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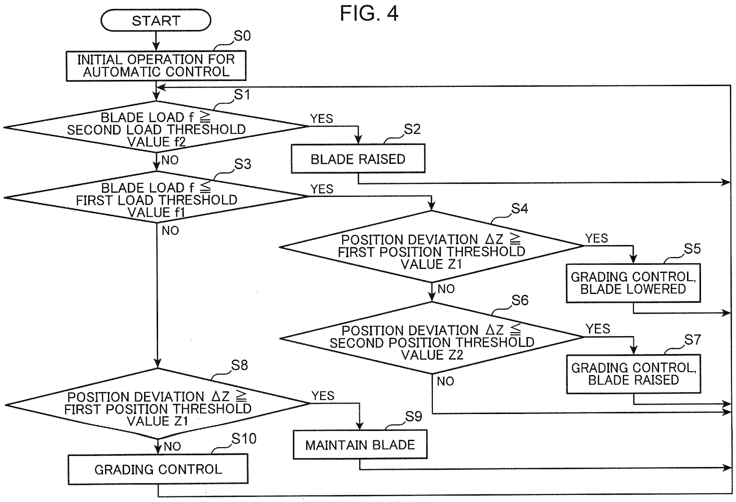
(54) BLADE CONTROL DEVICE FOR WORK MACHINERY

(57) A blade operation control part (15) of a blade control device (100) controls operation of a blade (4) such that when a blade load (f) is equal to or less than a first load threshold value (fl) and a position deviation (ΔZ) is equal to or greater than a position threshold value (Z1), the blade (4) is lowered to make the position deviation (ΔZ) approach zero, and the blade operation control part (15) controls operation of the blade (4) such that the blade (4) is raised regardless of the position deviation (ΔZ) when the blade load (f) is equal to or greater than a second load threshold value (f2).

FIG. 4



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Description

Technical Field

[0001] The present invention relates to a blade control device provided in a work machine including a blade.

Background Art

[0002] Conventionally, a work machine including a blade for use in digging of the ground, grading, transport of sediments, and the like has been used widely. In such a work machine, while conducting travelling manipulation, an operator conducts manipulation of raising and lowering a blade to adjust a blade position (a height of a blade edge) and to conduct digging of the ground, grading, or the like.

[0003] Patent Literature 1 discloses a blade control system which automatically controls the blade position. The blade control system recited in Patent Literature 1 executes digging control in a case where a distance determination part determines that a distance between a design surface and a blade edge exceeds a first distance, executes grading control in a case where the distance determination part determines that the distance between the design surface and the blade edge goes below a second distance, and executes digging control or grading control in a case where the distance determination part determines that the distance between the design surface and the blade edge is equal to or less than the first distance and equal to or greater than the second distance. In Patent Literature 1, the digging control is control for maintaining a blade load at a target load in order to conduct efficient digging work. The grading control is control for maintaining the distance between the blade edge and the design surface at a target distance in order to level the ground into a target shape.

[0004] The blade control system of Patent Literature 1, however, has a problem that control selected from the digging control and the grading control cannot be control appropriate for an actual digging condition. In a case, for example, where the distance between the design surface and the blade edge goes below the second distance, even if a blade load is large, the grading control, i.e., the control for maintaining the distance between the blade edge and the design surface at a target distance, is conducted without fail, so that the blade load might be excessively large depending on a state (e.g. hardness of sediments, a kind of sediments, etc.) of the ground to be dug. This might cause a work machine to be stuck. By contrast, in a case where the distance between the blade edge and the design surface exceeds the first distance, because the digging control is conducted without grading control even when a blade load is so small that control (grading control) to match the blade edge with the design surface can be conducted, high work execution efficiency cannot be obtained.

Citation List

Patent Literature

[0005] Patent Literature 1: JP 5247939 B

Summary of Invention

[0006] An object of the present invention is to provide a blade control device which is provided in a work machine including a blade and is capable of selecting control appropriate for an actual digging condition.

[0007] The blade control device of the present invention is a device which is provided in a work machine including a machine body and a blade attached to the machine body so as to be raised and lowered and which controls raising and lowering operation of the blade. The blade control device includes a target design surface setting part which sets a target design surface that specifies a target shape of an object to be dug by the blade; a position information acquiring part which acquires position information related to the work machine; a blade position calculating part which calculates a blade position as a position of the blade on the basis of the position information acquired by the position information acquiring part; a deviation calculating part which calculates a position deviation as a deviation between the blade position and the target design surface; a blade load acquiring part which acquires a blade load as a load applied on the blade; a storage part which stores a first load threshold value as a threshold value of the blade load, a second load threshold value which is a threshold value of the blade load and greater than the first load threshold value, and a position threshold value as a threshold value of the position deviation; and a blade operation control part which controls operation of the blade, in which the blade operation control part controls operation of the blade such that the blade is lowered to make the position deviation approach zero when the blade load is equal to or less than the first load threshold value and the position deviation is equal to or greater than the position threshold value. The blade operation control part controls operation of the blade such that the blade is raised regardless of the position deviation when the blade load is equal to or greater than the second load threshold value.

Brief Description of Drawings

[0008]

FIG. 1 is a side view showing a hydraulic excavator as an example of a work machine in which a blade control device according to an embodiment of the present invention is provided.

FIG. 2 is a block diagram showing a main function of the blade control device according to the embodiment.

FIG. 3 is a schematic view for explaining a relationship among a target design surface, a present surface, and a position deviation.

FIG. 4 is a flowchart showing one example of control operation executed by a controller included in the blade control device according to the embodiment.

FIG. 5 is a graph showing one example of control for operation of a blade on the basis of a position deviation as a deviation between the blade position and the target design surface in the blade control device according to the embodiment.

FIG. 6 is a graph showing another example of control for operation of the blade on the basis of a position deviation as a deviation between the blade position and the target design surface in the blade control device according to the embodiment.

FIG. 7 is a graph showing a further example of control for operation of the blade on the basis of a position deviation as a deviation between the blade position and the target design surface in the blade control device according to the embodiment.

FIG. 8 is a graph showing one example of control for operation of the blade on the basis of a blade load in the blade control device according to the embodiment.

Description of Embodiments

[0009] A preferred embodiment of the present invention will be described with reference to the drawings.

[Overall Structure of Work Machine]

[0010] FIG. 1 is a side view showing a hydraulic excavator 1 as an example of a work machine in which a blade control device according to an embodiment of the present invention is provided. The hydraulic excavator 1 includes a travelling device 2 (lower travelling body) capable of travelling on the ground G, a vehicle body 3 (upper slewing body) mounted on the travelling device 2, a work device mounted on the vehicle body 3, and a blade 4 (dozer) mounted on the travelling device 2 or the vehicle body 3. The travelling device 2 and the vehicle body 3 constitute a machine body of the work machine. The vehicle body 3 has a slewing frame, an engine, a driver's room, and the like.

[0011] The work device mounted on the vehicle body 3 includes a boom 5, an arm 6, and a bucket 7. The boom 5 has a base end portion supported at a front end of the slewing frame so as to go up and down, i.e., to be turnable around a horizontal axis, and a distal end portion on the opposite side. The arm 6 has a base end portion attached to the distal end portion of the boom 5 so as to be turnable around the horizontal axis, and a distal end portion on the opposite side. The bucket 7 is turnably attached to the distal end portion of the arm 6.

[0012] The hydraulic excavator 1 has a boom cylinder, an arm cylinder, and a bucket cylinder provided for the boom 5, the arm 6, and the bucket 7, respectively. The boom cylinder is interposed between the vehicle body 3 and the boom 5 and extends and contracts so as to cause the boom 5 to conduct up-down operation. The arm cylinder is interposed between the boom 5 and the arm 6 and extends and contracts so as to cause the arm 6 to conduct turning operation. The bucket cylinder is interposed between the arm 6 and the bucket 7 and extends and contracts so as to cause the bucket 7 to conduct turning operation.

[0013] The blade 4 mounted on the travelling device 2 or the vehicle body 3 is provided for conducting digging of the ground, grading, transport of sediments, and the like. Specifically, the blade 4 is supported by a lift frame 4a, and the lift frame 4a is supported to be turnable around a horizontal axis 4b with respect to the travelling device 2. Accordingly, the blade 4 can be displaced in an up-down direction with respect to the travelling device 2.

[0014] The hydraulic excavator 1 has a lift cylinder 8 provided for the blade 4. The lift cylinder 8 has a head chamber 8h and a rod chamber 8r (see FIG. 1), and extends to thereby cause the blade 4 to move in a down direction when a hydraulic oil is supplied to the head chamber 8h, as well as discharging the hydraulic oil in the rod chamber 8r, and also contracts to thereby cause the blade 4 to move in an up direction when the hydraulic oil is supplied to the rod chamber 8r, as well as discharging the hydraulic oil in the head chamber 8h.

[0015] The hydraulic excavator 1 has a hydraulic circuit not shown. The hydraulic circuit includes the boom cylinder, the arm cylinder, the bucket cylinder, and the lift cylinder 8. The hydraulic circuit further includes a hydraulic pump 9 (see FIG. 1), a lift cylinder control proportional valve 41 (see FIG. 2), and a lift cylinder flow rate control valve not shown.

