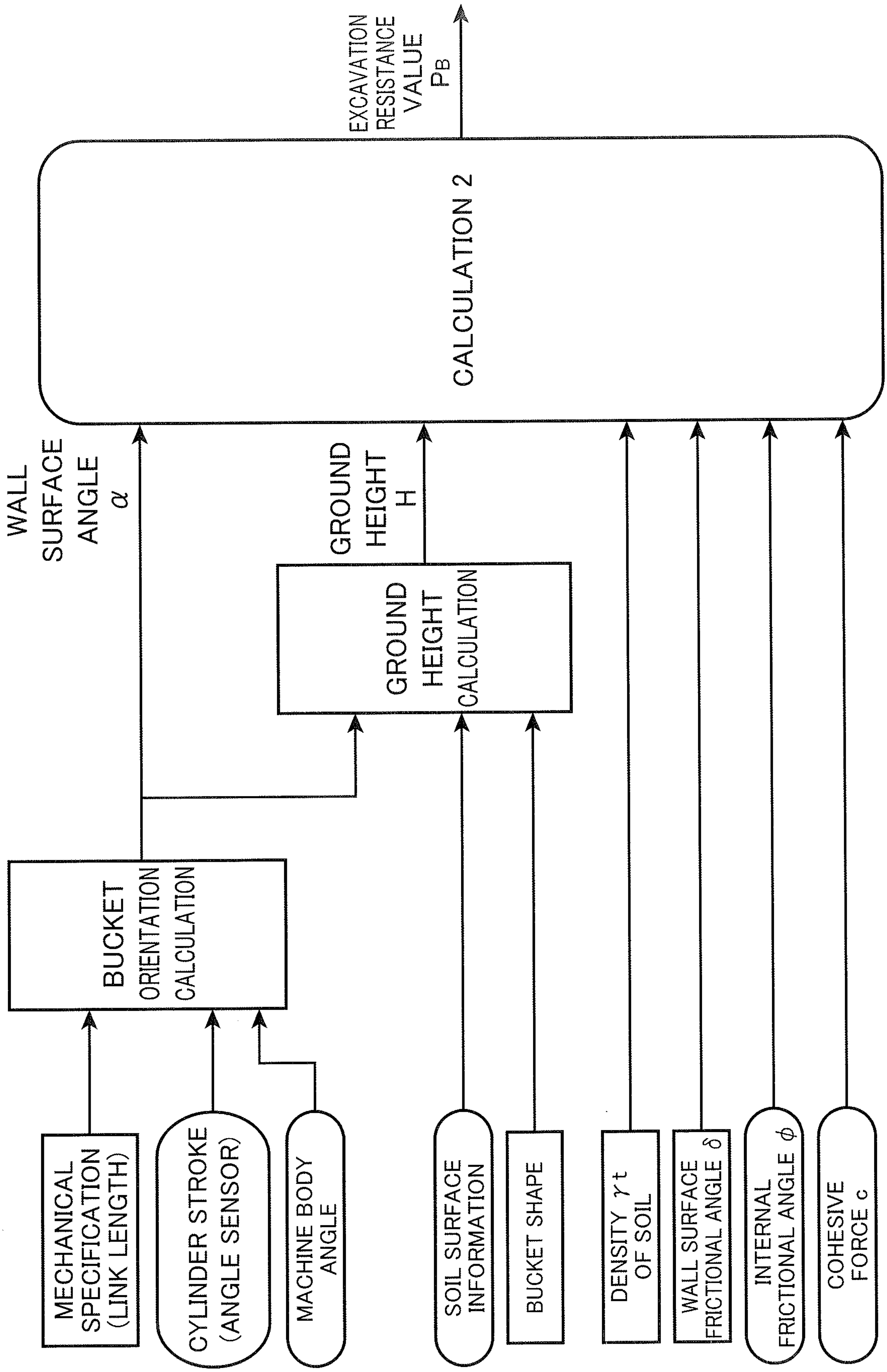

EXCAVATION RESISTANCE VALUE P_B
CALCULATION 2
WALL SURFACE ANGLE α
GROUND HEIGHT H
GROUND HEIGHT CALCULATION
BUCKET ORIENTATION CALCULATION
MECHANICAL SPECIFICATION (LINK LENGTH)
CYLINDER STROKE (ANGLE SENSOR)
MACHINE BODY ANGLE
SOIL SURFACE INFORMATION
BUCKET SHAPE
DENSITY γt OF SOIL
WALL SURFACE FRICTIONAL ANGLE δ
INTERNAL FRICTIONAL ANGLE ϕ
COHESIVE FORCE c

