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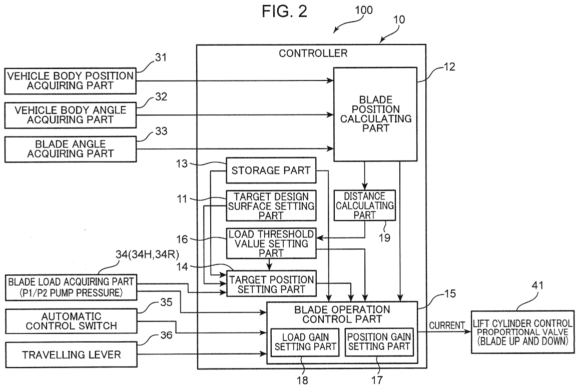
(54) **BLADE CONTROL DEVICE FOR WORK MACHINERY**

(57) In a blade control device (100), a blade operation control part (15) outputs a command for raising and lowering a blade (4) such that a position deviation (Δx) between a blade position (x) calculated by a blade position calculating part (12) and a blade target position (xref) approaches zero in a case where a blade load (f) is equal to or less than a second load threshold value (f2), and outputs a command for raising the blade (4) in a case where the blade load (f) is greater than the second load threshold value (f2). In a case where an update condition is satisfied, the update condition being set in advance so as to associate the blade load (f) and a first load threshold value (fl) with each other, a target position setting part (14) updates the blade target position (xref) using the blade position (x) obtained when the update condition is satisfied as a reference.

FIG. 2



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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, land grading, transport of sediments, and the like has been used widely. Patent Literature 1 discloses a load control device for a bulldozer, the load control device automatically controlling raising and lowering operation of a blade such that a blade load applied on the blade becomes substantially constant. The load control device recited in Patent Literature 1, however, has a problem of waviness of an execution surface generated due to raising and lowering operation of a blade.

[0003] Patent Literature 2 discloses a blade control device intended to cope with the above-described problem of Patent Literature 1. Patent Literature 2 discloses that the blade is controlled so as not to be closer to the designed surface than the virtual designed surface is, and can be inhibited from being greatly lowered, and discloses that continuous undulations can be thereby inhibited from being formed on the digging surface. In the blade control device recited in Patent Literature 2, in a case where a blade load is smaller than a first set load value, the blade is lowered and in a case where the blade load is greater than a second set load value which is greater than the first set load value, the blade is raised. In other words, in the blade control device recited in Patent Literature 2, raising and lowering operation of the blade is controlled on the basis of comparison between the blade load and the first set load value and the second set load value.

[0004] Since in such blade control device recited in Patent Literature 2 as described above, when the blade is above the virtual design surface, raising and lowering operation of the blade is controlled on the basis of a blade load but not on the basis of a blade position, waviness of an execution surface greatly depends on an increase and a decrease of the blade load. In the blade control device of Patent Literature 2, therefore, an effect of suppressing waviness of the execution surface is limitative and cannot be always considered sufficient.

Citation List

Patent Literature

[0005]

Patent Literature 1: JP 3537182 B
Patent Literature 2: JP 5285805 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 controls raising and lowering operation of the blade, the blade control device being capable of effectively suppressing waviness of an execution surface.

[0007] There is provided 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 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 in a global coordinate system on the basis of the position information acquired by the position information acquiring part; 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 and a second load threshold value which is a threshold value of the blade load and is greater than the first load threshold value; a target position setting part which sets a blade target position that is a position as a target of the blade position and that is a position above the target design surface; and a blade operation control part which outputs a command for raising and lowering the blade such that a position deviation as a deviation between the blade position calculated by the blade position calculating part and the blade target position approaches zero in a case where the blade load acquired by the blade load acquiring part is equal to or less than the second load threshold value, and outputs a command for raising the blade in a case where the blade load acquired by the blade load acquiring part is greater than the second load threshold value, in which in a case where an update condition is satisfied, the update condition being set in advance so as to associate the blade load and the first load threshold value with each other, the target position setting part updates the blade target position using the blade position obtained when the update condition is satisfied as a reference.

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.

FIG. 3 is a graph showing a relationship among a blade position, a blade target position, and raising and lowering operation of the blade in the blade control device.

FIG. 4 is a graph showing a relationship among a blade load, a first load threshold value, a second load threshold value, and the raising and lowering operation of the blade in the blade control device.

FIG. 5 is a flowchart showing one example of control operation to be executed by a controller included in the blade control device.

FIG. 6 is a graph showing a target track (target path) of a blade load and a change of an actual blade load in the blade control device.

FIG. 7 is one example of a time chart for explaining the blade target position to be updated on the basis of a blade load in the blade control device.

FIG. 8 is another example of a time chart for explaining the blade target position to be updated on the basis of a blade load in the blade control device.

FIG. 9 is a schematic view for explaining updating of the first load threshold value on the basis of a distance between a vehicle body position of a machine body and a target design surface in the blade control device.

FIG. 10 is a graph for explaining updating of the first load threshold value on the basis of a distance between the vehicle body position of the machine body and the target design surface in the blade control device.

FIG. 11 is a graph for explaining updating of a position gain on the basis of a deviation between the blade position and the blade target position in the blade control device.

FIG. 12 is a graph for explaining updating of a load gain on the basis of a deviation between a blade load and a second load threshold value in the blade control device.

FIG. 13 is a schematic view in which an execution surface executed by the work machine provided with the blade control device and an execution surface executed by a conventional work machine are compared.

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 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, land 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 position of the machine body 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 an angle of the machine body. The vehicle body angle acquiring part 32 is configured with, for example, a vehicle body angle sensor which detects an angle of the machine body (an angle of the vehicle body 3 in the present embodiment) 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 target position setting part 14, a blade operation control part 15, a load threshold value setting part 16, a position gain setting part 17, a load gain setting part 18, and a distance calculating part 19 as a function for executing the automatic control.

[0026] The target design surface setting part 11 sets a target design surface (see FIG. 9) which specifies a target shape of an object to be dug by the blade 4. The target design surface setting part 11 may store 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 setting part 11 inputs the set target design surface to the target position setting part 14. 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 x 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 x on the basis of the vehicle body position acquired by the vehicle body position acquiring part 31, the angle of the machine body 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 x 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 x is thus calculated from a relative angle between the angle of the machine body and the angle of the blade 4 in the global coordinate system, a calculation method for the blade position x is not limited thereto. The blade position x 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] Although in the present embodiment, the blade position x 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, the blade position may be set at other part of the blade 4.

[0029] The storage part 13 stores a first load threshold value f1 as a threshold value of the blade load f and a second load threshold value f2 which is a threshold value of the blade load f and is greater than the first load threshold value f1. 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 prevent occurrence of such a situation that the blade load f becomes excessively large to cause a stuck state. In other words, the second load threshold value f2 is a value set to realize stable and efficient digging operation. These load threshold values f1 and f2 may be manually input to the controller 10 by a worker before the digging work or appropriately calculated by the controller 10 and stored during the digging work.

[0030] The storage part 13 also stores an update condition set in advance. The update condition is a condition set in advance in which the blade load f and the first load threshold value are associated with each other and which is used as a reference for determining whether the target position setting part 14 should update the blade target position xref or not. The update condition includes a condition that the blade load f approaches the first load threshold value f1 and a deviation therebetween becomes sufficiently small. In the present embodiment, the update condition includes a condition that the blade load f reaches the first load threshold value f1, or a condition that the blade load f reaches a determination value which is set on the basis of the first load threshold value f1 for determining whether the blade load f has neared the first load threshold value f1. The determination value is a value by which determination is possible that a deviation (f - f1) obtained by subtracting the first load threshold value f1 from the blade load f becomes sufficiently small. The determination value is a threshold value set in advance through simulation, experiment, or the like.

[0031] The storage part 13 also stores a target track (see FIG. 6 to be described later). The target track is a target for an increase process of the blade load f when the blade load f approaches the first load threshold value f1 while being increased. The target track is set in advance for controlling the raising and lowering operation of the blade 4 such that in a case where the blade target position xref is not set at the start of the digging work when the automatic control mode is selected, the blade load f is increased up to the first load threshold value f1 while following a preferable increase process.

[0032] The target position setting part 14 sets the blade target position xref which is a position as a target for the blade position x and is a position above the target design surface. The target position setting part 14 sets the blade target position xref on the basis of, for example, the blade load f and the blade position x.