[Blade Control Device]

[0016] FIG. 2 is a block diagram showing a main function of a blade control device 100. The blade control device 100 is provided for controlling raising and lowering operation of the blade 4. The blade control device 100 includes a controller 10 (mechatronic controller), a position information acquiring part, a blade load acquiring part 34, an automatic control switch 35, and a travelling lever 36 for manipulating the travelling device 2. The controller 10, which is configured with, for example, a microcomputer, controls operation of each element included in the hydraulic circuit.

[0017] The position information acquiring part is configured to acquire position information about the hydraulic excavator 1. Specifically, in the present embodiment, the position information acquiring part includes a vehicle body position acquiring part 31, a vehicle body angle acquiring part 32, and a blade angle acquiring part 33. The vehicle body position acquiring part 31 is configured to acquire a vehicle body position as a position of the machine body. The vehicle body position acquiring part 31 is configured with, for example, a receiver, such as a GNSS receiver (GNSS sensor), capable of receiving satellite data (positioning signal) from a satellite measurement system, such as GNSS (Global Navigation Satellite System), and receives GNSS data indicative of a vehicle body position as a position of the vehicle body 3 in a global coordinate system. The global coordinate system is a three-dimensional coordinate system using an origin point defined on the earth as a reference, which is a coordinate system indicating an absolute position defined by the satellite measurement system.

[0018] The vehicle body angle acquiring part 32 is configured to acquire a vehicle body angle as an angle of the vehicle body 3. The vehicle body angle acquiring part 32 is configured with, for example, a vehicle body angle sensor which detects an angle of the vehicle body 3 in a global coordinate system. Specifically, the vehicle body angle sensor may be configured with, for example, one or a plurality of receivers provided in the machine body and capable of receiving satellite data (positioning signal) from a satellite measurement system.

[0019] The blade angle acquiring part 33 is configured to acquire an angle of the blade 4. The blade angle acquiring part 33 is configured with, for example, a blade angle sensor which detects the angle of the blade 4 in a global coordinate system. Specifically, the blade angle sensor may be configured with, for example, one or a plurality of receivers provided in the machine body and capable of receiving satellite data (positioning signal) from a satellite measurement system.

[0020] A local coordinate system may be used in place of the global coordinate system. Both the global coordinate system and the local coordinate system may be used together. Examples of the local coordinate system include a three-dimensional coordinate system using the vehicle body position as a reference and a three-dimensional coordinate system using a specific position at a work site as a reference. In the above case, the vehicle body angle sensor may be configured with, for example, an inertia measurement device, or may be configured with, for example, the inertia measurement device and the receiver capable of receiving the satellite data. The inertia measurement device may be configured to be capable of, for example, measuring an acceleration and an angular velocity of the vehicle body 3, and detecting an inclination (e.g., a pitch indicative of rotation with respect to an X-axis, a yaw indicative of rotation with respect to a Y-axis, and a roll indicative of rotation with respect to a Z-axis) of the vehicle body 3 on the basis of a measurement result. The blade angle sensor may be configured with, for example, a stroke sensor which detects a cylinder stroke of the blade cylinder 8, or may be configured with the stroke sensor and the receiver capable of receiving the satellite data.

[0021] Although, in the present embodiment, the vehicle body position acquiring part 31 and the vehicle body angle acquiring part 32 are attached to an upper portion of the vehicle body 3 and the blade angle acquiring part 33 is attached to an upper portion of the blade 4 as shown in FIG. 1, the attachment positions are not limited to the specific example shown in FIG. 1. Detection signals as electrical signals generated by these acquiring parts 31, 32, and 33 are input to the controller 10.

[0022] In the present embodiment, the blade load acquiring part 34 is configured to acquire a blade load as a load applied on the blade 4 during digging work. The blade load corresponds to, for example, a pump pressure of the hydraulic pump 9 which drives the blade 4. Accordingly, the blade load acquiring part 34 is capable of detecting the blade load by detecting the pump pressure. In the present embodiment, the blade load acquiring part 34 includes a head pressure sensor 34H which detects a head pressure PI as a pressure of a hydraulic oil in the head chamber 8h of the lift cylinder 8, and a rod pressure sensor 34R which detects a rod pressure P2 as a pressure of a hydraulic oil in the rod chamber 8r of the lift cylinder 8. The sensors 34H and 34R respectively convert their detected physical quantities into detection signals as electrical signals corresponding to the physical quantities and input the detection signals to the controller 10.

[0023] The automatic control switch 35 is arranged in the driver's room and is electrically connected to the controller 10. Upon receiving manipulation for switching a control mode of the controller 10 from a manual manipulation mode to an automatic control mode, the automatic control switch 35 inputs a mode command signal related to the manipulation to the controller 10. The controller 10 switches setting of the control mode from the manual manipulation mode to the automatic control mode by the mode command signal input from the automatic control switch 35.

[0024] In the automatic control mode, the controller 10 is configured to automatically control operation of the lift cylinder 8 such that an execution surface to be executed by the blade 4 approaches a target design surface set in advance. When a command value (command current) to the lift cylinder control proportional valve 41 for controlling operation of the lift cylinder 8 is output from the controller 10, a secondary pressure of the proportional valve 41 changes according to the command value and opening of the lift cylinder flow rate control valve changes according to the secondary pressure. As a result, a supply flow and a supply direction of a hydraulic oil to be supplied from the hydraulic pump 9 to the lift cylinder 8 via the lift cylinder flow rate control valve change to control an operation speed and a driving direction of the lift cylinder 8. On the other hand, in the manual manipulation mode, when a worker manipulates the travelling lever 36, a manipulation signal of the manipulation is input to the controller 10, and the command value to the lift cylinder control proportional valve 41 or a command value to the lift cylinder flow rate control valve is output from the controller 10 according to an amount of manipulation of a manipulation lever not shown for manipulating raising and lowering of the blade 4.

[0025] The controller 10 has a target design surface setting part 11, a blade position calculating part 12, a storage part 13, a deviation calculating part 14, a blade operation control part 15, a threshold value setting part 16 as a function for executing the automatic control.

[0026] The target design surface setting part 11 sets a target design surface which specifies a target shape of an object to be dug by the blade 4. The target design surface setting part 11 may store data of a design surface input by a target design surface input part provided in the driver's room and set the design surface as a target design surface. The target design surface setting part 11 may also store data of a design surface acquired via various kinds of storage media, a communication network, or the like and set the design surface as a target design surface. The target design surface is a surface which specifies a three-dimensional design topography as a target shape of the ground which is an object to be dug. The target design surface may be specified by external data such as BIM or CIM (Building/Construction Information Modeling, Management). The target design surface may be set using a position of the work machine as a reference.

[0027] The blade position calculating part 12 calculates a blade position as a position of the blade 4 in the global coordinate system on the basis of the position information acquired by the position information acquiring part. In the present embodiment, the blade position calculating part 12 calculates the blade position on the basis of the vehicle body position acquired by the vehicle body position acquiring part 31, the vehicle body angle acquired by the vehicle body angle acquiring part 32, and the angle of the blade 4 acquired by the blade angle acquiring part 33. In other words, the blade position is calculated from a sum of a vector from a reference point to the vehicle body position and a vector from the vehicle body position to the blade position. Although in the present embodiment, a blade position is thus calculated from a relative angle between the vehicle body angle and the angle of the blade 4 in the global coordinate system, a blade position calculation method is not limited thereto. The blade position may be calculated on the basis of, for example, a length of the lift cylinder 8, or may be calculated on the basis of GNSS data received by a GNSS receiver (GNSS sensor) attached to the blade 4.

[0028] The deviation calculating part 14 calculates a position deviation ΔZ as a deviation between the blade position and the target design surface SD.

[0029] FIG. 3 is a schematic view for explaining a relationship among a target design surface SD, a present surface SP, and a position deviation ΔZ. In FIG. 3, the hydraulic excavator 1 (work machine) is illustrated in a simplified manner. Although in the present embodiment, the blade position is set at a blade edge position (a position of a lower edge of a distal end of the blade 4) as the distal end of the blade 4 as shown in FIG. 3, the blade position may be set at other part of the blade 4. The position deviation ΔZ is a deviation between the blade position and the target design surface SD. In other words, the position deviation ΔZ can be obtained by subtracting a height of the target design surface SD from the blade position (a blade edge height of the blade 4). The present surface SP shown in FIG. 3 is the ground which is an object to be dug.

[0030] The threshold value setting part 16 sets a first load threshold value f1, a second load threshold value f2, a first position threshold value Z1, and a second position threshold value Z2 for use in calculation of the blade operation control part 15. These threshold values may be manually input to the controller 10 by a worker before the digging work or appropriately calculated by the controller 10 during the digging work.

[0031] The storage part 13 stores the first load threshold value f1, the second load threshold value f2, the first position threshold value Z1, and the second position threshold value Z2 set by the threshold value setting part 16.