FIG.7

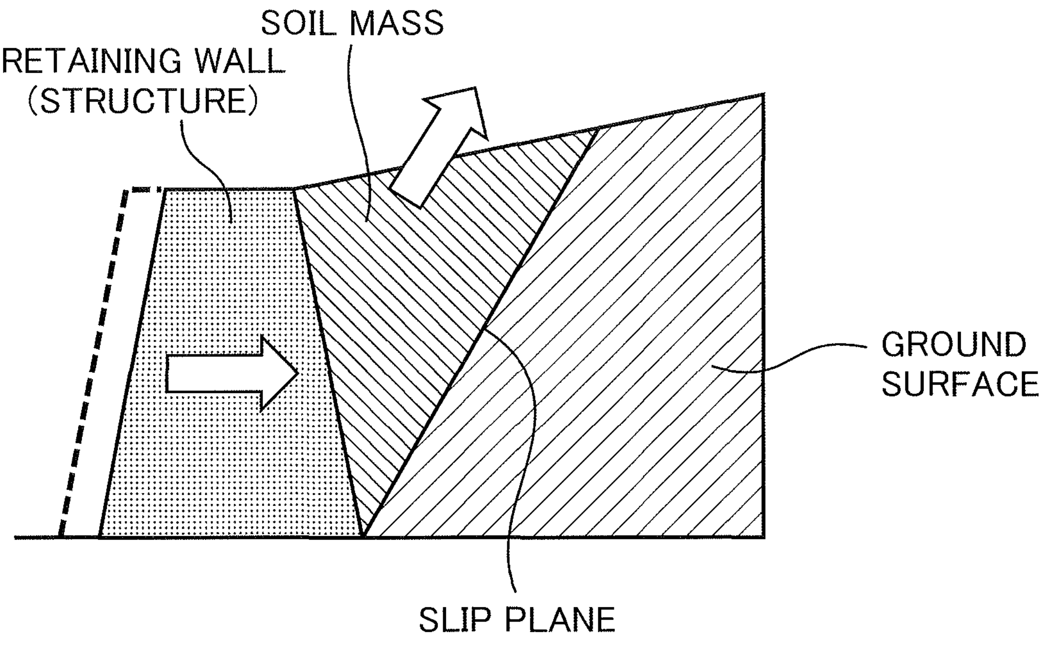

SOIL MASS
RETAINING WALL
(STRUCTURE)
GROUND
SURFACE
SLIP PLANE

FIG.8

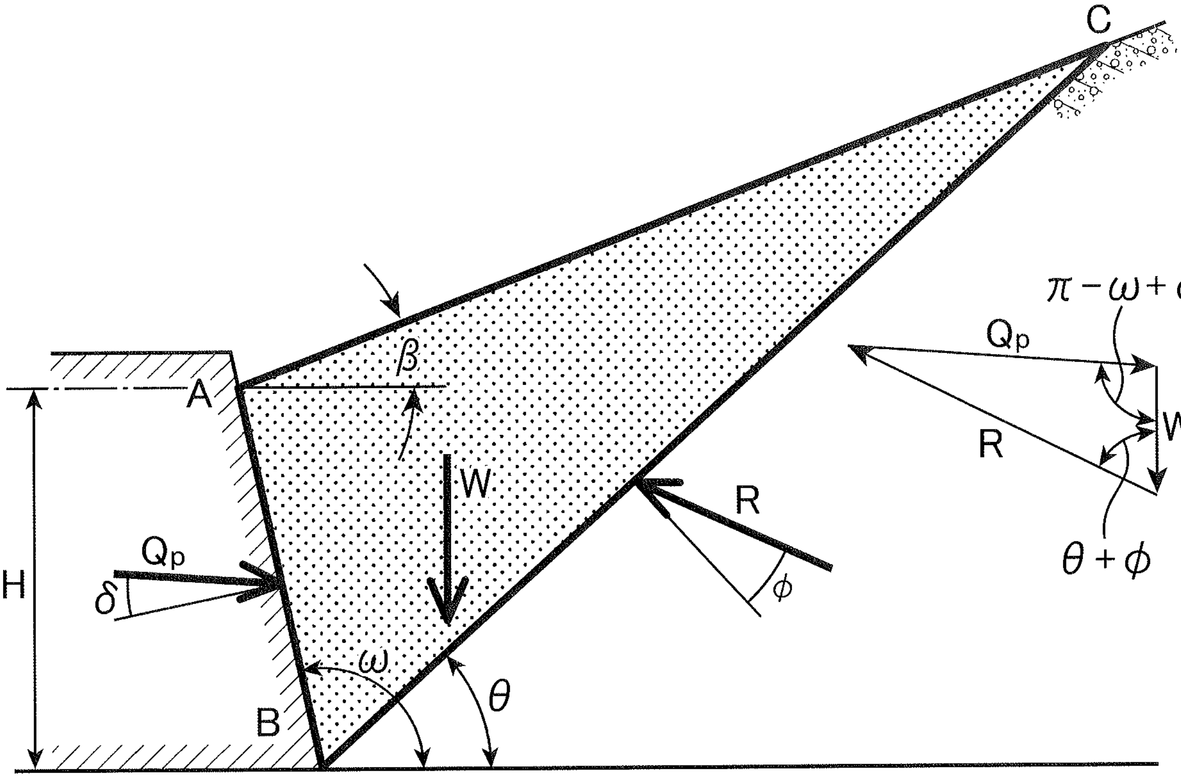


FIG.9

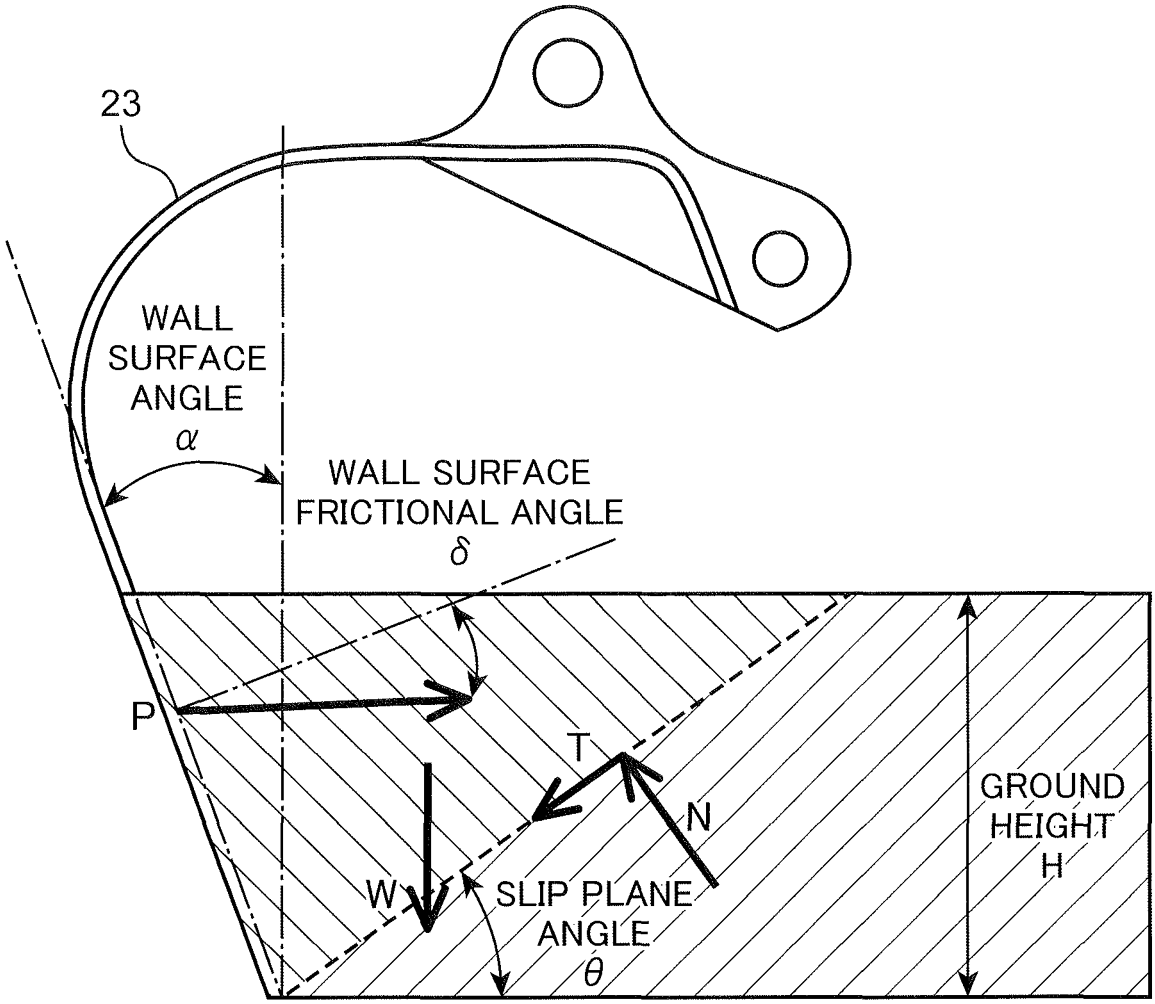

23
WALL
SURFACE
ANGLE
α
WALL SURFACE
FRICTIONAL ANGLE
δ
P
T
N
W
SLIP PLANE
ANGLE
θ
GROUND
HEIGHT
H

FIG.10

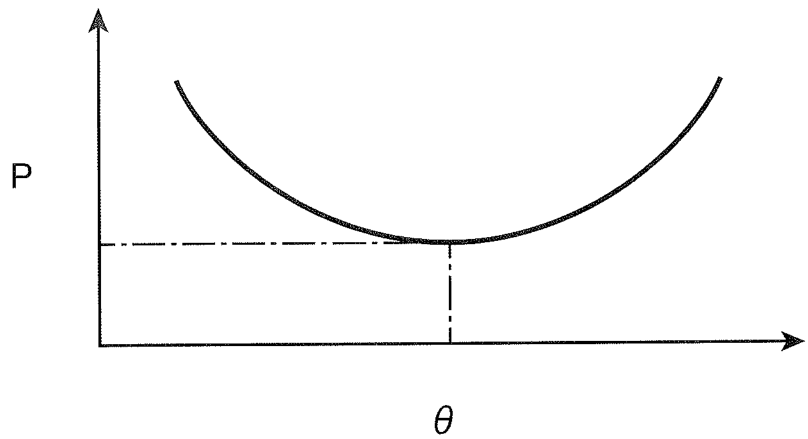