[0033] The load threshold value setting part 16 sets the first load threshold value f1. The position gain setting part 17 sets the position gain kx. The load gain setting part 18 sets the load gain kf. These load threshold value setting part 16, position gain setting part 17, and load gain setting part 18 will be detailed later.

[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. Specifically, the operation is conducted in the following manner.

[0035] FIG. 3 is a graph showing a relationship among the blade position x, the blade target position xref, and the raising and lowering operation of the blade 4 in the blade control device 100. The blade operation control part 15 calculates and outputs a command (command value) for raising and lowering the blade 4 such that a position deviation Δx approaches zero, the position deviation Δx being a deviation between the blade position x calculated by the blade position calculating part 12 and the blade target position xref.

[0036] Control of the blade position x is feedback control in which an amount of control is changed according to an amount of the position deviation Δx which is a deviation between the blade position x and the blade target position xref. Specifically, the blade operation control part 15 calculates and outputs the command on the basis of a function having a term including, as a variable, the position deviation Δx which is an elevation difference between the blade position x and the blade target position xref and including the position gain kx by which the position deviation Δx is multiplied. In FIG. 3, the blade target position xref is at a position corresponding to an origin point on a lateral axis in the graph and is given a hysteresis for suppressing hunting. In other words, in a case where the blade position x is included in a predetermined range (e.g. a range of the blade target position xref $\pm\alpha$ as shown in FIG. 3) with respect to the blade target position xref as a reference, the blade operation control part 15 refrains from controlling the blade position x.

[0037] FIG. 4 is a graph showing a relationship among the blade load f, the first load threshold value f1, the second load threshold value f2, and the raising and lowering operation of the blade 4 in the blade control device 100. As shown in FIG. 4, in a case where the blade load f acquired by the blade load acquiring part 34 is greater than the second load threshold value f2, the blade operation control part 15 calculates and outputs a command (command value) for raising the blade 4. Specifically, the blade operation control part 15 calculates and outputs the command on the basis of, for example, a function having a term including, as a variable, a load deviation Δf which is a deviation (f - f2) obtained by subtracting the second load threshold value f2 from the blade load f and including the load gain kf by which the load deviation Δf is multiplied.

[0038] In the present embodiment, such position control of the blade 4 as shown in FIG. 3 is given priority. Meanwhile, in a case where the blade load f is greater than the second load threshold value f2, the blade position is controlled so as to quickly raise the blade 4. Such control as gives priority to the position control enables stable and efficient digging operation while suppressing waviness of an execution surface.

[0039] 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. 5.

[0040] The controller 10 determines whether the automatic control switch 35 is on or not, i.e., the automatic control mode is selected or not (Step S1). In a case where the automatic control mode is not selected (NO in Step S1), the controller 10 finishes the processing without conducting control of the automatic control mode.

[0041] In a case where the automatic control mode is selected (YES in Step S1), the controller 10 takes in a signal to be input to the controller 10, to be specific, a detection signal of each sensor and designation signals (Step S2). 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 an angle of the machine body 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.

[0042] Next, the controller 10 determines whether the blade target position xref is set or not (Step S3). In a case where the blade target position xref is not set (NO in Step S3), the blade operation control part 15 outputs a command for raising and lowering the blade 4 such that the blade load f approaches the first load threshold value f1 while following an increase process close to the target track (Step S4). Although setting of the target track is not essential in the blade control device of the present invention, setting the target track and controlling the blade position x on the basis of the target track as in the present embodiment has the following merits. Specifically, the merits are as follows.

[0043] FIG. 6 is a graph showing a target track (target path) of the blade load f and a change of an actual blade load f in the blade control device 100. In FIG. 6, a curved line indicated by a chain line represents the target track (target path) and a curved line indicated by a solid line represents a change of an actual blade load f.

[0044] In a case where such a target track as shown in FIG. 6 is not set, when the digging work is started at a stage prior to setting of the blade target position xref, the blade 4 enters into the ground at a high lowering speed in some cases, so that a depth of entering of the blade 4 into the ground when the blade load f reaches the first load threshold value f1 is likely to be increased. In such a case, an amount of soil on the blade 4 might change greatly with respect to a travel distance of the hydraulic excavator 1 and the blade load f might also change greatly in some cases.

[0045] On the other hand, in a case where the target track shown in FIG. 6 is set as in the present embodiment, since at a stage prior to setting of the blade target position xref, the blade load f approaches the first load threshold value f1 while following an increase process close to the target track, the blade 4 enters the ground at a moderate lowering speed, resulting in suppressing an increase in a depth of entering of the blade 4 into the ground when the blade load f reaches the first load threshold value f1. This causes an amount of soil on the blade 4 to change little with respect to a travel distance of the hydraulic excavator 1 and causes the blade load f to also change little. As a result, an effect of suppressing waviness of an execution surface can be further enhanced. Any target track (target path) can be used that enables the blade load f to be controlled such that the blade load f gradually approaches the first load threshold value f1 as described above, and a target track is not specifically limited. The target track (target path) may be provided by a function representing, for example, a curved line path which is indicated by a chain line in FIG. 6 and in which the blade load f gradually approaches the first load threshold value f1. The target track (target path) may be also provided by a function representing a straight path (linear function), and may be further provided by a function representing a combination of a curved line path and a straight path.

[0046] Then, in the present embodiment, when the condition is satisfied, the condition being that the blade load f approaches the first load threshold value f1 while following the increase process close to the target track and the load deviation as a deviation therebetween becomes sufficiently small, the target position setting part 14 sets the blade target position xref. In the present embodiment, the condition is that the blade load f reaches the first load threshold value f1, more specifically, that the load deviation which is the deviation (f - f1) of these loads becomes a positive value from a negative value. In the present embodiment, the blade target position xref set by the target position setting part 14 is set at a position passing the blade position x when the condition is satisfied, the position being on a plane parallel to the target design surface. After the blade target position xref is set, the blade operation control part 15 controls the raising and lowering operation of the blade 4 such that the position deviation Δx between the blade position x and the blade target position xref approaches zero.

[0047] Next, the controller 10 compares the blade load f acquired by the blade load acquiring part 34 and a flag threshold value as a threshold value set in advance (Step S5). In the present embodiment, although the flag threshold value is the same as the second load threshold value f2, the flag threshold value is not limited thereto and may be different from the second load threshold value f2. The flag threshold value, however, should be set to be any value greater than the first load threshold value f1.

[0048] In a case where the blade load f is greater than the second load threshold value f2 (flag threshold value) ($f > f2$, NO in Step S5), the storage part 13 stores a first state (an update flag = 1) indicating allowance of update of the blade target position xref (Step S6). On the other hand, in a case where the blade load f is equal to or less than the second load threshold value f2 (flag threshold value) ($f \leq f2$, YES in Step S5), storage of the update flag is not changed.

[0049] Next, the controller 10 determines whether a condition (update condition) is satisfied or not, the condition including that the first state is stored in the storage part 13 (the update flag = 1) and that the blade load f reaches the first load threshold value f1 (Step S7). Specifically, in the present embodiment, the controller 10 determines whether an update condition is satisfied or not, the update condition including a first condition that the first state is stored in the storage part 13 (the update flag =1), a second condition that the blade load f acquired this time by the blade load acquiring part 34 is greater than the first load threshold value f1 ($f > f1$), and a third condition that the blade load f acquired last time by the blade load acquiring part 34 is smaller than the first load threshold value f1 ($f < f1$) (Step S7).

[0050] In a case where the update condition is satisfied (YES in Step S7), the target position setting part 14 updates the blade target position xref (Step S8). In the present embodiment, the blade target position xref to be updated by the target position setting part 14 is set at a position passing the blade position x when the update condition is satisfied, the position being on the plane parallel to the target design surface. When the blade target position xref is updated, the storage part 13 stores a second state (the update flag = 0) indicating non-allowance of update of the blade target position xref in place of the first state (Step S8).

[0051] The processing of Steps S5 to S8 will be specifically described with reference to FIG. 7. FIG. 7 is one example of a time chart for explaining the blade target position xref to be updated on the basis of the blade load f in the blade control device 100.