[0032] The first load threshold value f1 is set to be a value corresponding to a proper blade load f with which the hydraulic excavator 1 can stably travel. The second load threshold value f2 is a value set to realize stably efficient digging operation. The second load threshold value f2 is a value set to prevent occurrence of such a situation that the blade load f becomes excessively large to cause a stuck condition (a state where the blade load f becomes excessively so large that the work machine has difficult in advancing). Accordingly, the second load threshold value f2 is set to be a value greater than the first load threshold value f1. The second load threshold value f2 is preferably set to be a value smaller than the blade load f with which such a situation as described above occurs. In other words, the second load threshold value f2 is preferably set to be a value with which the work machine can travel even when the blade load f reaches the second load threshold value f2.

[0033] The first position threshold value Z1 is a value as a reference for determining whether or not to control blade operation so as to lower the blade 4 such that a position deviation approaches zero in a case where the blade load f is equal to or less than the first load threshold value f1. The first position threshold value Z1 is also a value as a reference for determining whether or not to maintain a relative position of the blade 4 with respect to the machine body in a case where the blade load f is within an intermediate load region, i.e., where the blade load f is greater than the first load threshold value f1 and smaller than the second load threshold value f2. The first position threshold value Z1 is set to be, for example, zero or a positive value. The second position threshold value Z2 is a value as a reference for determining whether or not to control the blade operation so as to raise the blade 4 such that the position deviation approaches zero in a case where the blade load f is within the intermediate load region. Accordingly, the second position threshold value Z2 is set to be a value smaller than the first position threshold value Z1.

[0034] The blade operation control part 15 calculates and outputs a command value to the lift cylinder control proportional valve 41 for controlling operation of the lift cylinder 8. There are input to the blade operation control part 15, an automatic control switch manipulation signal of the automatic control switch 35, a travelling lever manipulation signal of the travelling lever 36, the blade load f acquired by the blade load acquiring part 34, each threshold value set by the threshold value setting part 16 and stored in the storage part 13, and the position deviation ΔZ calculated by the deviation calculating part 14, on the basis of which, a command current to be output to the lift cylinder control proportional valve 41 is calculated.

[0035] Next, description will be made of control operation conducted by the controller 10 for the driving of the blade 4 in the automatic control mode with reference to the flowchart of FIG. 4.

[0036] When the automatic control switch 35 (see FIG. 2) is turned on, the controller 10 conducts initial operation for the automatic control (Step S0). In the initial operation, the controller 10 takes in a signal to be input to the controller 10, specifically, a detection signal of each sensor and designation signals. The designation signals include a signal for a target design surface designated by manipulation of the target design surface input part by an operator, a signal for a blade load f acquired by the blade load acquiring part 34, a signal for the vehicle body position acquired by the vehicle body position acquiring part 31, a signal for a vehicle body angle acquired by the vehicle body angle acquiring part 32, a signal for an angle of the blade 4 acquired by the blade angle acquiring part 33, a signal for a travelling speed corresponding to manipulation received by the travelling lever 36, and the like. The controller 10 acquires an initial state of the hydraulic excavator 1 on the basis of these designation signals. The target design surface setting part 11 of the controller 10 sets a target design surface on the basis of the signal for the target design surface. Then, the blade operation control part 15 of the controller 10 controls operation of the blade 4 in the following manner.

[0037] The blade operation control part 15 determines whether the blade load f acquired by the blade load acquiring part 34 is equal to or greater than the second load threshold value f2 or not (Step S1). In a case where the blade load f is equal to or greater than the second load threshold value f2 (YES in Step S1), the blade operation control part 15 controls operation of the blade 4 such that the blade 4 is raised (Step S2), and the controller 10 again conducts the processing of Step S1.

[0038] In a case where the blade load f is smaller than the second load threshold value f2 (NO in Step S1), the blade operation control part 15 determines whether the blade load f is equal to or less than the first load threshold value f1 or not (Step S3).

[0039] In a case where the blade load f is equal to or less than the first load threshold value f1 (YES in Step S3), the blade operation control part 15 determines whether the position deviation ΔZ is equal to or greater than the first position threshold value Z1 or not (Step S4).

[0040] In a case where the position deviation ΔZ is equal to or greater than the first position threshold value Z1 (YES in Step S4), the blade operation control part 15 conducts grading control (Step S5). Specifically, the blade operation control part 15 controls the operation of the blade 4 such that the blade 4 is lowered to make the position deviation ΔZ approach zero (Step S5), and the controller 10 again conducts the processing of Step S1.

[0041] On the other hand, in a case where the position deviation ΔZ is smaller than the first position threshold value Z1 (NO in Step S4), the blade operation control part 15 determines whether the position deviation ΔZ is equal to or less than the second position threshold value Z2 or not (Step S6).

[0042] In a case where the position deviation ΔZ is equal to or less than the second position threshold value Z2 (YES in Step S6), the blade operation control part 15 conducts the grading control. Specifically, the blade operation control part 15 controls the operation of the blade 4 such that the blade 4 is raised to make the position deviation ΔZ approach zero (Step S7), and the controller 10 again conducts the processing of Step S1.

[0043] In a case where the position deviation ΔZ is smaller than the first position threshold value Z1 (NO in Step S4) and the position deviation ΔZ is greater than the second position threshold value Z2 (NO in Step S6), the blade operation control part 15 refrains from conducting such control (control for the raising operation or the lowering operation of the blade 4) to change the relative position of the blade 4 with respect to the machine body, so that the relative position is maintained and the controller 10 again conducts the processing of Step S1.

[0044] In a case where the blade load f is smaller than the second load threshold value f2 (NO in Step S1) and the blade load f is greater than the first load threshold value f1 (NO in Step S3), i.e., the blade load f is within the intermediate load region, the blade operation control part 15 determines whether the position deviation ΔZ is equal to or greater than the first position threshold value Z1 or not (Step S8).

[0045] In a case where the position deviation ΔZ is equal to or greater than the first position threshold value Z1 (YES in Step S8), the blade operation control part 15 refrains from conducting such control (control for the raising operation or the lowering operation of the blade 4) to change the relative position of the blade 4 with respect to the machine body, so that the relative position is maintained (Step S9). In other words, the blade operation control part 15 does not output a command to the lift cylinder control proportional valve 41. That is, as an amount of lift of the blade 4 with respect to the machine body, a previous value is maintained. Thereafter, the controller 10 again conducts the processing of Step S1.

[0046] On the other hand, in a case where the position deviation ΔZ is smaller than the first position threshold value Z1 (NO in Step S8), the blade operation control part 15 conducts the grading control (Step S10). Specifically, the blade operation control part 15 controls the operation of the blade 4 such that the blade 4 is lowered or raised to make the position deviation ΔZ approach zero (Step S10), and the controller 10 again conducts the processing of Step S1.

[0047] The above-described control by the blade control device 100 shown in the flowchart of FIG. 4 will be summarized as follows. The controller 10 of the blade control device 100 executes a first control mode, a second control mode, and a third control mode. The first control mode is a mode for conducting the grading control, the second control mode is a mode for conducting blade raising control (lift-up control), and the third control mode is a mode for conducting blade maintaining control (lift maintaining control).

[0048] The grading control for the first control mode is to control the operation of the blade 4 such that the position deviation ΔZ approaches zero. In other words, in the grading control, the operation of the blade 4 is controlled such that the blade edge (the blade position) of the blade 4 is substantially matched with a target design surface. The first control mode is conducted in a case where the blade load f is equal to or less than the first load threshold value f1. Specifically, in the present embodiment, the first control mode is conducted in a case where the blade load f is equal to or less than the first load threshold value f1 and the position deviation ΔZ is equal to or greater than the first position threshold value Z1 (Step S5). Additionally, the first control mode is conducted also in a case where the blade load f is equal to or less than the first load threshold value f1 and the position deviation ΔZ is equal to or less than the second position threshold value Z2 (Step S7). Further, the first control mode is conducted also in a case where within the intermediate load region, the position deviation ΔZ is smaller than the first position threshold value Z1 (Step S10).

[0049] In the second control mode, the operation of the blade 4 is controlled such that the blade 4 is raised. The second control mode is conducted in a case where the blade load f is equal to or greater than the second load threshold value f2 (Step S2).

[0050] In the third control mode, the relative position of the blade 4 with respect to the machine body is maintained. The third control mode is conducted in a case where within the intermediate load region, the position deviation ΔZ is equal to or greater than the first position threshold value Z1 (Step S9). Additionally, in the present embodiment, the third control mode is conducted also in a case where the blade load f is equal to or less than the first load threshold value f1 and the position deviation ΔZ is smaller than the first position threshold value Z1 and greater than the second position threshold value Z2 (NO in Step S6).

[0051] FIG. 5, FIG. 6, and FIG. 7 are graphs respectively showing examples of control for the operation of the blade 4 on the basis of the position deviation ΔZ between the blade position and the target design surface SD. The control for the operation of the blade 4 shown in FIG. 5, FIG. 6, and FIG. 7 is used for the grading control in the first control mode.