FIG.11

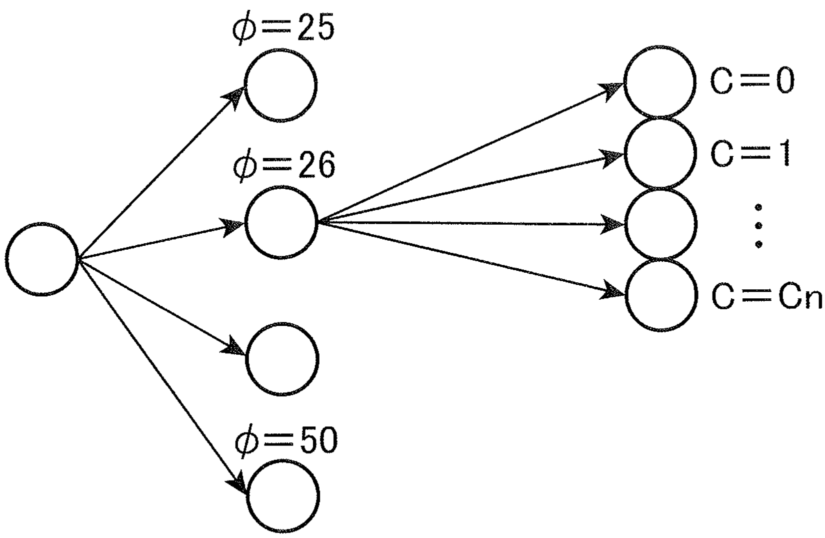


FIG.12

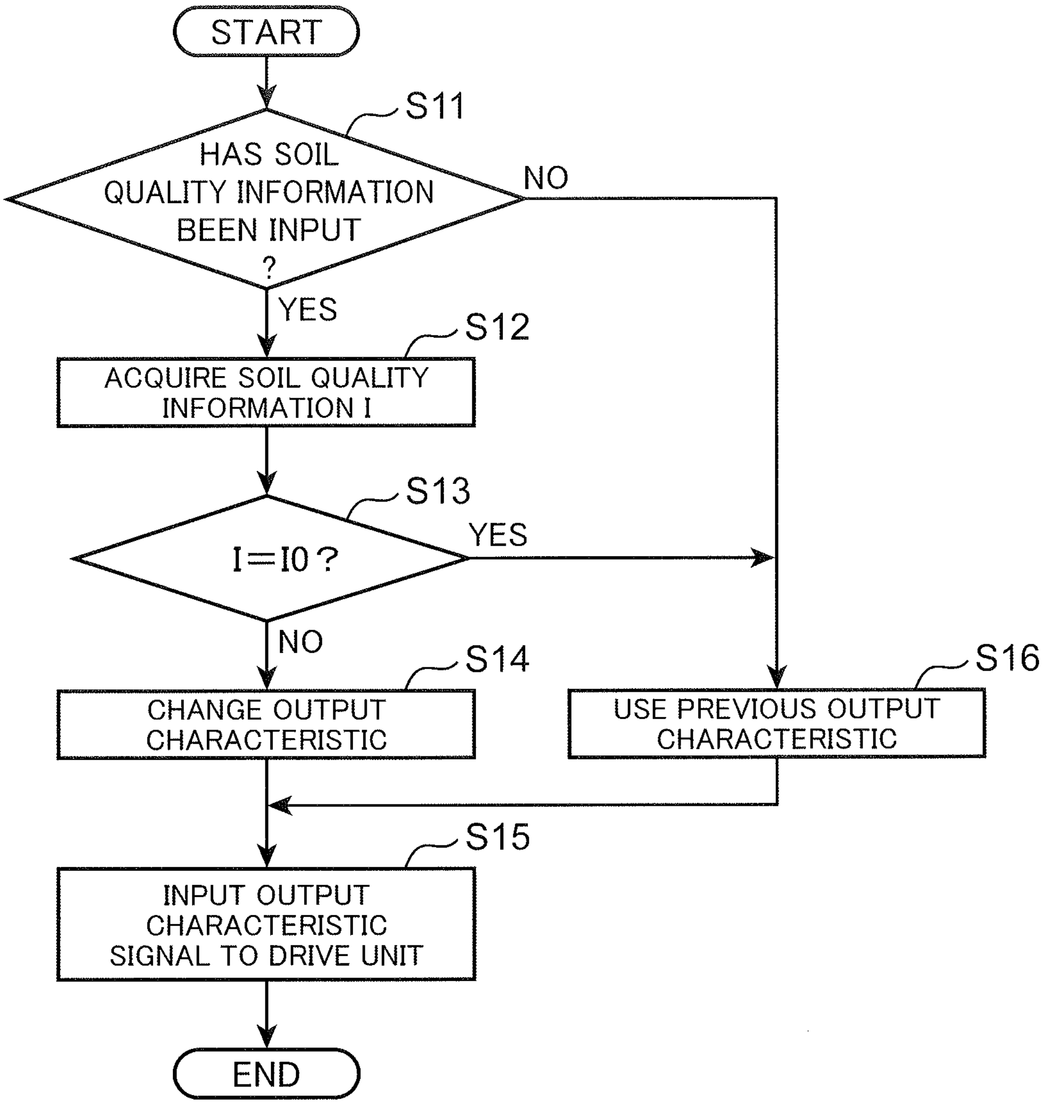

START
S11
HAS SOIL QUALITY INFORMATION BEEN INPUT ?
NO
YES
S12
ACQUIRE SOIL QUALITY INFORMATION I
S13
YES
I=I0 ?
NO
S14
CHANGE OUTPUT CHARACTERISTIC
S16
USE PREVIOUS OUTPUT CHARACTERISTIC
S15
INPUT OUTPUT CHARACTERISTIC SIGNAL TO DRIVE UNIT
END