[0052] At times t1 and t2 shown in FIG. 7, the second condition and the third condition included in the update condition are satisfied. However, since at times t1 and t2, the storage part 13 stores the second state (the update flag = 0) indicating non-allowance of update of the blade target position xref, the first condition included in the update condition is not satisfied. Accordingly, since at the times t1 and t2, the update condition is not satisfied (NO in Step S7), the target position setting part 14 refrains from updating the blade target position xref.

[0053] On the other hand, since at time t3 shown in FIG. 7, the blade load f becomes greater than the second load threshold value f2 (flag threshold value) and the storage part 13 stores the first state (the update flag = 1) (Step S6), all conditions included in the update condition are satisfied (YES in Step S7) at time t4. Accordingly, at time t4, the target position setting part 14 updates the blade target position xref.

[0054] Update of the blade target position xref is not limited to the mode shown in FIG. 7. FIG. 8 is another example of a time chart for explaining the blade target position xref to be updated on the basis of the blade load f. In the mode shown in FIG. 8, the update condition does not include the first condition and includes the second condition and the third condition among the first condition, the second condition, and the third condition. In the mode shown in FIG. 8, at time when the update condition is satisfied, i.e., at times t1, t2, and t4 when the second condition and the third condition are satisfied, the target position setting part 14 updates the blade target position xref.

[0055] In the mode shown in FIG. 7, since while when the update flag for the blade target position xref is in the first state (the update flag = 1), update of the blade target position xref is allowed, when the update flag is in the second state (the update flag = 0), update of the blade target position xref is not allowed, frequent update of the blade target position xref can be suppressed.

[0056] Next, the blade operation control part 15 calculates a command value to the lift cylinder control proportional valve 41 for controlling operation of the lift cylinder 8 (Step S9). The blade operation control part 15 determines whether the command value is equal to or less than an upper limit value set in advance or not (Step S10). In a case where the command value is equal to or less than the upper limit value set in advance (YES in Step S10), the blade operation control part 15 outputs the command value and the output command value is input to the proportional valve 41 (see FIG. 2), so that the control is applied (Step S12). On the other hand, in a case where the command value is greater than the upper limit value set in advance (NO in Step S10), using a command value cut off to the upper limit value as a command value (Step S11), the blade operation control part 15 outputs the cut off command value and the output command value is input to the proportional valve 41 (see FIG. 2), so that the control is applied (Step S12).

[0057] In the present embodiment, the command value to be calculated by the blade operation control part 15 in Step S9 is calculated on the basis of, for example, a function represented by Formula (1) below.

$$\text{Command value} = k\,x\,(\Delta x) \times \Delta x + kf\,(\Delta f) \times \Delta f \ldots (1)$$

[0058] The function represented by the above Formula (1) has a term including, as a variable, a position deviation Δx as an elevation difference between the blade position x and the blade target position xref and also including a position gain kx by which the position deviation Δx is multiplied, and a term including, as a variable, a load deviation Δf which is a deviation (f - f2) obtained by subtracting the second load threshold value f2 from the blade load f and also including a load gain kf by which the load deviation is multiplied.

[0059] FIG. 9 is a schematic view for explaining updating of the first load threshold value f1 on the basis of a distance between a vehicle body position of the machine body and a target design surface in the blade control device 100, and FIG. 10 is a graph for explaining the updating.

[0060] As shown in FIG. 9 and FIG. 10, the load threshold value setting part 16 is configured to update the first load threshold value f1 such that the first load threshold value f1 becomes smaller when a body distance Z is a second distance Z2 than when the body distance Z is a first distance Z1, the body distance Z being a distance between the vehicle body position acquired by the vehicle body position acquiring part 31 and the target design surface, the second distance Z2 being smaller than the first distance Z1. The distance calculating part 19 calculates the body distance Z on the basis of the target design surface and the vehicle body position.

[0061] In such present embodiment as described above, the blade load f is more liable to reach the first load threshold value f1 in a case where the body distance Z is the second distance Z2 (i.e., in a case where the machine body is close to the target design surface) as compared with a case where the body distance Z is the first distance Z1 (i.e., in a case where the machine body is away from the target design surface). In the specific example of FIG. 9, since the second distance Z2 is smaller than the first distance Z1, a distance ΔZ2 between the vehicle body position and the blade target position xref in the former case is smaller than a distance ΔZ1 between the vehicle body position and the blade target position xref in the latter case. This mode increases the update frequency of the blade target position xref and increases a possibility that the blade target position xref is set at a more proper position corresponding to a state of the ground as a digging target.

[0062] Specific examples of the present mode include the following. For example, the first load threshold value f1 at the time of execution of grading operation at a final stage of work by the hydraulic excavator 1 is set to be a value smaller than the first load threshold value f1 at the time of execution of digging operation at an initial stage or an intermediate stage of the work. In such a case, it is possible to execute, by using the same control algorithm, both the digging operation in which more importance is applied to quick digging work than in grading operation, and the grading operation in which much importance is applied to precision in causing an execution surface to approach a target design surface.

[0063] In the present embodiment, the load threshold value setting part 16 updates the first load threshold value f1 such that the first load threshold value f1 becomes smaller as the body distance Z becomes smaller in a part of the entire range of the body distance Z, the part including the first distance Z1 and the second distance Z2 as shown in FIG. 10. Then, the load threshold value setting part 16 refrains from updating the first load threshold value f1 in a range where the body distance Z is greater than the part of the range and in a range where the body distance Z is smaller than the part of the range. Update of the first load threshold value f1 is, however, not limited to the specific example shown in FIG. 10.

[0064] FIG. 11 is a graph for explaining updating of the position gain kx on the basis of the position deviation Δx as a deviation (x-xref) between the blade position x and the blade target position xref in the blade control device 100.

[0065] As shown in FIG. 11, in a case where the blade position x is below the blade target position xref, the position gain setting part 17 updates the position gain kx such that a raising speed of the blade 4 is increased on the basis of the position deviation Δx. In this mode, since in a case where the blade position x is below the blade target position xref, the raising speed of the blade 4 is increased, an effect of suppressing digging of the ground as a digging target to a position below the blade target position xref is further enhanced, resulting in further enhancing an effect of suppressing digging of the ground to a position below a target design surface.

[0066] Additionally, in a case where the blade load f is greater than the second load threshold value f2 (YES in Step S5), the blade operation control part 15 outputs a command value for raising the blade 4. FIG. 12 is a graph for explaining updating of the load gain kf on the basis of the deviation Δf between the blade load f and the second load threshold value f2 in the blade control device 100.

[0067] As shown in FIG. 12, in a case where the blade load f is greater than the second load threshold value f2, the load gain setting part 18 updates the load gain kf such that the raising speed of the blade 4 is increased on the basis of the load deviation Δf. Since this increases the raising speed of the blade 4 in a case where the blade load f is greater than the second load threshold value f2, it is possible to further enhance an effect of more quickly reducing the blade load f to prevent a stuck state and the like caused by an excessive load, thereby enabling stable travel of the hydraulic excavator 1.

[0068] According to the foregoing-described device, it is possible to more effectively suppress waviness of an execution surface executed by the hydraulic excavator 1 provided with the blade control device 100 according to the present embodiment than waviness of an execution surface executed by a conventional hydraulic excavator 1, as shown, for example, in FIG. 13.

[0069] The present invention is not limited to the above-described embodiment. The present invention may include the following modes, for example.

[0070] 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 other work machines each provided with a blade, such as a wheel loader, a bulldozer, and a grader.

[0071] As described in the foregoing, there is provided a blade control device capable of effectively suppressing waviness of an execution surface.

[0072] There is provided 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 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 in a global coordinate system on the basis of the position information acquired by the position information acquiring part; 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 and a second load threshold value which is a threshold value of the blade load and is greater than the first load threshold value; a target position setting part which sets a blade target position that is a position as a target of the blade position and that is a position above the target design surface; and a blade operation control part which outputs a command for raising and lowering the blade such that a position deviation as a deviation between the blade position calculated by the blade position calculating part and the blade target position approaches zero in a case where the blade load acquired by the blade load acquiring part is equal to or less than the second load threshold value, and outputs a command for raising the blade in a case where the blade load acquired by the blade load acquiring part is greater than the second load threshold value, in which in a case where an update condition is satisfied, the update condition being set in advance so as to associate the blade load and the first load threshold value with each other, the target position setting part updates the blade target position using the blade position obtained when the update condition is satisfied as a reference.