[0052] In the specific example shown in FIG. 5, the first position threshold value Z1 is set to be a positive value and the second position threshold value Z2 is set to be zero. In the specific example shown in FIG. 6, the first position threshold value Z1 is set to be a positive value and the second position threshold value Z2 is set to be a negative value. In the specific example shown in FIG. 7, only the first position threshold value Z1 is set and the second position threshold value Z2 is not set. As described above, the position deviation ΔZ is a value obtained by subtracting the height of the target design surface SD from the blade position (the blade edge height of the blade 4). Accordingly, in a case where the blade position is higher than the height of the target design surface SD, the position deviation ΔZ has a positive value and in a case where the blade position is lower than the height of the target design surface SD, the position deviation ΔZ has a negative value.

[0053] In the control examples shown in FIG. 5, FIG. 6, and FIG. 7, in a case where the position deviation ΔZ is equal to or greater than the first position threshold value Z1 (YES in Step S4), as the position deviation ΔZ is increased, a command value of a blade lowering command (lift-down command) is increased. Additionally, in these control examples, in a case where the position deviation ΔZ is equal to or greater than a predetermined value, the command value is set to be a fixed value (maximum value). It may be configured that when the position deviation ΔZ becomes equal to or greater than the first position threshold value Z1, the command value is immediately set to be a fixed value (maximum value).

[0054] As the command value is increased, the operation speed of the lift cylinder 8 is increased and an operation speed of the blade 4 is increased.

[0055] In the control examples shown in FIG. 5 and FIG. 6, the first position threshold value Z1 is set to be a positive value slightly greater than zero, and in the control example shown in FIG. 7, the first position threshold value Z1 is set to be zero.

[0056] In the control examples shown in FIG. 5 and FIG. 6, in a case where the position deviation ΔZ is equal to or less than the second position threshold value Z2 (YES in Step S6), as the position deviation ΔZ is decreased, a command value of a blade raising command (lift-up command) is increased. In the control example shown in FIG. 7, in a case where the position deviation ΔZ is equal to or less than the first position threshold value Z1, as the position deviation ΔZ is decreased, the command value of the blade raising command (lift-up command) is increased. In these control examples, in a case where the position deviation ΔZ is equal to or less than the predetermined value, the command value is set to be a fixed value (maximum value). It may be configured that when the position deviation ΔZ becomes equal to or less than the second position threshold value Z2, the command value is immediately set to be a fixed value (maximum value).

[0057] In the control example shown in FIG. 5, the second position threshold value Z2 is set to be zero, and in the control example shown in FIG. 6, the second position threshold value Z2 is set to be a negative value slightly smaller than zero. In the control example shown in FIG. 7, the first position threshold value Z1 is set to be zero.

[0058] In the control examples shown in FIG. 5 and FIG. 6, in a case where the position deviation ΔZ is smaller than the first position threshold value Z1 and greater than the second position threshold value Z2 (NO in Step S6), neither blade lowering operation (lift-down) nor blade raising operation (lift-up) is conducted, so that the relative position of the blade 4 with respect to the machine body is maintained (the above-described third control mode). By thus providing, in a region in which the position deviation ΔZ is near zero, a region (dead zone) in which the relative position is maintained, excessive occurrence of up-down movement of the blade 4 can be suppressed in the region in which the position deviation ΔZ is near zero.

[0059] When a condition for the execution of the first control mode is satisfied in a region where the blade load f is smaller than the second load threshold value f2, in a case where the blade edge height of the blade 4 is greater than the target design surface SD, the blade lowering operation (lift-down) is executed such that as the position deviation ΔZ is increased, the command value of the blade lowering command (lift-down command) is increased as in the control examples shown in FIG. 5, FIG. 6, and FIG. 7. On the other hand, in a case where the blade edge height of the blade 4 is smaller than the target design surface SD, the blade raising operation (lift-up) is executed such that as the position deviation ΔZ is decreased (according to an increase in an absolute value of the position deviation ΔZ), the command value of the blade raising command (lift-up command) is increased. As a result of execution of such first control mode, an amount of lift (the relative position of the blade 4 with respect to the machine body) is controlled such that the blade edge height of the blade 4 is matched with the height of the target design surface SD to thereby conduct grading by the blade 4.

[0060] FIG. 8 is a graph showing one example of control for operation of the blade 4 on the basis of the blade load f. The control of the operation of the blade 4 shown in FIG. 8 is used for the blade raising control (lift-up control) in the second control mode.

[0061] In the control example in FIG. 8, in a case where the blade load f is equal to or greater than the second load threshold value f2 (YES in Step S1), as the blade load f is increased, the command value of the blade raising command (lift-up command) is increased. Also in this control example, in a case where the blade load f is equal to or greater than a predetermined value, the command value is set to a fixed value (maximum value). It may be configured that when the blade load f becomes equal to or greater than the second load threshold value f2, the command value is immediately set to the fixed value (maximum value).

[0062] In a case where the blade load f is equal to or greater than the second load threshold value f2 as in the control example shown in FIG. 8, when the second control mode is executed, the lift-up control is conducted according to an increase in the blade load f, so that the blade edge of the blade 4 is raised to reduce the blade load f. This prevents travelling of the work machine from being stuck due to an increase in the blade load f.

[0063] In a case where in the intermediate load region, the position deviation ΔZ is equal to or greater than the first position threshold value Z1 (YES in Step S8), the third control mode is executed to thereby maintain the relative position of the blade 4 with respect to the machine body. As a result, since digging is conducted while the blade edge height of the blade 4 is fixed within a range in which the travelling of the work machine is not stuck, unnecessary up-down movement of the blade 4 is suppressed to obtain an effect of smoothing the execution surface (digging surface).

[0064] Further, in a case where the position deviation ΔZ is smaller than the first position threshold value Z1 in the intermediate load region (NO in Step S8), the first control mode is executed. Here, when the second position threshold value Z2 (the first position threshold value Z1 in the control example in FIG. 7) is set to be, for example, zero as in the control example in FIG. 5, in a case where the blade edge height of the blade 4 is smaller than the target design surface SD, the blade raising operation (lift-up) is executed in the first control mode, resulting in obtaining an effect of suppressing occurrence of a problem of excessive digging caused by a reduction of the blade edge height of the blade 4 to be smaller than the target design surface SD.

[0065] The first position threshold value Z1 may be set to an appropriate positive value as shown in the control examples in FIG. 5 and FIG. 6. In these cases, in a case where the blade load f is between the first position threshold value Z1 and the second position threshold value Z2, and the blade edge height of the blade 4 is greater than the target design surface SD, when the position deviation ΔZ is smaller than the first position threshold value Z1, the blade lowering operation (lift-down) is executed. This enables grading to be conducted in which the blade edge height of the blade 4 is matched with the height of the target design surface SD. When the first position threshold value Z1 is set to be too large a value, however, the blade lowering operation (lift-down) is executed even when the blade load f is between the first load threshold value f1 and the second load threshold value f2, and the blade edge height of the blade 4 is in a state of being relatively greatly away from the height of the target design surface SD. In such a case, the blade load f is increased to immediately become equal to or greater than the second load threshold value f2, resulting in increasing a possibility of execution of the blade raising operation (lift-up). In such a case, the blade lowering operation (lift-down) and the blade raising operation (lift-up) are frequently conducted, so that the execution surface (digging surface) is likely to have waviness (heave). It is accordingly preferable to set the first position threshold value Z1 to a value to such an extent that prevents the blade load f from becoming equal to or greater than the second load threshold value f2 even when the position deviation ΔZ becomes smaller than the first position threshold value Z1 and greater than zero, so that the blade lowering operation (lift-down) is conducted. With the first position threshold value Z1 set to such a value, even when the position deviation ΔZ becomes smaller than the first position threshold value Z1 to cause execution of the blade lowering operation (lift-down) and the blade load f is gradually increased, the blade load f is unlikely to become equal to or greater than the second load threshold value f2. Therefore, an effect is obtained of suppressing generation of waviness on the execution surface caused by frequent up-down movement of the blade 4 and enabling stable grading control to be executed within the intermediate load region, thereby increasing work execution efficiency.

[0066] The present invention is not limited to the above-described embodiment. The present invention may include the following modes, for example.

[0067] A work machine to which the blade control device according to the present invention is applied is not limited to a hydraulic excavator. The present invention is widely applicable to another work machine provided with a blade, such as a wheel loader, a bulldozer, and a grader.

[0068] As described in the foregoing, a blade control device is provided which is capable of selecting control appropriate for an actual digging condition.

[0069] The blade control device is a device which is provided in a work machine including a machine body and a blade attached to the machine body so as to be raised and lowered and which controls raising and lowering operation of the blade. The blade control device includes a target design surface setting part which sets a target design surface that specifies a target shape of an object to be dug by the blade; a position information acquiring part which acquires position information related to the work machine; a blade position calculating part which calculates a blade position as a position of the blade on the basis of the position information acquired by the position information acquiring part; a deviation calculating part which calculates a position deviation as a deviation between the blade position and the target design surface; a blade load acquiring part which acquires a blade load as a load applied on the blade; a storage part which stores a first load threshold value as a threshold value of the blade load, a second load threshold value which is a threshold value of the blade load and greater than the first load threshold value, and a position threshold value as a threshold value of the position deviation; and a blade operation control part which controls operation of the blade, in which the blade operation control part controls operation of the blade such that the blade is lowered to make the position deviation approach zero when the blade load is equal to or less than the first load threshold value and the position deviation is equal to or greater than the position threshold value. The blade operation control part controls operation of the blade such that the blade is raised regardless of the position deviation when the blade load is equal to or greater than the second load threshold value.