FIG.13

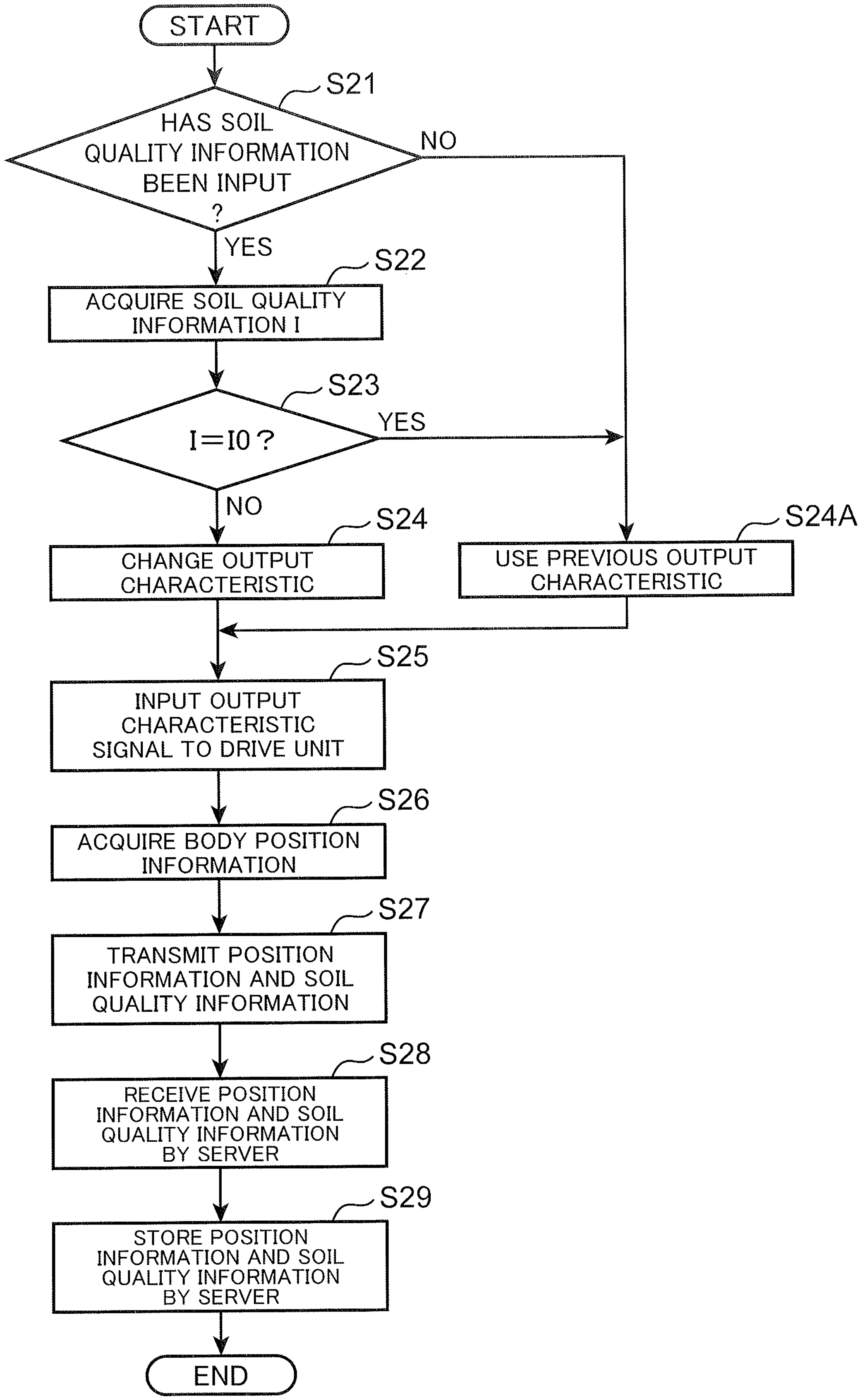

START
S21
HAS SOIL QUALITY INFORMATION BEEN INPUT ?
NO
YES
S22
ACQUIRE SOIL QUALITY INFORMATION I
S23
I=I0 ?
YES
NO
S24
CHANGE OUTPUT CHARACTERISTIC
S24A
USE PREVIOUS OUTPUT CHARACTERISTIC
S25
INPUT OUTPUT CHARACTERISTIC SIGNAL TO DRIVE UNIT
S26
ACQUIRE BODY POSITION INFORMATION
S27
TRANSMIT POSITION INFORMATION AND SOIL QUALITY INFORMATION
S28
RECEIVE POSITION INFORMATION AND SOIL QUALITY INFORMATION BY SERVER
S29
STORE POSITION INFORMATION AND SOIL QUALITY INFORMATION BY SERVER
END