[0073] In a case where a blade load is greater than the second load threshold value, the blade control device conducts control to raise the blade, thereby preventing a stuck state and the like caused by an excessive load and enabling stable travel of the work machine. On the other hand, in a case where a blade load is equal to or less than the second load threshold value, the blade control device controls raising and lowering operation of the blade such that the position deviation between the blade position and the blade target position approaches zero. Also in a case where a blade load is equal to or less than the second load threshold value, conducting position control of the blade such that the position deviation approaches zero enables waviness of an execution surface to be suppressed more effectively than in such a device as recited in the above Patent Literature 2, in which raising and lowering operation of a blade is controlled on the basis of a blade load also in a case where a blade load is equal to or less than the second set load value. Then, such effective suppression of waviness of an execution surface improves efficiency of digging work.

[0074] Additionally, in the blade control device, the first load threshold value is set to a value corresponding to a proper blade load with which the work machine can stably travel. Then, the update condition is set in advance in which the actual blade load varying during digging work and the first load threshold value corresponding to a proper blade load are associated with each other. Then, since the blade target position is updated using, as a reference, a blade position when the update condition is satisfied, the blade target position will be associated with a blade position at which a blade load is proper. Accordingly, repeated update of the blade target position during the digging work allows a blade load during the digging work to be stable irrespective of a state (e.g. hardness of sediments, a kind of sediments, etc.) of the ground as a digging target.

[0075] Additionally, in the blade control device, the second load threshold value is a value set for preventing occurrence of a stuck situation caused by an excessive blade load and is a value greater than the first load threshold value. In the blade control device, in a case where a blade load becomes greater than the second load threshold value, control to raise the blade is conducted. This causes reduction in a blade load to prevent a stuck state and the like caused by an excessive load, thereby enabling stable travel of the work machine as described above.

[0076] From the foregoing, the blade control device enables waviness of an execution surface to be effectively suppressed, and besides, enables stable and efficient digging operation of a work machine.

[0077] In the blade control device, the update condition preferably includes a condition that the blade load reaches the first load threshold value, or a condition that the blade load reaches a determination value for determining whether the blade load has neared the first load threshold value or not, the determination value being set on the basis of the first load threshold value. In this mode, since the blade target position is updated using, as a reference, a blade position obtained when the blade load reaches or nears the first load threshold value, the blade target position is substantially matched with a blade position when the blade load is proper. Accordingly, a blade load during the digging work is more liable to be stabilized.

[0078] In the blade control device, the storage part may be configured to store a first state indicating allowance of update of the blade target position when the blade load becomes greater than a flag threshold value as a threshold value set in advance, and also store a second state indicating non-allowance of update of the blade target position in place of the first state when the blade target position is updated, and the update condition may include a condition that the blade load reaches the first load threshold value when the first state is stored in the storage part, or a condition that the blade load reaches a determination value when the first state is stored in the storage part, the determination value being set on the basis of the first load threshold value for determining whether the blade load has neared the first load threshold value or not. In this mode, since while update of a blade target position is allowed when the update flag for the blade target position is in the first state, update of the blade target position is not allowed when the update flag is in the second state, frequent update of the blade target position can be suppressed.

[0079] In the blade control device, the blade target position to be updated by the target position setting part is preferably set at a position which passes the blade position when the update condition is satisfied and is on a plane parallel to the target design surface. In this mode, since raising and lowering operation of the blade is controlled such that the position deviation between a blade target position set at a position on a plane parallel to the target design surface and the blade position approaches zero, efficiency of digging work for causing an execution surface to approach a target design surface is further improved.

[0080] The blade control device may be configured such that the storage part stores a target track as a target for an increase process of the blade load when the blade load approaches the first load threshold value while being increased, and the blade operation control part outputs a command for raising and lowering the blade such that the blade load approaches the first load threshold value while following an increase process close to the target track before the blade target position is set by the target position setting part. In a case where the target track is set as in the this mode, since at a stage prior to setting of the blade target position, the blade load approaches the first load threshold value while following an increase process close to the target track, the blade enters the ground at a moderate lowering speed, resulting in suppressing an increase in a depth of entering of the blade into the ground when the blade load reaches the first load threshold value. This causes an amount of soil on the blade to change little with respect to a travel distance of the work machine and also causes the blade load to change little. As a result, an effect of suppressing waviness of an execution surface can be further enhanced. Then, in the present mode, when the update condition is satisfied, the condition being that the blade load reaches or nears the first load threshold value while following the increase process close to the target track, the target position setting part sets the blade target position. Then, after the blade target position is set, the blade operation control part controls the raising and lowering operation of the blade such that the position deviation between the blade position and the blade target position approaches zero.

[0081] The blade control device may be configured to further include a load threshold value setting part which sets the first load threshold value, and such that the position information acquiring part includes a vehicle body position acquiring part which acquires a vehicle body position as a position of the machine body, and the load threshold value setting part updates the first load threshold value such that the first load threshold value becomes smaller when a body distance is a second distance than when the body distance is a first distance, the body distance being a distance between the vehicle body position acquired by the vehicle body position acquiring part and the target design surface, the second distance being smaller than the first distance. In this mode, the blade load is more liable to reach the first load threshold value in a case where the body distance is the second distance (i.e., in a case where the machine body is close to the target design surface) as compared with a case where the body distance is the first distance (i.e., in a case where the machine body is away from the target design surface). This increases the update frequency of the blade target position and increases a possibility that the blade target position is set at a more proper position corresponding to a state of the ground as a digging target. Specific examples of the present mode include the following. For example, the first load threshold value at the time of execution of grading operation at a final stage of work by the work machine is set to be a value smaller than the first load threshold value at the time of execution of digging operation at an initial stage or an intermediate stage of the work. In such a case, it is possible to execute, by using the same control algorithm, both the digging operation in which more importance is applied to quick digging work than in grading operation, and the grading operation in which much importance is applied to precision in causing an execution surface to approach a target design surface.

[0082] It is preferable that in the blade control device, the blade operation control part outputs the command on the basis of a function having a term including, as a variable, a position deviation which is an elevation difference between the blade position and the blade target position and including a position gain by which the position deviation is multiplied, the blade control device further including a position gain setting part which sets the position gain, in which in a case where the blade position is below the blade target position, the position gain setting part updates the position gain such that a raising speed of the blade is increased on the basis of the position deviation. In this mode, since in a case where the blade position is below the blade target position, the raising speed of the blade is increased, the effect of suppressing digging of the ground as a digging target to a position below the blade target position is further enhanced, resulting in further enhancing the effect of suppressing digging of the ground to a position below a target design surface.

[0083] It is preferable that in the blade control device, the function further has a term including, as a variable, a load deviation which is a deviation obtained by subtracting the second load threshold value from the blade load and including a load gain by which the load deviation is multiplied, the blade control device further including a load gain setting part which sets the load gain, in which in a case where the blade load is greater than the second load threshold value, the load gain setting part updates the load gain such that the raising speed of the blade is increased on the basis of the load deviation. In this mode, since the raising speed of the blade is increased in a case where the blade load is greater than the second load threshold value, it is possible to further enhance the effect of more quickly reducing the blade load to prevent a stuck state and the like caused by an excessive load, thereby enabling stable travel of the work machine.

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 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 and a second load threshold value which is a threshold value of the blade load and is greater than the first load threshold value;
a target position setting part which sets a blade target position that is a position as a target of the blade position and that is a position above the target design surface; and
a blade operation control part which outputs a command for raising and lowering the blade such that a position deviation as a deviation between the blade position calculated by the blade position calculating part and the blade target position approaches zero in a case where the blade load acquired by the blade load acquiring part is equal to or less than the second load threshold value, and outputs a command for raising the blade in a case where the blade load acquired by the blade load acquiring part is greater than the second load threshold value, wherein
in a case where an update condition is satisfied, the update condition being set in advance so as to associate the blade load and the first load threshold value with each other, the target position setting part updates the blade target position using the blade position obtained when the update condition is satisfied as a reference.

2. The blade control device according to claim 1, wherein
the update condition includes a condition that the blade load reaches the first load threshold value, or a condition that the blade load reaches a determination value for determining whether the blade load has neared the first load threshold value or not, the determination value being set on the basis of the first load threshold value.