[0070] Since the above-described control is conducted in the blade control device, control appropriate for actual digging can be selected. Specifically, the control is conducted in the following manner. In the blade control device, even in a case where the position deviation has a value equal to or greater than the position threshold value, when the blade load has a value equal to or less than the first load threshold value, control to make a blade position approach a target design surface is conducted. Since the control enables an execution surface for a blade to quickly approach the target design surface, work execution efficiency is improved. Additionally, in the blade control device, when a blade load has a value equal to or greater than the second load threshold value, even if the position deviation is small, control for raising the blade is conducted irrespective of the position deviation. This control restrains a blade load from becoming excessively large irrespective of a state of the ground to be dug and accordingly suppresses the work machine from being stuck.

[0071] In the blade control device, in a case where the blade load is greater than the first load threshold value and smaller than the second load threshold value, and the position deviation is equal to or greater than the position threshold value, it is preferable that a relative position of the blade with respect to the machine body is maintained.

[0072] In this mode, since an increase in a blade load is suppressed, generation of waviness of an execution surface can be restrained. Specifically, the control is conducted in the following manner. In this mode, an intermediate load region, where a blade load is greater than the first load threshold value and smaller than the second load threshold value, is a region to which a moderate load is applied to the blade. In a case where the position deviation is equal to or greater than the position threshold value (first position threshold value), specifically, where a deviation between a blade position and a target design surface is large, when control to make the position deviation approach zero is conducted, the blade enters into the ground so deeply that a possibility of an increase in a blade load from a moderate load to a load equal to or greater than the second load threshold value is increased. When the blade load becomes equal to or greater than the second load threshold value, control to raise the blade is conducted irrespective of the position deviation. Such rise of the blade position causes generation of waviness (heave) of an execution surface. Accordingly, in the present mode, in a case where the position deviation is equal to or greater than the position threshold value (first position threshold value) in the intermediate load region having a moderate load state, the blade operation control part refrains from conducting such control to change a relative position of the blade with respect to the machine body, so that the relative position is maintained. This control suppresses an increase in the blade load to thereby suppress generation of waviness of the execution surface.

[0073] In the blade control device, in a case where the blade load is greater than the first load threshold value and smaller than the second load threshold value, and the position deviation is smaller than the position threshold value, the blade operation control part may control operation of the blade such that the position deviation approaches zero.

[0074] In this mode, in a case where the position deviation is smaller than the position threshold value (first position threshold value) in the intermediate load region, the blade operation control part conducts the control to make the blade position approach the target design surface. This control improves work execution efficiency. Specifically, the control is conducted in the following manner. In a case where the position deviation is smaller than the position threshold value (first position threshold value), specifically, in a case where a deviation between the blade position and the target design surface is small, even when the control to make the position deviation approach zero is conducted, because the blade position is close to the target design surface, a possibility that the blade enters into the ground deeply and a possibility of an increase in a blade load to become equal to or greater than the second load threshold value are low. Accordingly, in the present mode, in such a case, the blade operation control part conducts the control to make the blade position approach the target design surface. Since the control enables an execution surface for a blade to quickly approach the target design surface, work execution efficiency is improved.

[0075] The blade control device may be configured such that the position threshold value is a first position threshold value, the storage part further stores a second position threshold value which is a threshold value of the position deviation and is smaller than the first position threshold value, and the blade operation control part controls operation of the blade such that the blade is raised to make the position deviation approach zero in a case where the blade load is equal to or less than the first load threshold value and the position deviation is equal to or less than the second position threshold value.

[0076] In this mode, since the control to raise the blade when the position deviation becomes equal to or less than the second position threshold value is conducted, it is possible to suppress excessive digging due to falling of the blade below the target design surface.

Claims

1. A blade control device which is provided in a work machine including a machine body and a blade attached to the machine body so as to be raised and lowered and which controls raising and lowering operation of the blade, the blade control device comprising:

   a target design surface setting part which sets a target design surface that specifies a target shape of an object to be dug by the blade;
   a position information acquiring part which acquires position information related to the work machine;
   a blade position calculating part which calculates a blade position as a position of the blade on the basis of the position information acquired by the position information acquiring part;
   a deviation calculating part which calculates a position deviation as a deviation between the blade position and the target design surface;
   a blade load acquiring part which acquires a blade load as a load applied on the blade;
   a storage part which stores a first load threshold value as a threshold value of the blade load, a second load threshold value which is a threshold value of the blade load and greater than the first load threshold value, and a position threshold value as a threshold value of the position deviation; and
   a blade operation control part which controls operation of the blade, wherein
   the blade operation control part controls operation of the blade such that the blade is lowered to make the position deviation approach zero when the blade load is equal to or less than the first load threshold value and the position deviation is equal to or greater than the position threshold value, and
   the blade operation control part controls operation of the blade such that the blade is raised regardless of the position deviation when the blade load is equal to or greater than the second load threshold value.

2. The blade control device according to claim 1, wherein
   in a case where the blade load is greater than the first load threshold value and smaller than the second load threshold value, and the position deviation is equal to or greater than the position threshold value, a relative position of the blade with respect to the machine body is maintained.

3. The blade control device according to claim 1 or 2, wherein
   in a case where the blade load is greater than the

first load threshold value and smaller than the second load threshold value, and the position deviation is smaller than the position threshold value, the blade operation control part controls operation of the blade such that the position deviation approaches zero.

4. The blade control device according to any one of claims 1 to 3, wherein
the position threshold value is a first position threshold value,
the storage part further stores a second position threshold value which is a threshold value of the position deviation and is smaller than the first position threshold value, and
the blade operation control part controls operation of the blade such that the blade is raised to make the position deviation approach zero in a case where the blade load is equal to or less than the first load threshold value and the position deviation is equal to or less than the second position threshold value.