FIG.14

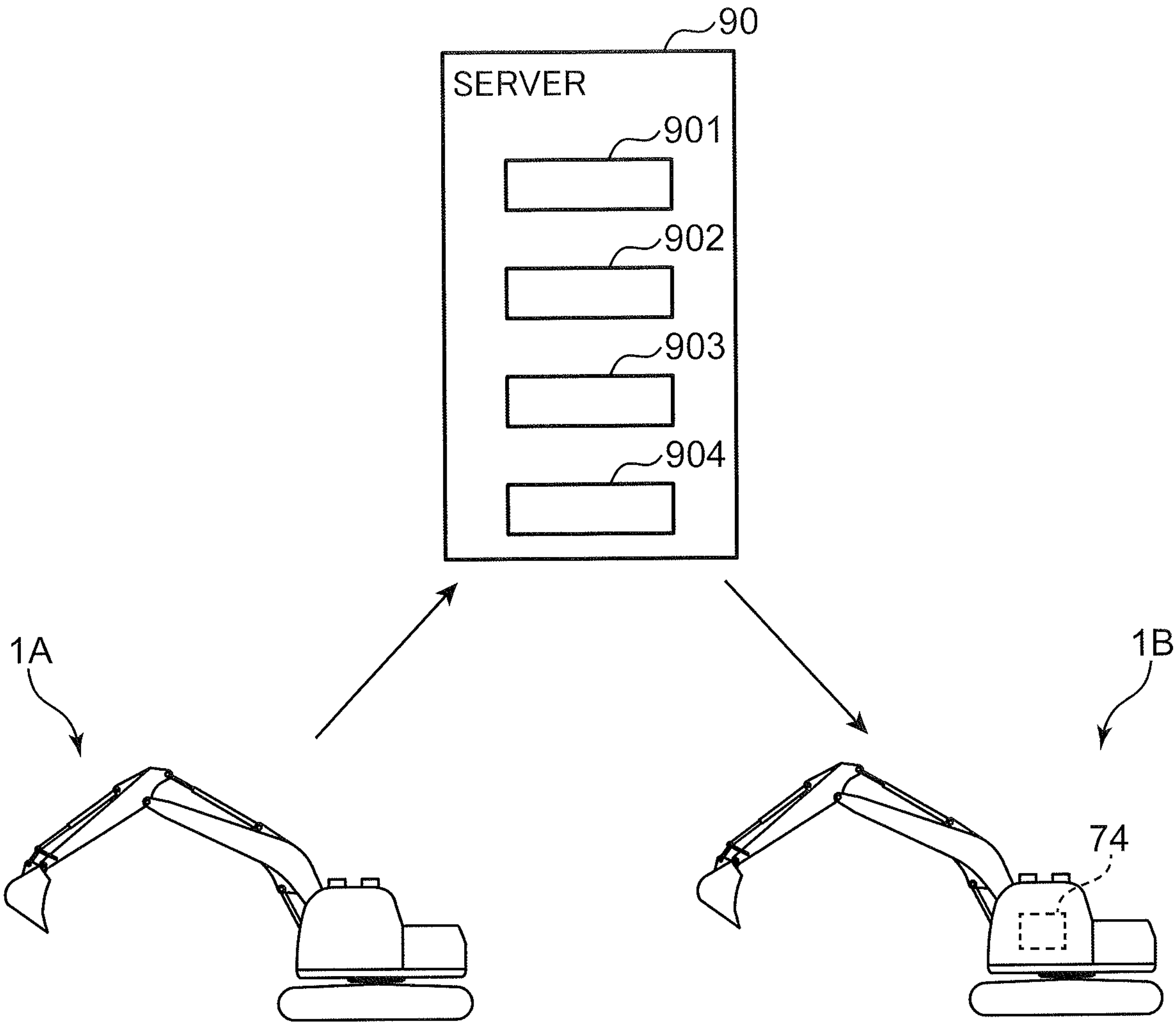


FIG.15

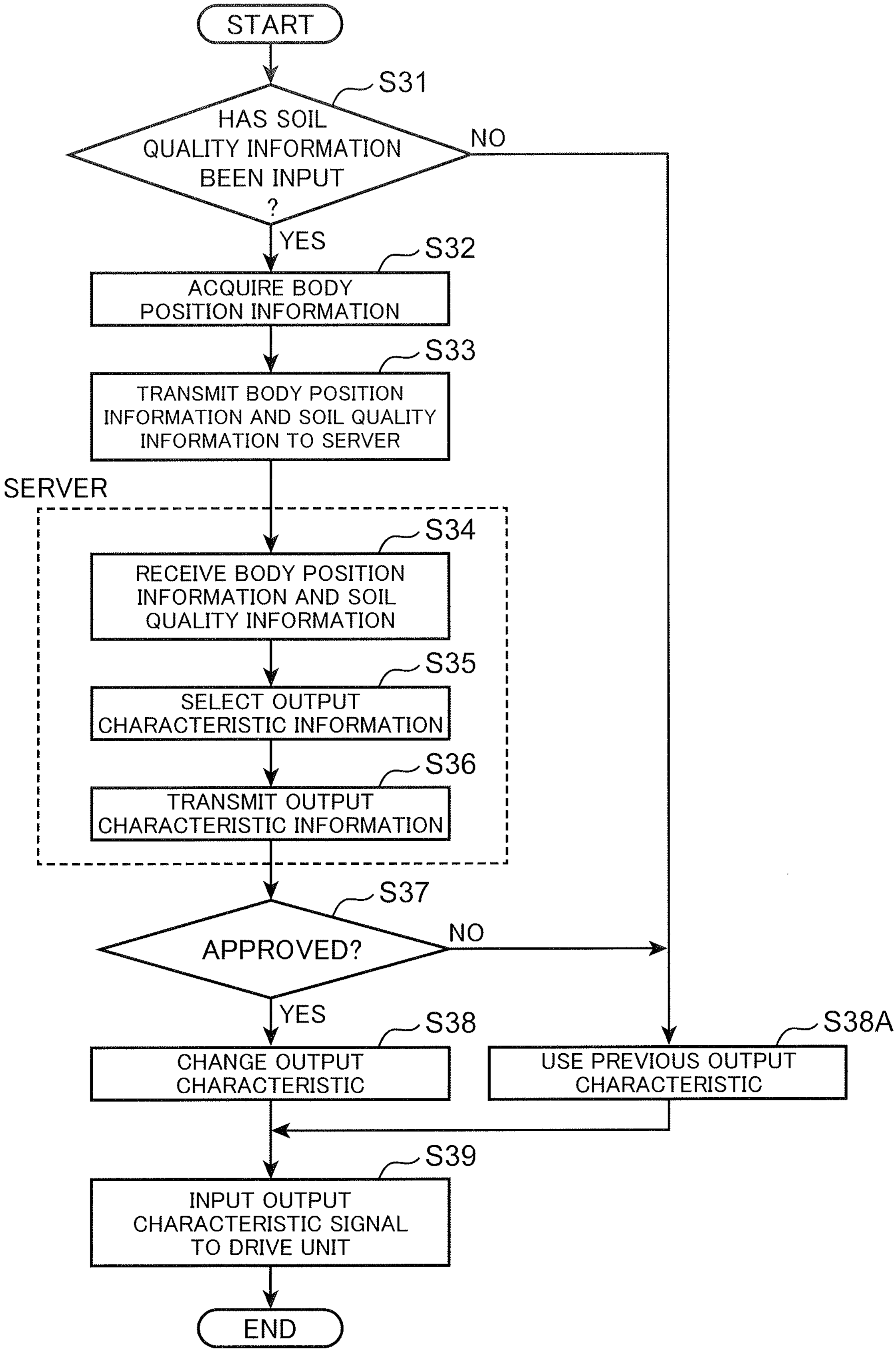

START
S31
HAS SOIL QUALITY INFORMATION BEEN INPUT ?
NO
YES
S32
ACQUIRE BODY POSITION INFORMATION
S33
TRANSMIT BODY POSITION INFORMATION AND SOIL QUALITY INFORMATION TO SERVER
SERVER
S34
RECEIVE BODY POSITION INFORMATION AND SOIL QUALITY INFORMATION
S35
SELECT OUTPUT CHARACTERISTIC INFORMATION
S36
TRANSMIT OUTPUT CHARACTERISTIC INFORMATION
S37
APPROVED?
NO
YES
S38
CHANGE OUTPUT CHARACTERISTIC
S38A
USE PREVIOUS OUTPUT CHARACTERISTIC
S39
INPUT OUTPUT CHARACTERISTIC SIGNAL TO DRIVE UNIT
END

FIG.16

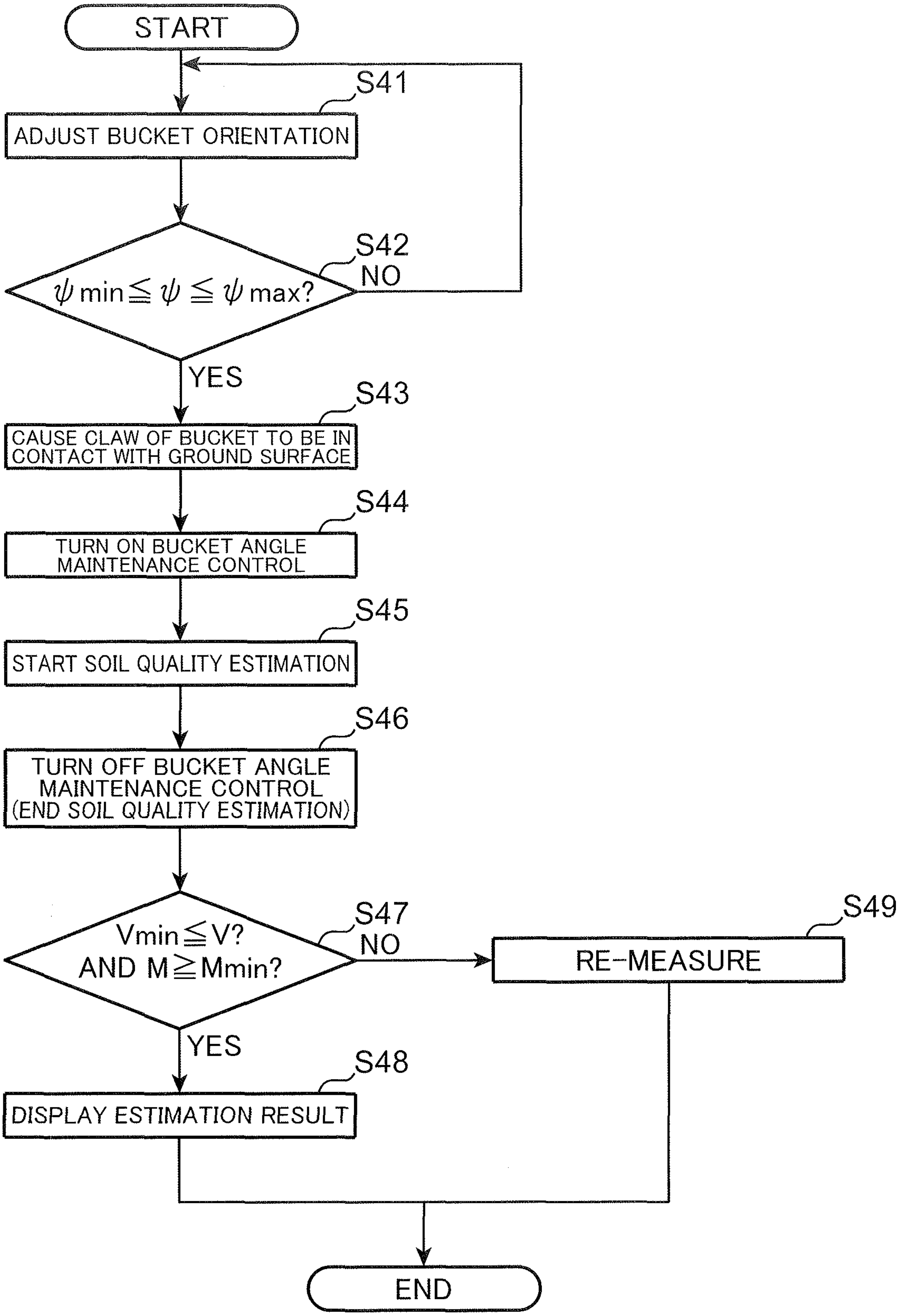

START
S41
ADJUST BUCKET ORIENTATION
S42
NO
ψ min≦ψ≦ψ max?
YES
S43
CAUSE CLAW OF BUCKET TO BE IN CONTACT WITH GROUND SURFACE
S44
TURN ON BUCKET ANGLE MAINTENANCE CONTROL
S45
START SOIL QUALITY ESTIMATION
S46
TURN OFF BUCKET ANGLE MAINTENANCE CONTROL (END SOIL QUALITY ESTIMATION)
S47
NO
Vmin≦V? AND M≧Mmin?
S49
RE-MEASURE
YES
S48
DISPLAY ESTIMATION RESULT
END