3. The blade control device according to claim 1, wherein
the storage part is configured to store a first state indicating allowance of update of the blade target position when the blade load becomes greater than a flag threshold value as a threshold value set in advance, and also store a second state indicating non-allowance of update of the blade target position in place of the first state when the blade target position is updated, and
the update condition includes a condition that the blade load reaches the first load threshold value when the first state is stored in the storage part, or a condition that the blade load reaches a determination value when the first state is stored in the storage part, the determination value being set on the basis of the first load threshold value for determining whether the blade load has neared the first load threshold value or not.

4. The blade control device according to any one of claims 1 to 3, wherein
the blade target position to be updated by the target position setting part is set at a position which passes the blade position when the update condition is satisfied and is on a plane parallel to the target design surface.

5. The blade control device according to any one of claims 1 to 4, wherein
the storage part stores a target track as a target for an increase process of the blade load when the blade load approaches the first load threshold value while being increased, and
the blade operation control part outputs a command for raising and lowering the blade such that the blade load approaches the first load threshold value while following an increase process close to the target track before the blade target position is set by the target position setting part.

6. The blade control device according to any one of claims 1 to 5, further comprising:

a load threshold value setting part which sets the first load threshold value,
wherein
the position information acquiring part includes a vehicle body position acquiring part which acquires a vehicle body position as a position of the machine body, and
the load threshold value setting part updates the first load threshold value such that the first load threshold value becomes smaller when a body distance is a second distance than when the body distance is a first distance, the body distance being a distance between the vehicle body position acquired by the vehicle body position acquiring part and the target design surface, the second distance being smaller than the first distance.

7. The blade control device according to any one of claims 1 to 6, wherein
the blade operation control part outputs the command on the basis of a function having a term including, as a variable, a position deviation which is an elevation difference between the blade position and the blade target position and including a position gain by which the position deviation is multiplied, the blade control device further comprising:

a position gain setting part which sets the position gain,
in a case where the blade position is below the blade target position, the position gain setting part updates the position gain such that a raising speed of the blade is increased on the basis of the position deviation.

8. The blade control device according to claim 7, wherein
the function further has a term including, as a variable, a load deviation which is a deviation obtained by subtracting the second load threshold value from the blade load and including a load gain by which the load deviation is multiplied,
the blade control device further comprising:

a load gain setting part which sets the load gain,
in a case where the blade load is greater than the second load threshold value, the load gain setting part updates the load gain such that the raising speed of the blade is increased on the basis of the load deviation.