FIG. 1

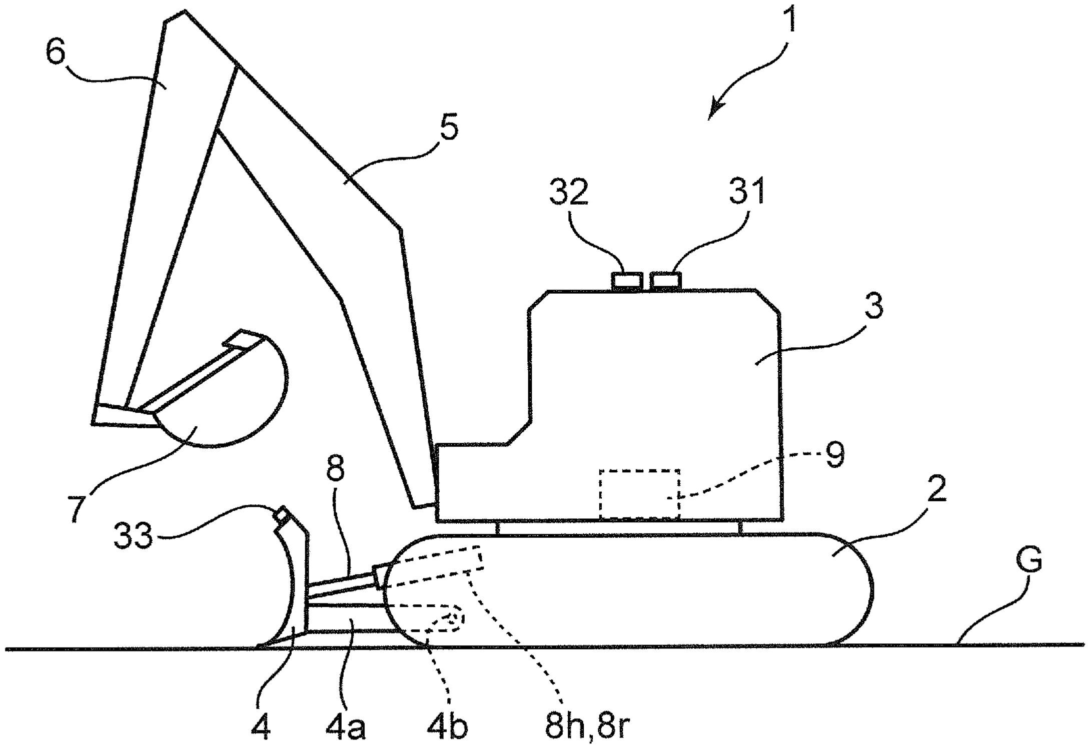


FIG. 2

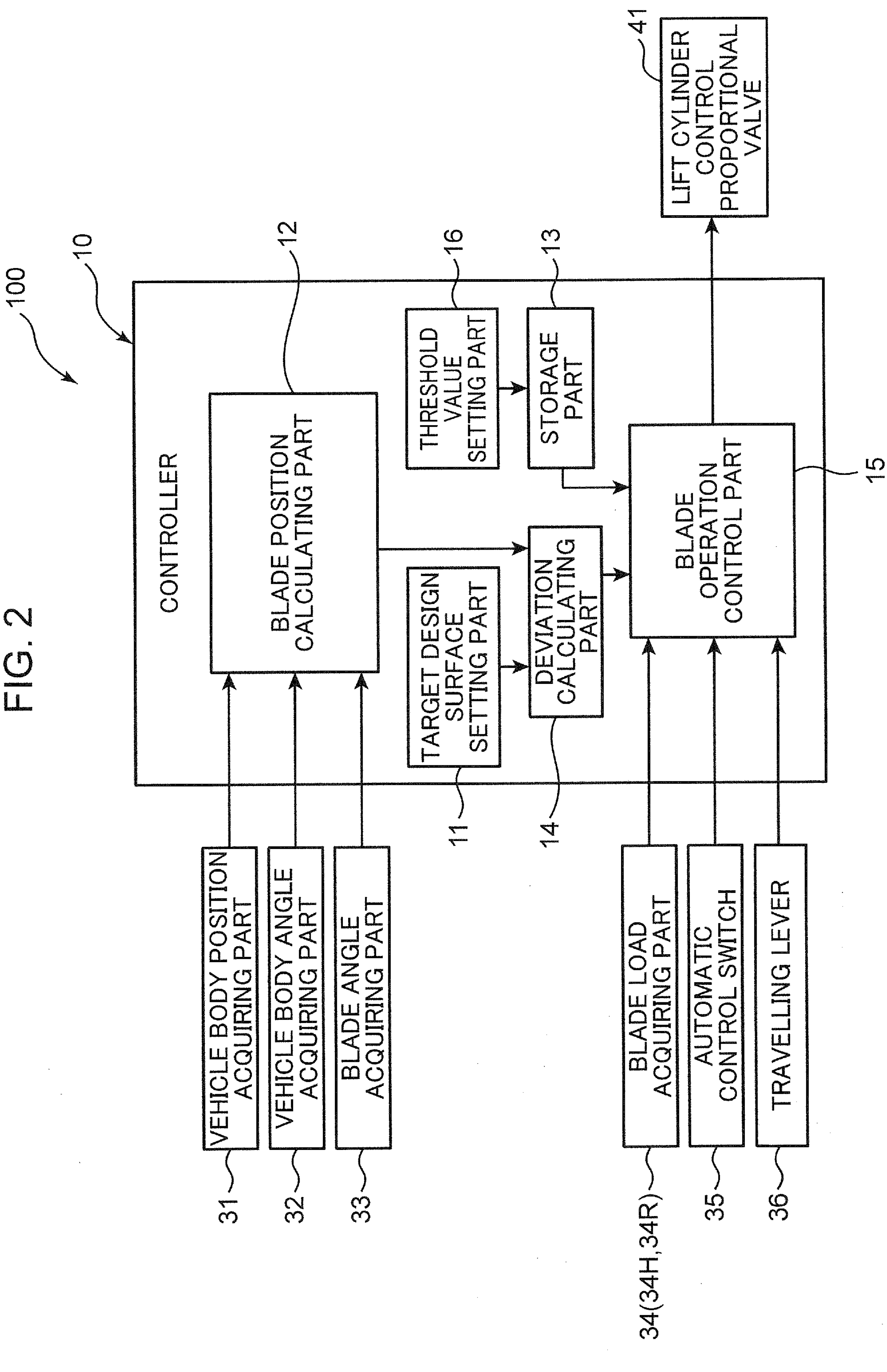

100
10
CONTROLLER
BLADE POSITION CALCULATING PART
12
THRESHOLD VALUE SETTING PART
16
STORAGE PART
13
TARGET DESIGN SURFACE SETTING PART
11
DEVIATION CALCULATING PART
14
BLADE OPERATION CONTROL PART
15
LIFT CYLINDER CONTROL PROPORTIONAL VALVE
41
VEHICLE BODY POSITION ACQUIRING PART
31
VEHICLE BODY ANGLE ACQUIRING PART
32
BLADE ANGLE ACQUIRING PART
33
BLADE LOAD ACQUIRING PART
34(34H,34R)
AUTOMATIC CONTROL SWITCH
35
TRAVELLING LEVER
36