FIG.17

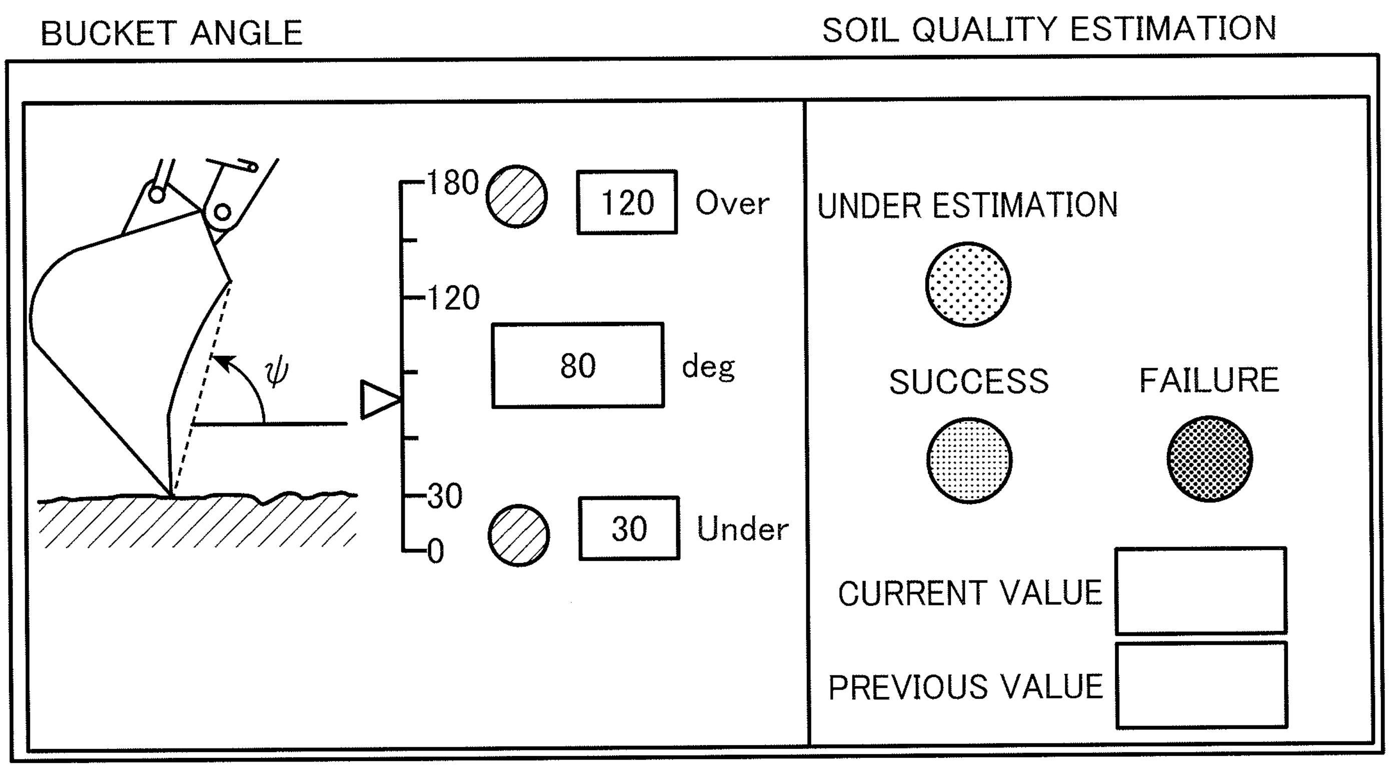

BUCKET ANGLE
ψ
180
120
30
0
120
Over
80
deg
30
Under
SOIL QUALITY ESTIMATION
UNDER ESTIMATION
SUCCESS
FAILURE
CURRENT VALUE
PREVIOUS VALUE

FIG.18

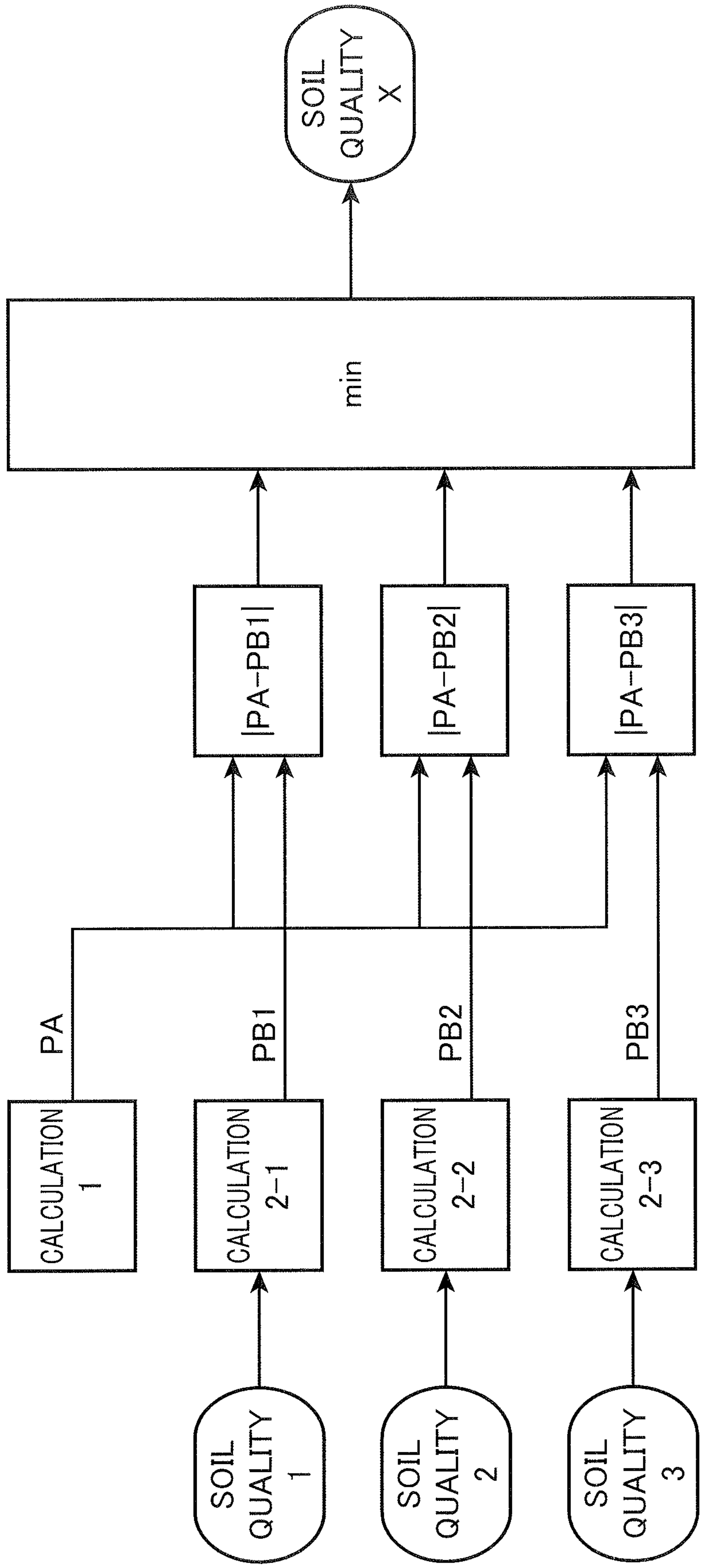

SOIL QUALITY 1
SOIL QUALITY 2
SOIL QUALITY 3
CALCULATION 1
CALCULATION 2−1
CALCULATION 2−2
CALCULATION 2−3
PA
PB1
PB2
PB3
|PA−PB1|
|PA−PB2|
|PA−PB3|
min
SOIL QUALITY X