FIG. 1

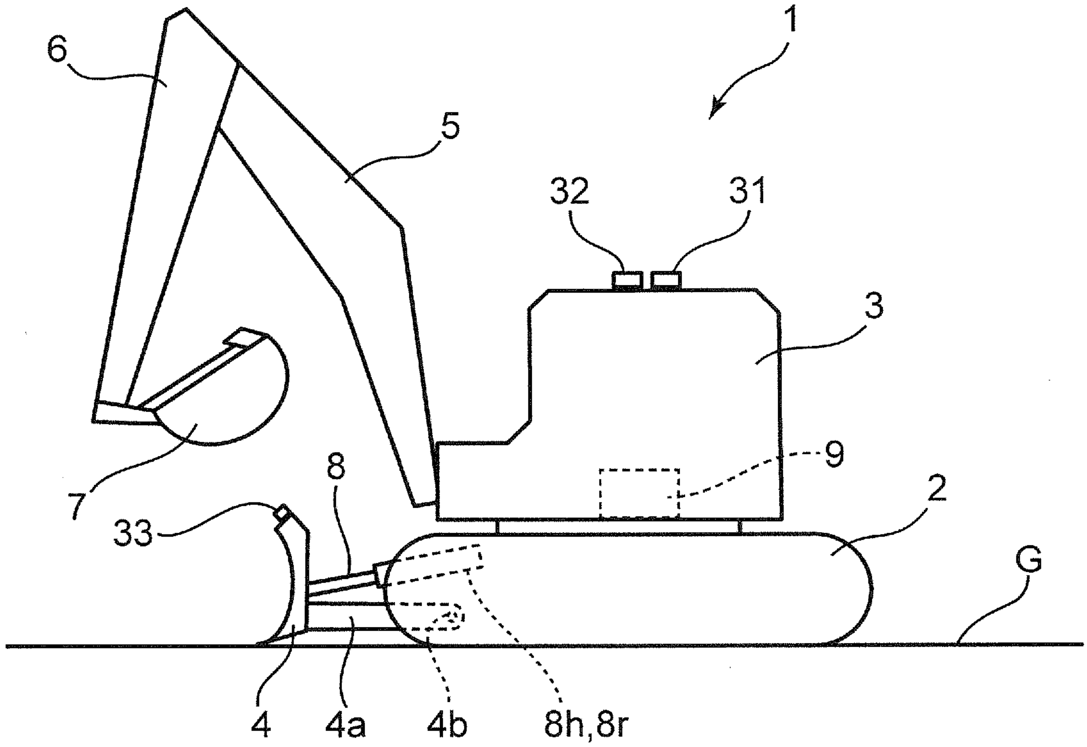


FIG. 2

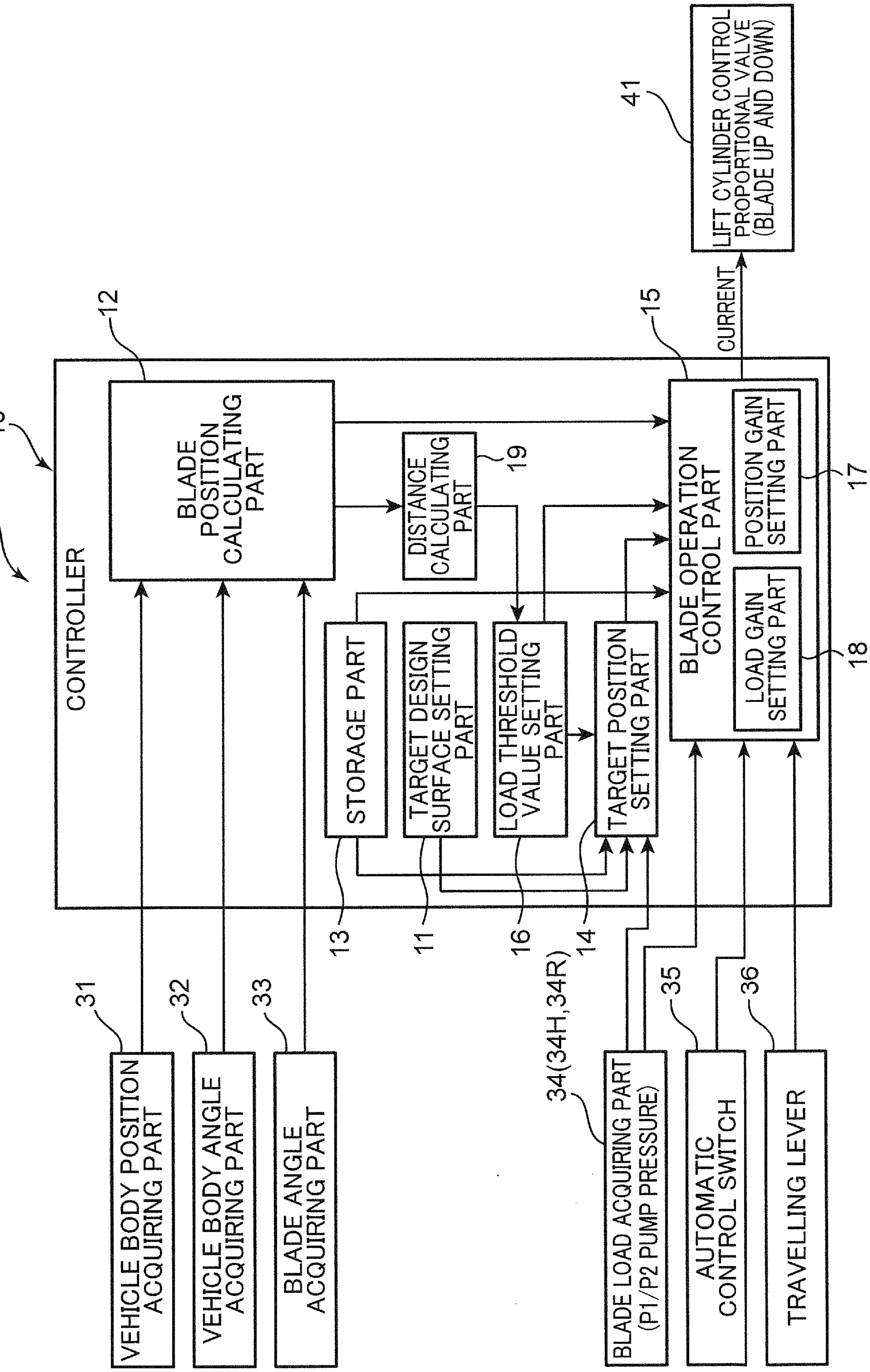

100
10
CONTROLLER
BLADE POSITION CALCULATING PART
12
DISTANCE CALCULATING PART
19
STORAGE PART
TARGET DESIGN SURFACE SETTING PART
LOAD THRESHOLD VALUE SETTING PART
TARGET POSITION SETTING PART
BLADE OPERATION CONTROL PART
POSITION GAIN SETTING PART
LOAD GAIN SETTING PART
15
17
18
13
11
16
14
CURRENT
LIFT CYLINDER CONTROL PROPORTIONAL VALVE (BLADE UP AND DOWN)
41
VEHICLE BODY POSITION ACQUIRING PART
31
VEHICLE BODY ANGLE ACQUIRING PART
32
BLADE ANGLE ACQUIRING PART
33
BLADE LOAD ACQUIRING PART (P1/P2 PUMP PRESSURE)
34(34H,34R)
AUTOMATIC CONTROL SWITCH
35
TRAVELLING LEVER
36