FIG. 3

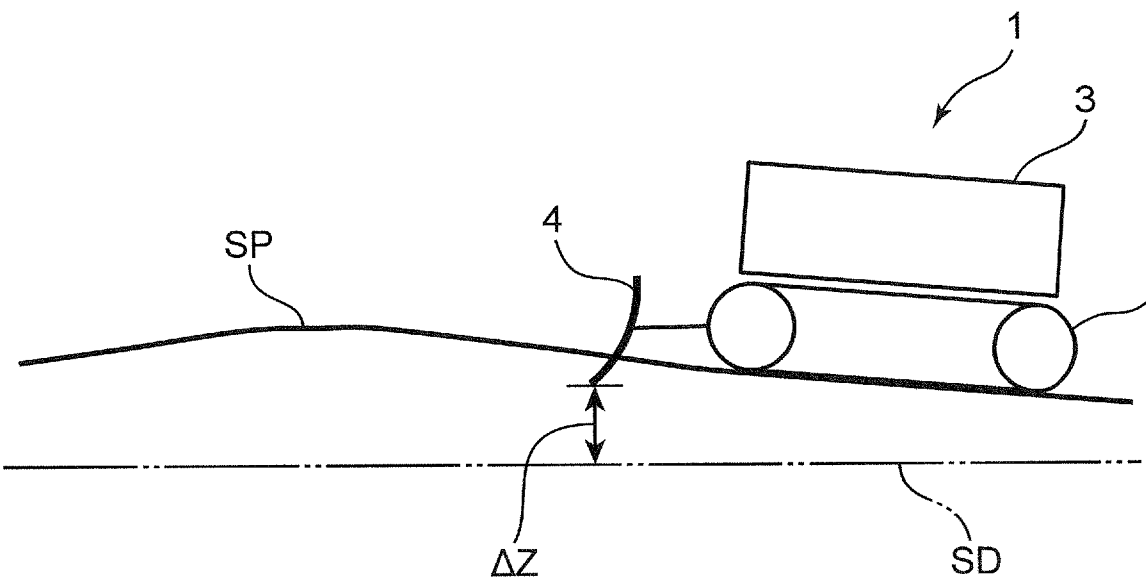


FIG. 4

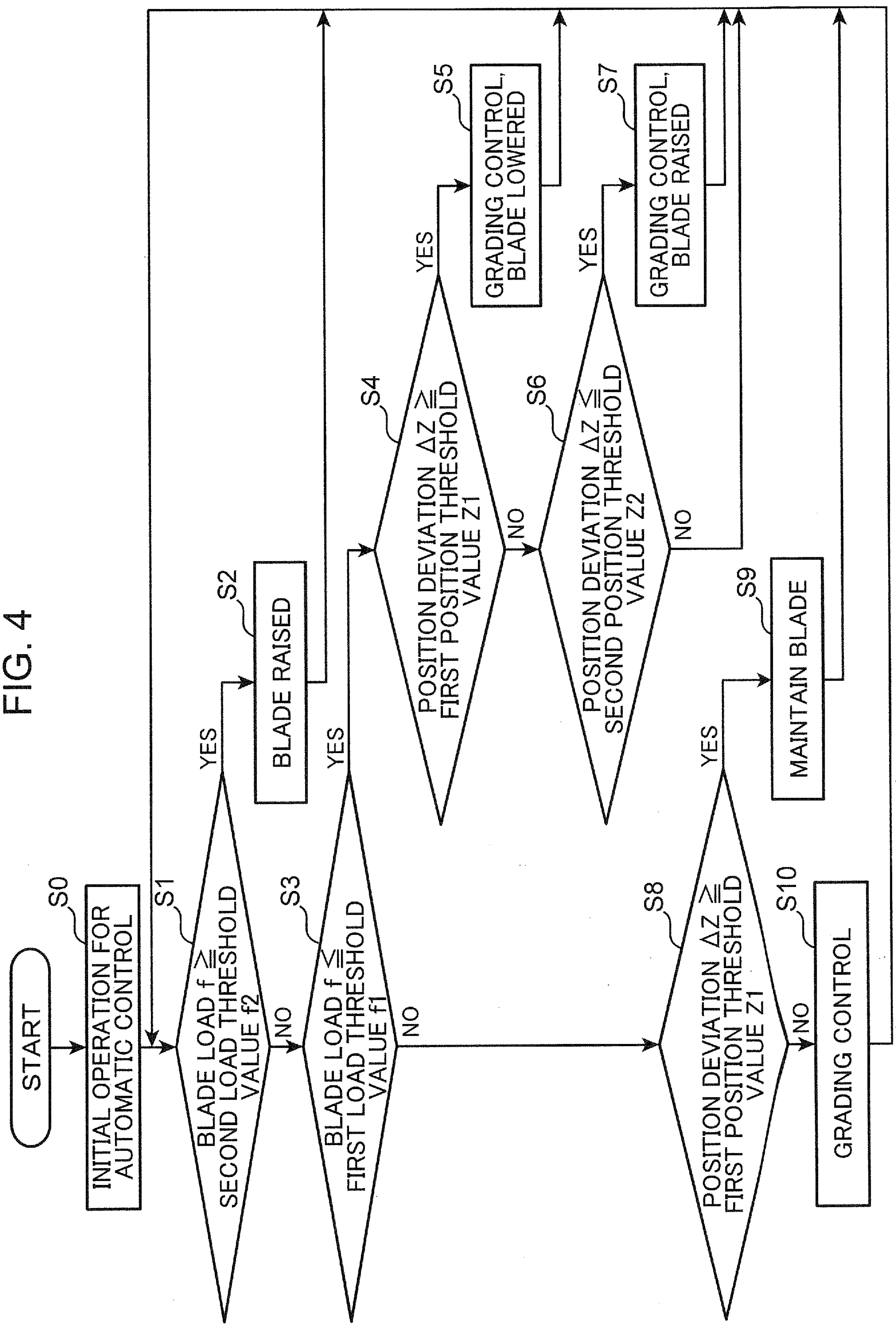

START
S0
INITIAL OPERATION FOR AUTOMATIC CONTROL
S1
BLADE LOAD f ≧ SECOND LOAD THRESHOLD VALUE f2
YES
NO
S2
BLADE RAISED
S3
BLADE LOAD f ≦ FIRST LOAD THRESHOLD VALUE f1
YES
NO
S4
POSITION DEVIATION ΔZ ≧ FIRST POSITION THRESHOLD VALUE Z1
YES
NO
S5
GRADING CONTROL, BLADE LOWERED
S6
POSITION DEVIATION ΔZ ≦ SECOND POSITION THRESHOLD VALUE Z2
YES
NO
S7
GRADING CONTROL, BLADE RAISED
S8
POSITION DEVIATION ΔZ ≧ FIRST POSITION THRESHOLD VALUE Z1
YES
NO
S9
MAINTAIN BLADE
S10
GRADING CONTROL

FIG. 5

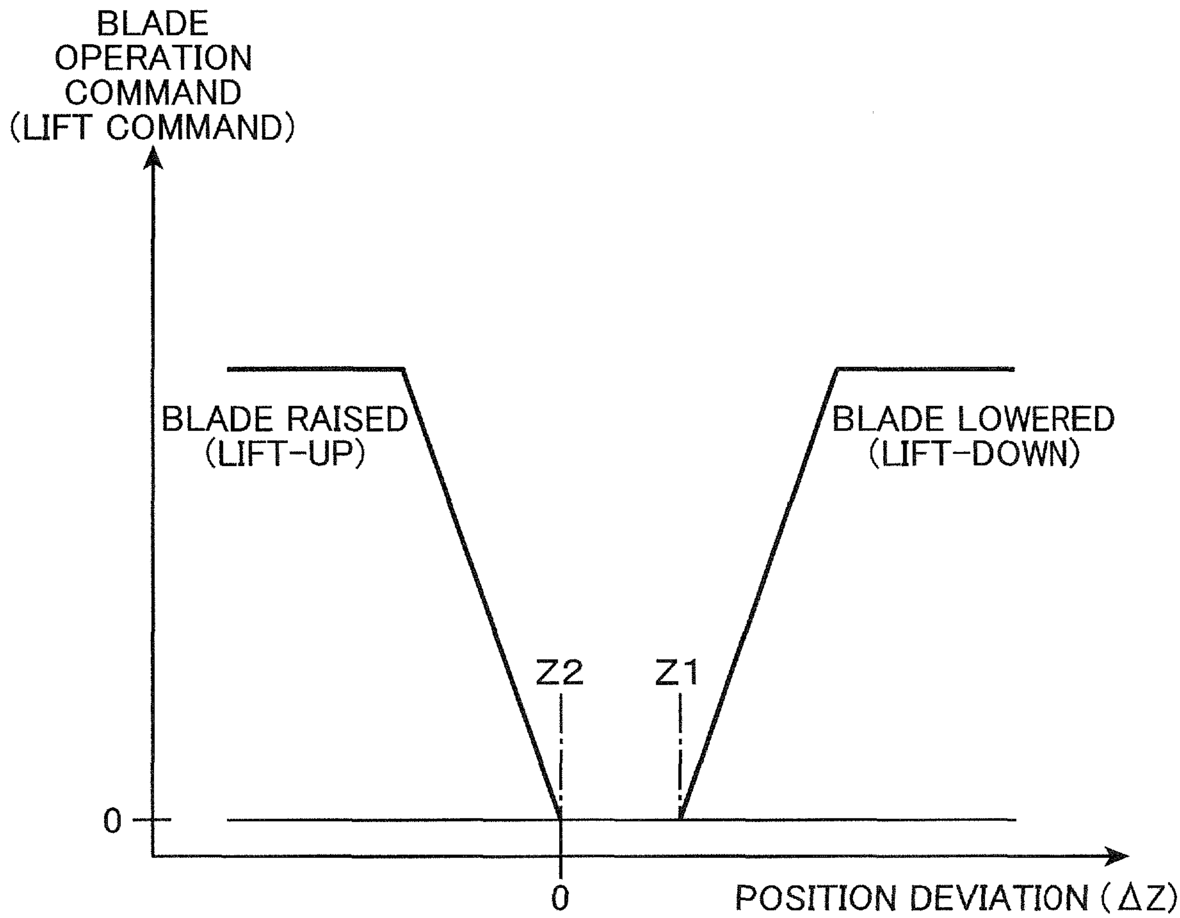

BLADE
OPERATION
COMMAND
(LIFT COMMAND)
BLADE RAISED
(LIFT-UP)
BLADE LOWERED
(LIFT-DOWN)
Z2
Z1
0
0
POSITION DEVIATION (ΔZ)

FIG. 6

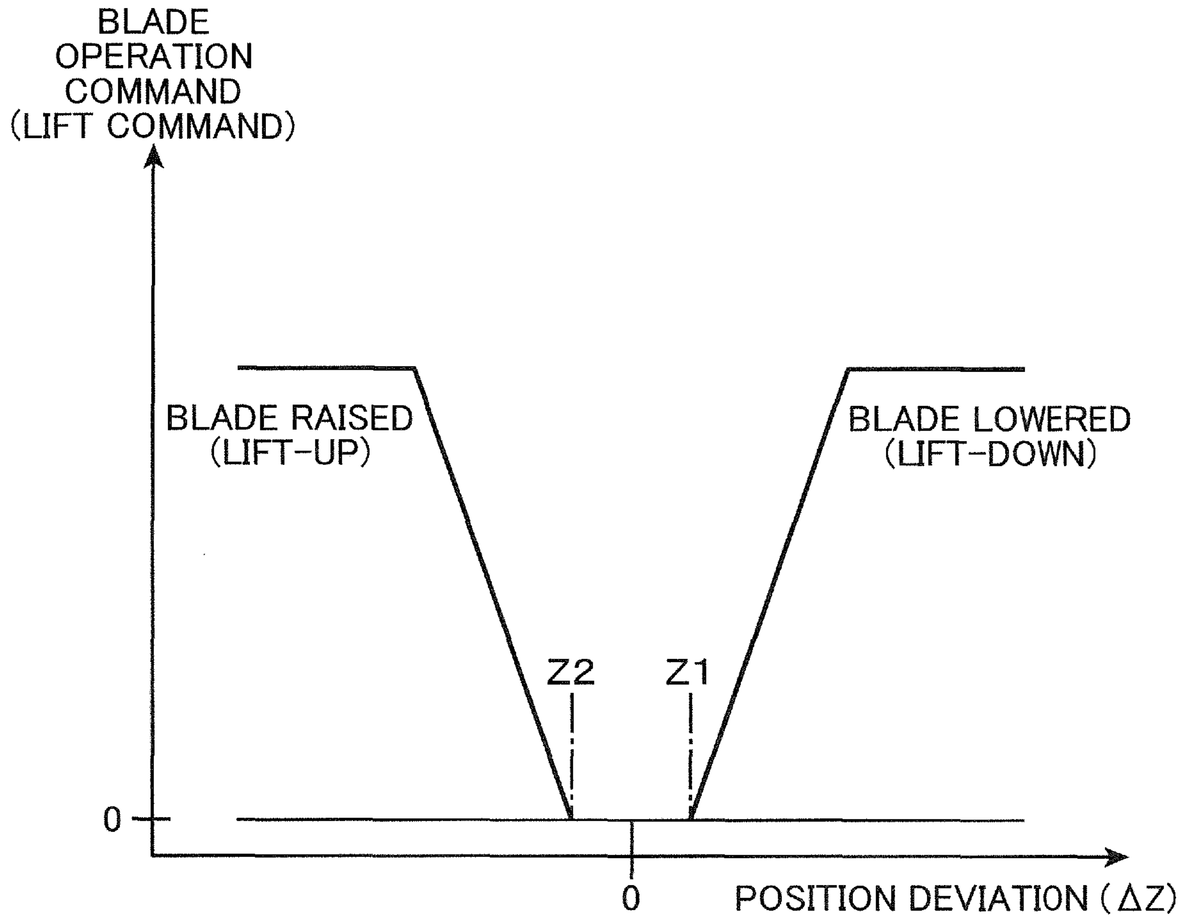

BLADE
OPERATION
COMMAND
(LIFT COMMAND)
BLADE RAISED
(LIFT-UP)
BLADE LOWERED
(LIFT-DOWN)
Z2
Z1
0
0
POSITION DEVIATION (ΔZ)