FIG.19

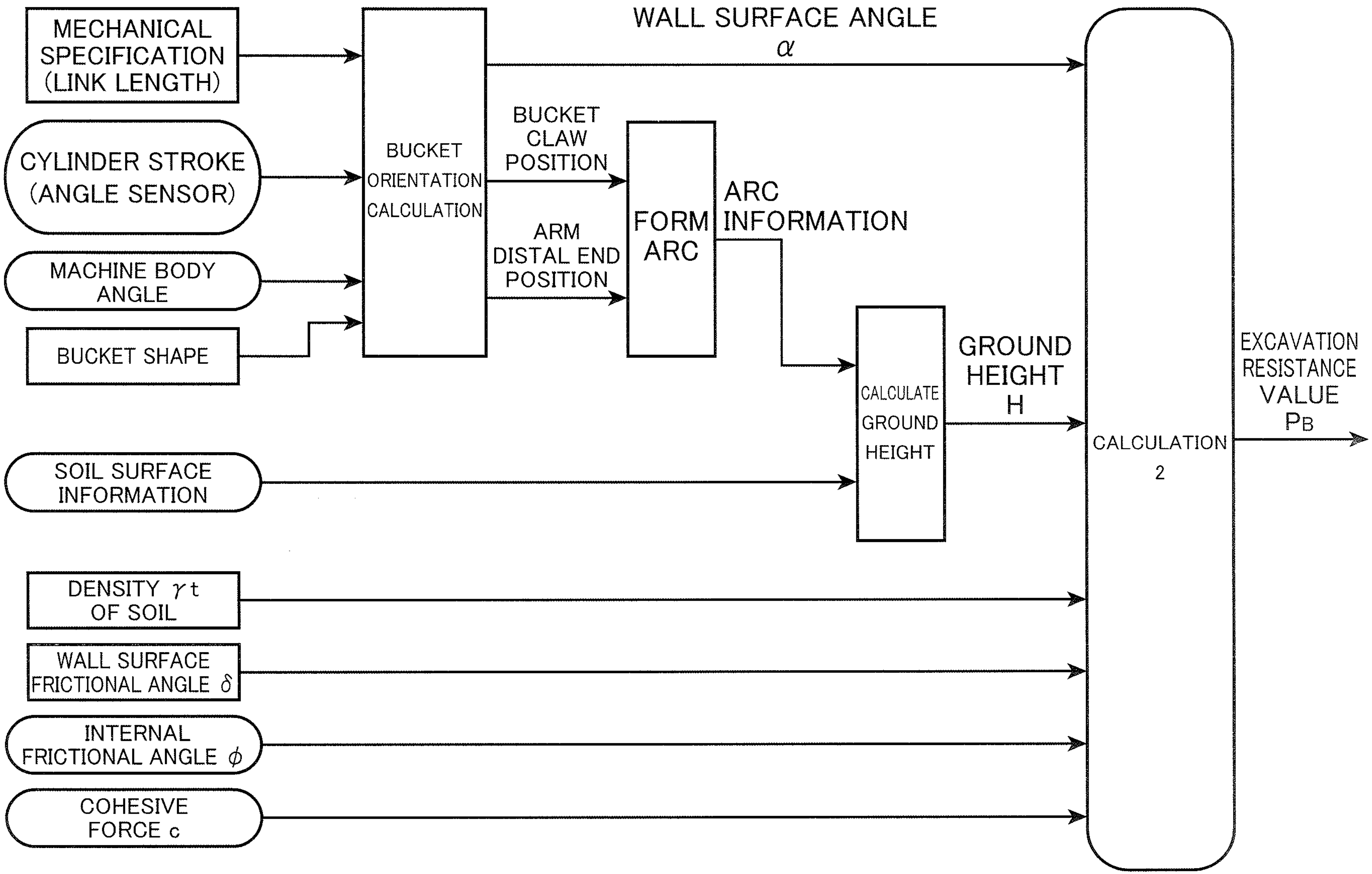

MECHANICAL SPECIFICATION (LINK LENGTH)
CYLINDER STROKE (ANGLE SENSOR)
MACHINE BODY ANGLE
BUCKET SHAPE
SOIL SURFACE INFORMATION
DENSITY γt OF SOIL
WALL SURFACE FRICTIONAL ANGLE δ
INTERNAL FRICTIONAL ANGLE ϕ
COHESIVE FORCE c
BUCKET ORIENTATION CALCULATION
WALL SURFACE ANGLE α
BUCKET CLAW POSITION
ARM DISTAL END POSITION
FORM ARC
ARC INFORMATION
CALCULATE GROUND HEIGHT
GROUND HEIGHT H
CALCULATION 2
EXCAVATION RESISTANCE VALUE PB

FIG.20

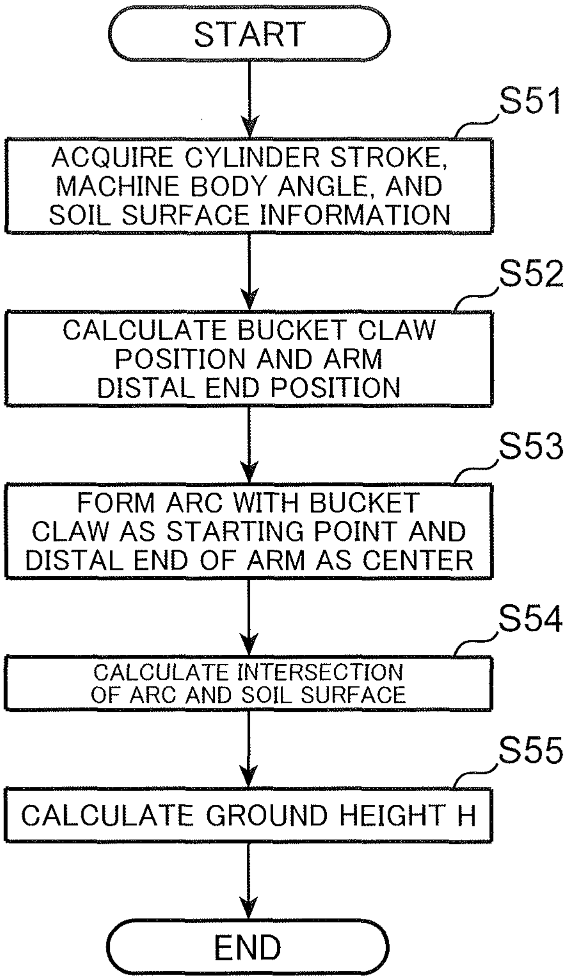

START
S51
ACQUIRE CYLINDER STROKE, MACHINE BODY ANGLE, AND SOIL SURFACE INFORMATION
S52
CALCULATE BUCKET CLAW POSITION AND ARM DISTAL END POSITION
S53
FORM ARC WITH BUCKET CLAW AS STARTING POINT AND DISTAL END OF ARM AS CENTER
S54
CALCULATE INTERSECTION OF ARC AND SOIL SURFACE
S55
CALCULATE GROUND HEIGHT H
END