FIG. 3

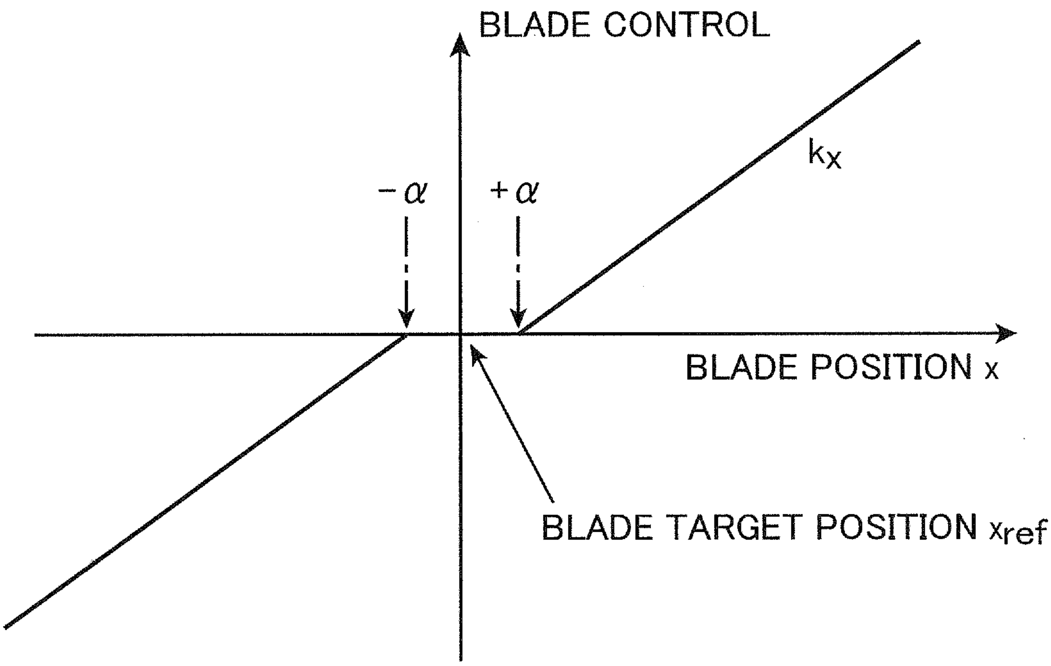

BLADE CONTROL
kX
−α
+α
BLADE POSITION x
BLADE TARGET POSITION xref

FIG. 4

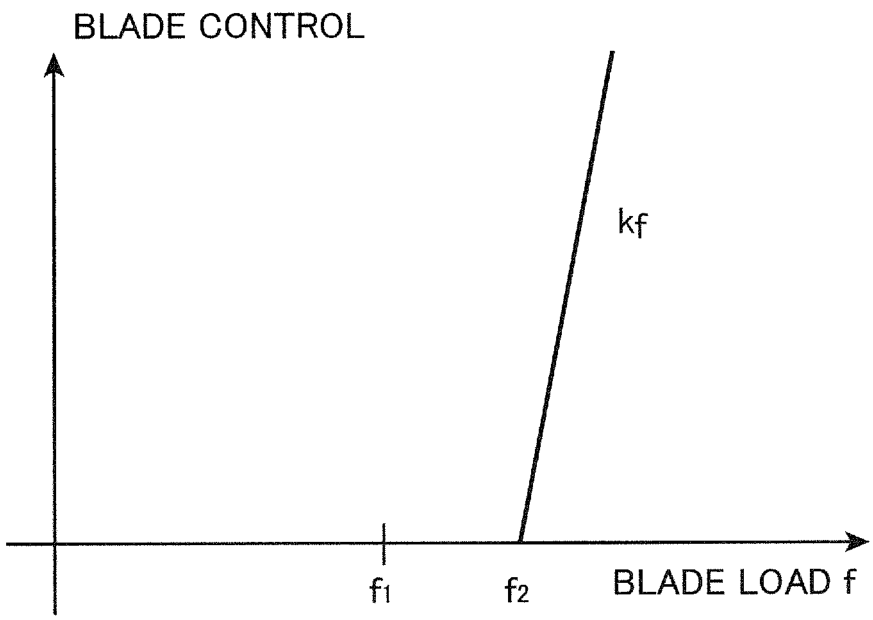


FIG. 5

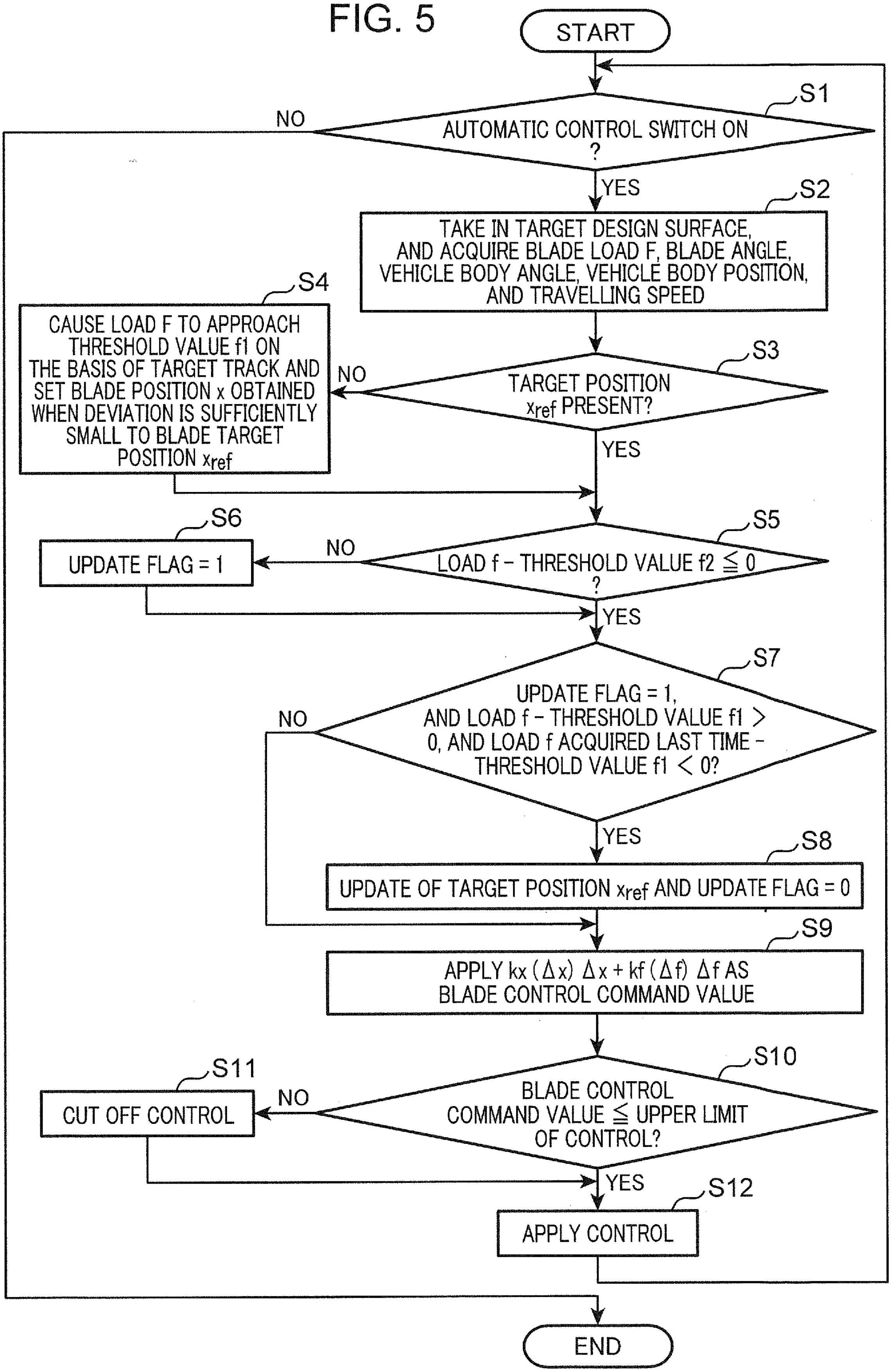

START
S1
AUTOMATIC CONTROL SWITCH ON ?
NO
YES
S2
TAKE IN TARGET DESIGN SURFACE, AND ACQUIRE BLADE LOAD F, BLADE ANGLE, VEHICLE BODY ANGLE, VEHICLE BODY POSITION, AND TRAVELLING SPEED
S3
TARGET POSITION x_{ref} PRESENT?
NO
S4
CAUSE LOAD F TO APPROACH THRESHOLD VALUE f1 ON THE BASIS OF TARGET TRACK AND SET BLADE POSITION x OBTAINED WHEN DEVIATION IS SUFFICIENTLY SMALL TO BLADE TARGET POSITION x_{ref}
YES
S5
LOAD f − THRESHOLD VALUE f2 ≦ 0 ?
NO
S6
UPDATE FLAG = 1
YES
S7
UPDATE FLAG = 1, AND LOAD f − THRESHOLD VALUE f1 > 0, AND LOAD f ACQUIRED LAST TIME − THRESHOLD VALUE f1 < 0?
NO
YES
S8
UPDATE OF TARGET POSITION x_{ref} AND UPDATE FLAG = 0
S9
APPLY kx (Δx) Δx + kf (Δf) Δf AS BLADE CONTROL COMMAND VALUE
S10
BLADE CONTROL COMMAND VALUE ≦ UPPER LIMIT OF CONTROL?
NO
S11
CUT OFF CONTROL
YES
S12
APPLY CONTROL
END