FIG. 7

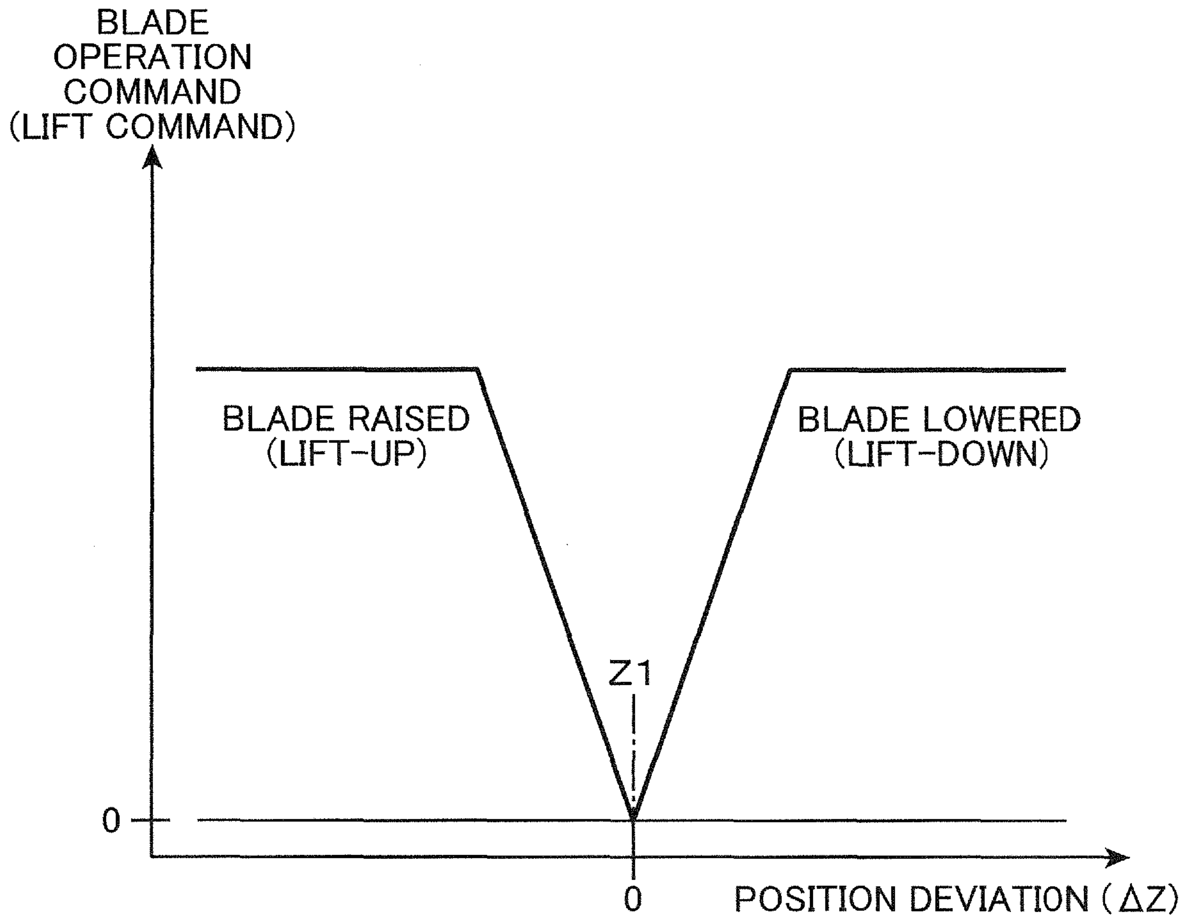
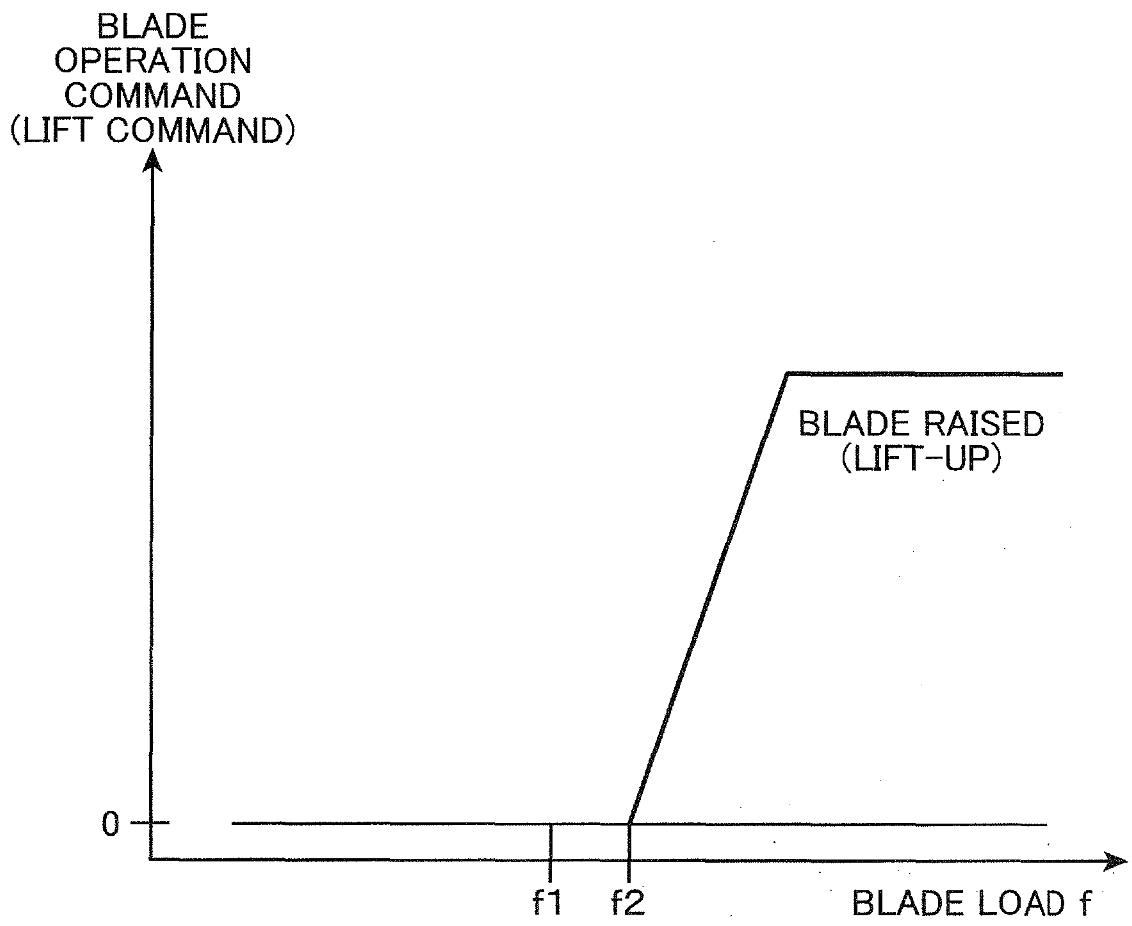

BLADE
OPERATION
COMMAND
(LIFT COMMAND)
BLADE RAISED
(LIFT-UP)
BLADE LOWERED
(LIFT-DOWN)
Z1
0
0
POSITION DEVIATION (ΔZ)

FIG. 8


BLADE
OPERATION
COMMAND
(LIFT COMMAND)
BLADE RAISED
(LIFT-UP)
0
f1
f2
BLADE LOAD f

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/031264

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. E02F3/85(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl. E02F3/85

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	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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 2017-521580 A (CATERPILLAR INC.) 03 August 2017, paragraphs [0010]-[0064], fig. 1-7 & US 2015/0361640 A1, paragraphs [0016]-[0070], fig. 1-7 & WO 2015/191224 A1	1-4
A	WO 2013/051379 A1 (KOMATSU LTD.) 11 April 2013, paragraphs [0018]-[0083], fig. 1-7 & US 2013/0090817 A1, paragraphs [0027]-[0091], fig. 1-7 & CN 103154385 A	1-4

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

* Special categories of cited documents:
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"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
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"&" 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 October 2019 (18.10.2019)	29 October 2019 (29.10.2019)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/031264

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 5247939 B1 (KOMATSU LTD.) 24 July 2013, paragraphs [0019]-[0087], fig. 1-9 & US 2013/0081831 A1, paragraphs [0033]-[0100], fig. 1-9 & WO 2013/047187 A1 & CN 103119224 A	1-4

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 5247939 B **[0005]**