FIG.21

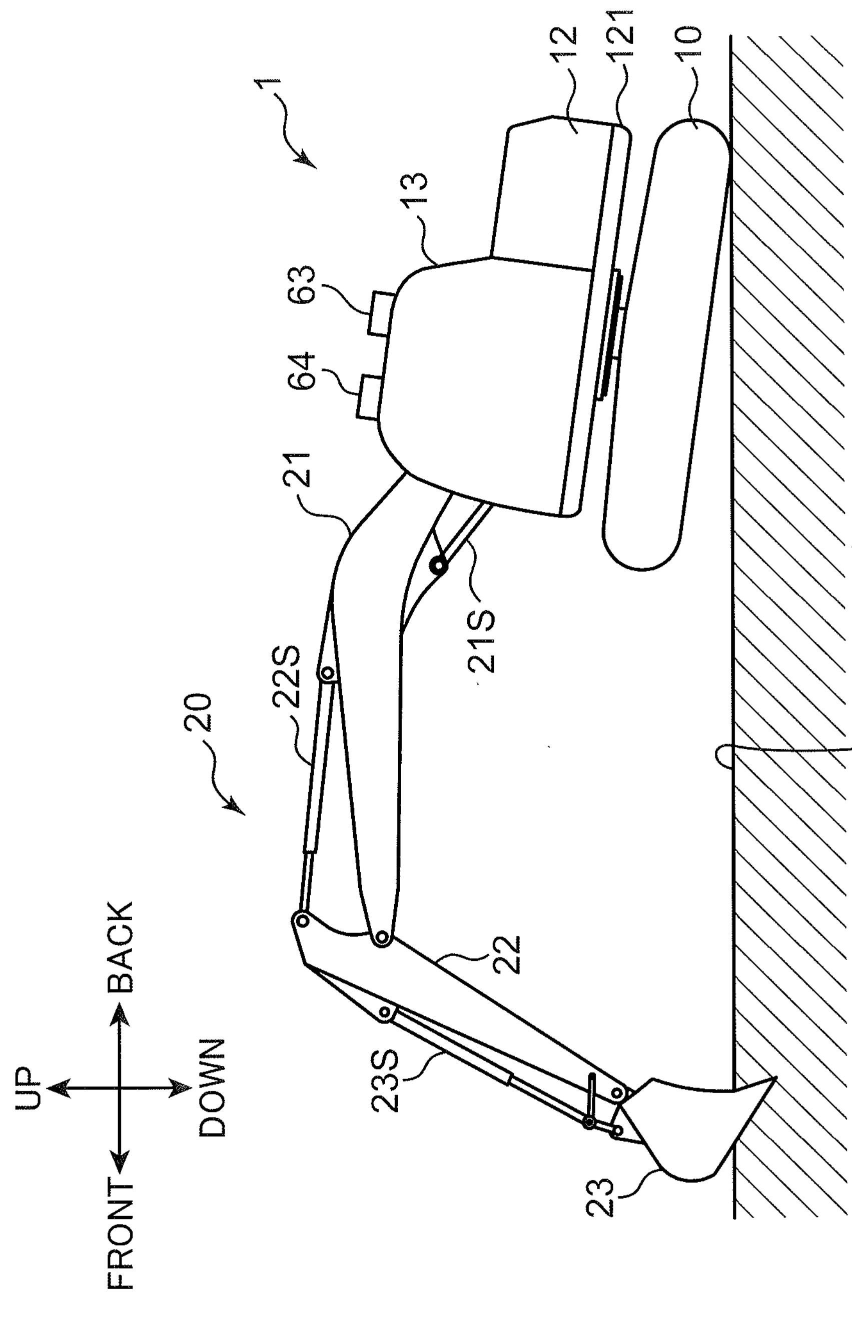
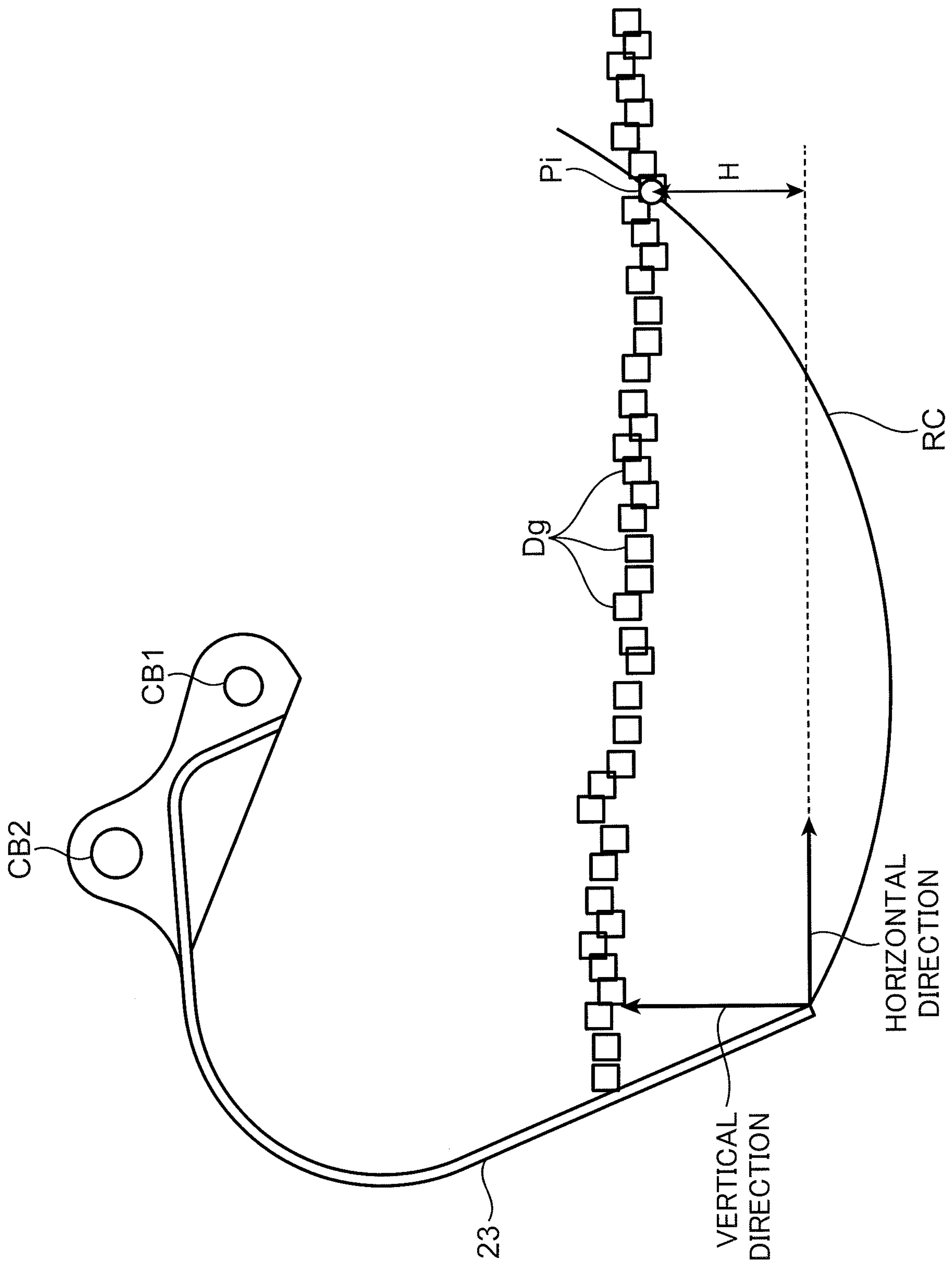


FIG.22


CB2
CB1
Dg
Pi
H
RC
HORIZONTAL DIRECTION
VERTICAL DIRECTION
23

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/024030

A. CLASSIFICATION OF SUBJECT MATTER

E02F 9/26(2006.01)i
FI: E02F9/26 A

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E02F9/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2019-159727 A (HITACHI CONSTR. MACH. CO., LTD.) 19 September 2019 (2019-09-19) entire text, all drawings	1-30
A	JP 2020-165254 A (SUMITOMO HEAVY IND., LTD.) 08 October 2020 (2020-10-08) entire text, all drawings	1-30
A	JP 2019-163621 A (SUMITOMO HEAVY IND., LTD.) 26 September 2019 (2019-09-26) entire text, all drawings	1-30
A	JP 2002-007029 A (DAI NIPPON CONSTRUCTION) 08 March 2002 (2002-03-08) entire text, all drawings	1-30

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
18 August 2022	**30 August 2022**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/024030

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2019-159727 A	19 September 2019	(Family: none)	
JP 2020-165254 A	08 October 2020	(Family: none)	
JP 2019-163621 A	26 September 2019	(Family: none)	
JP 2002-007029 A	08 March 2002	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2019163621 A **[0004]**