FIG. 6

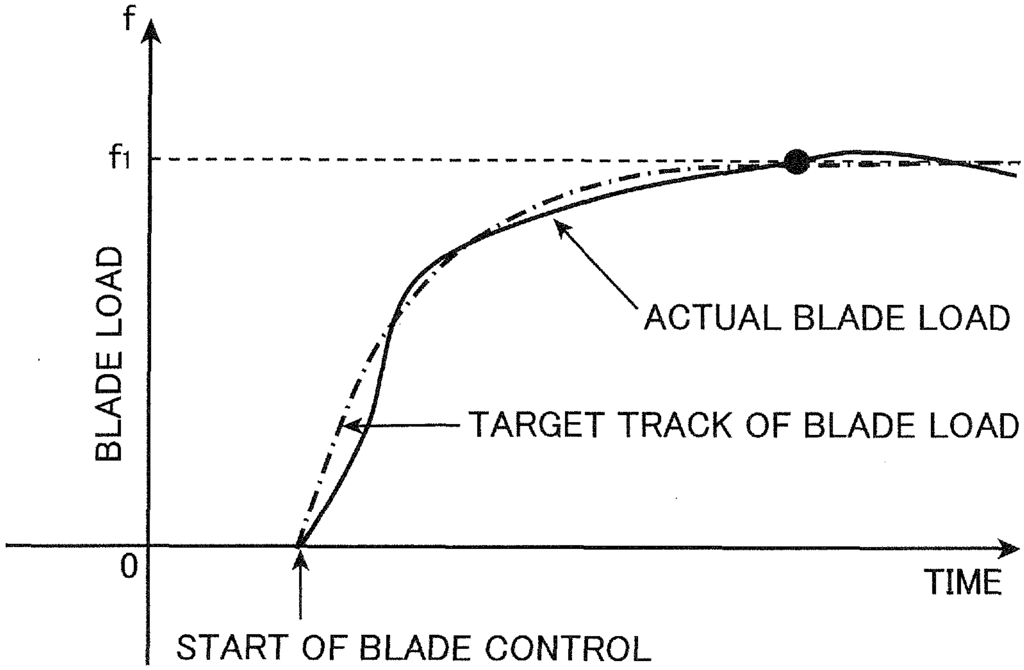

f
f1
BLADE LOAD
ACTUAL BLADE LOAD
TARGET TRACK OF BLADE LOAD
0
TIME
START OF BLADE CONTROL

FIG. 7

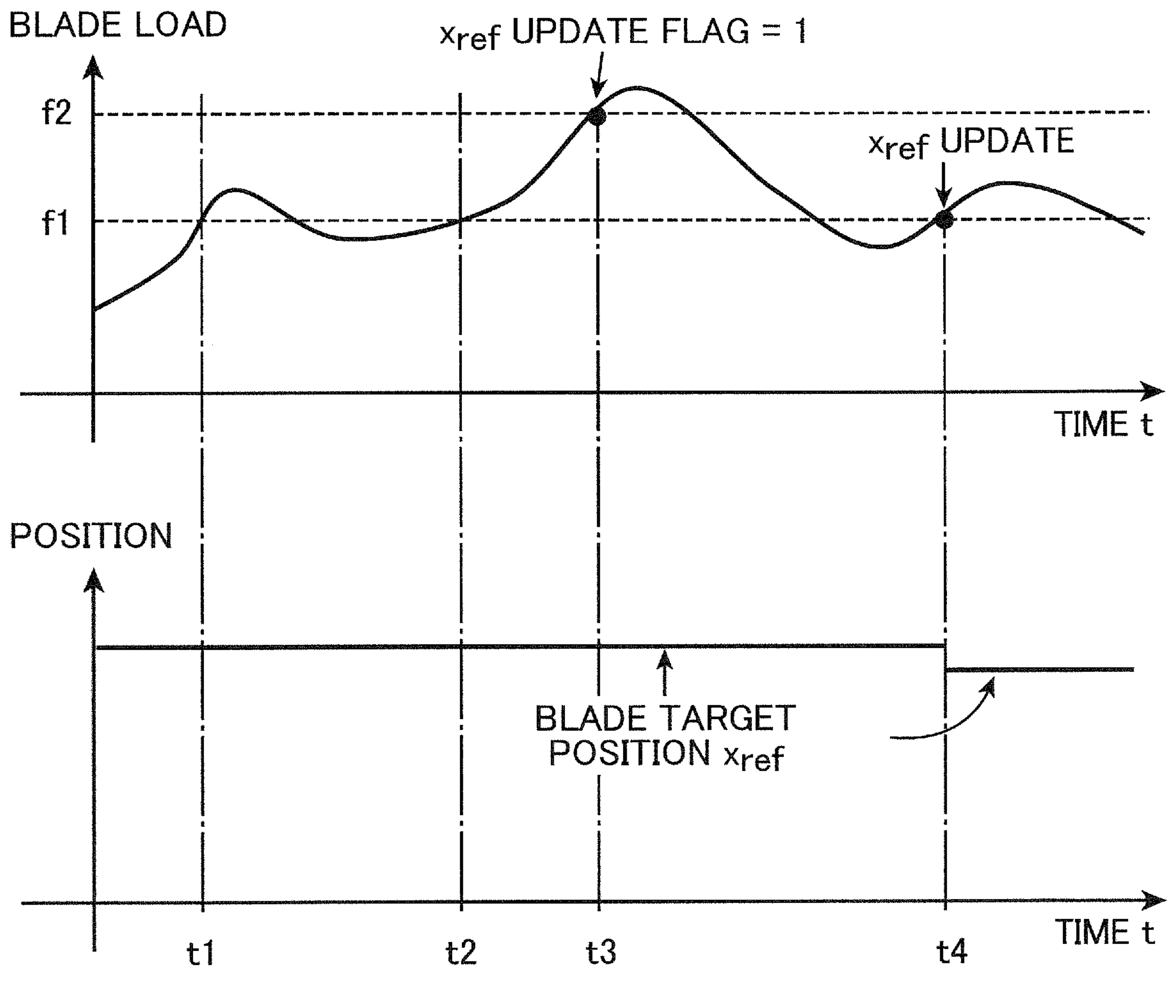
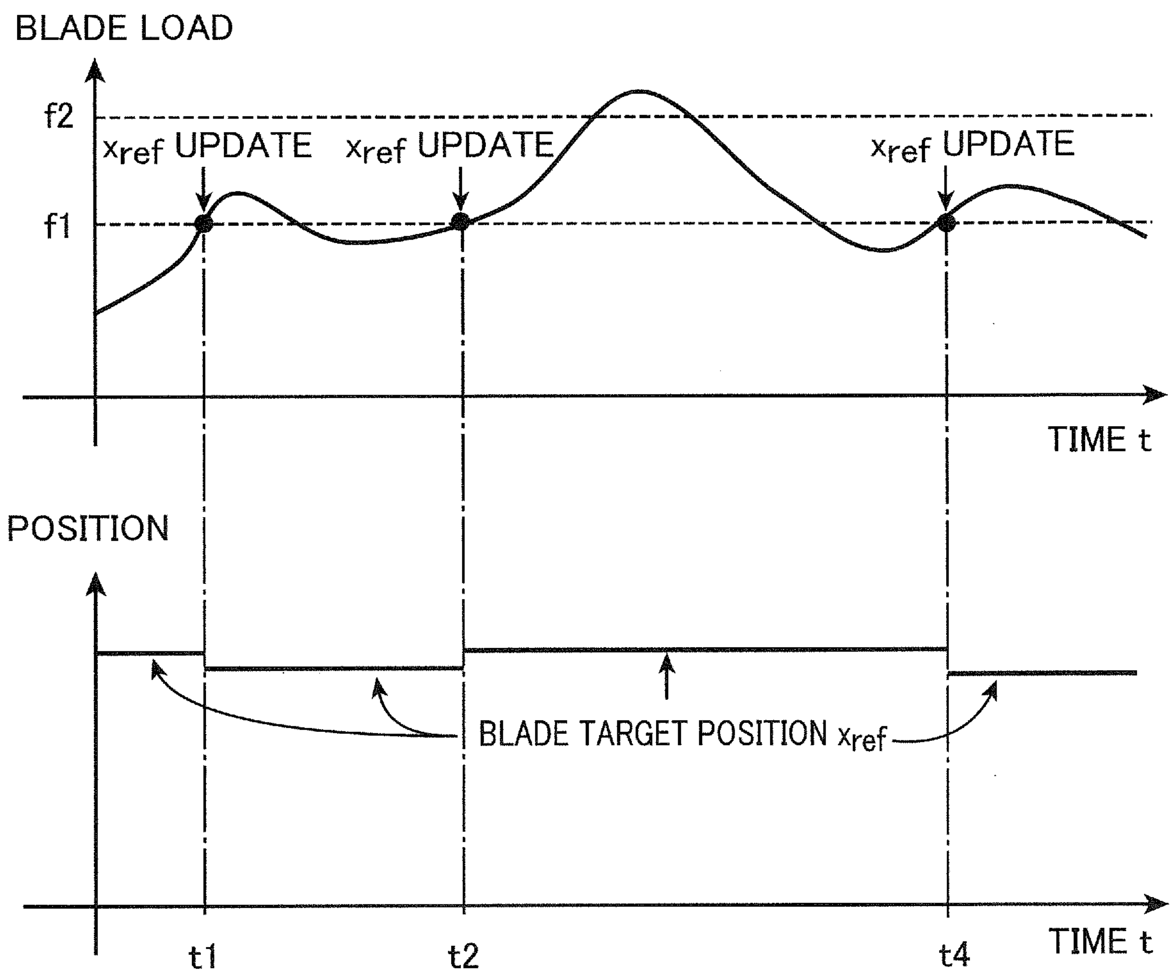

BLADE LOAD
x_{ref} UPDATE FLAG = 1
f2
f1
x_{ref} UPDATE
TIME t
POSITION
BLADE TARGET
POSITION x_{ref}
TIME t
t1
t2
t3
t4

FIG. 8



BLADE LOAD
f2
f1
x_{ref} UPDATE
x_{ref} UPDATE
x_{ref} UPDATE
TIME t
POSITION
BLADE TARGET POSITION x_{ref}
t1
t2
t4
TIME t

FIG. 9

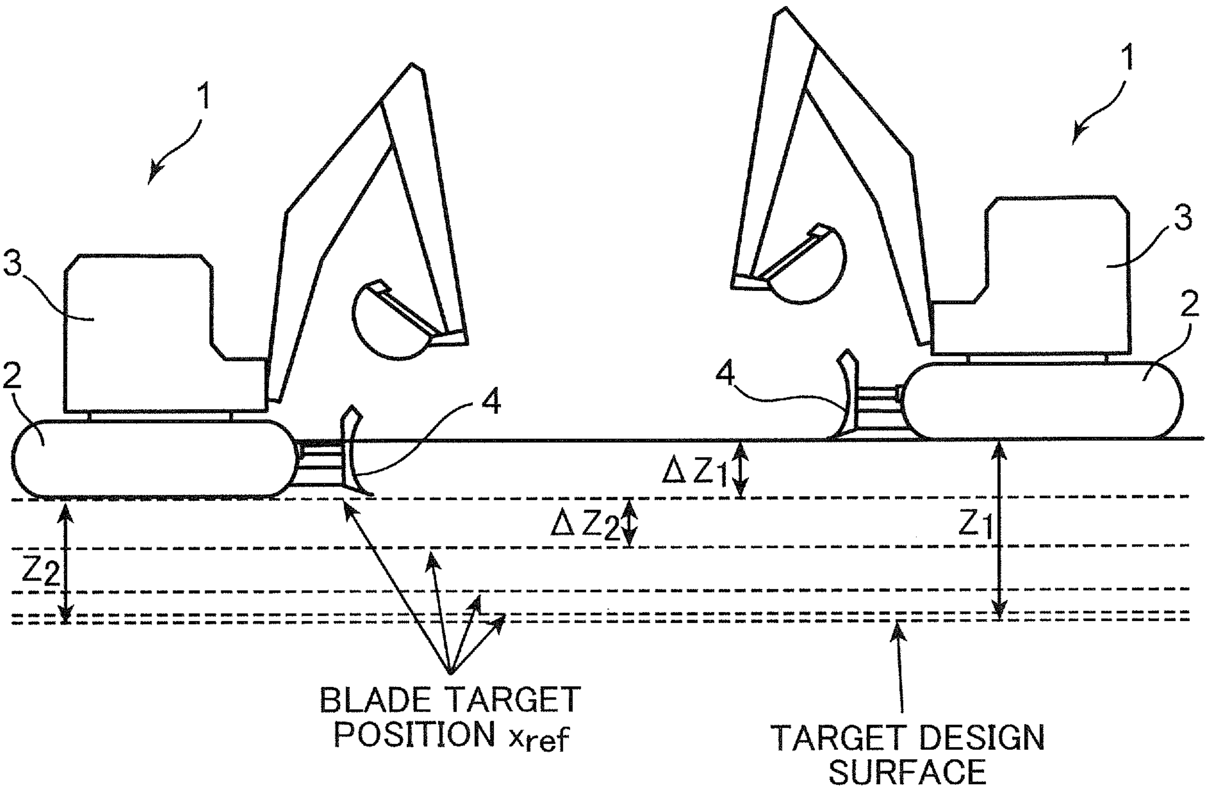

1
1
3
3
2
2
4
4
ΔZ1
ΔZ2
Z1
Z2
BLADE TARGET
POSITION xref
TARGET DESIGN
SURFACE

FIG. 10

FIG. 11

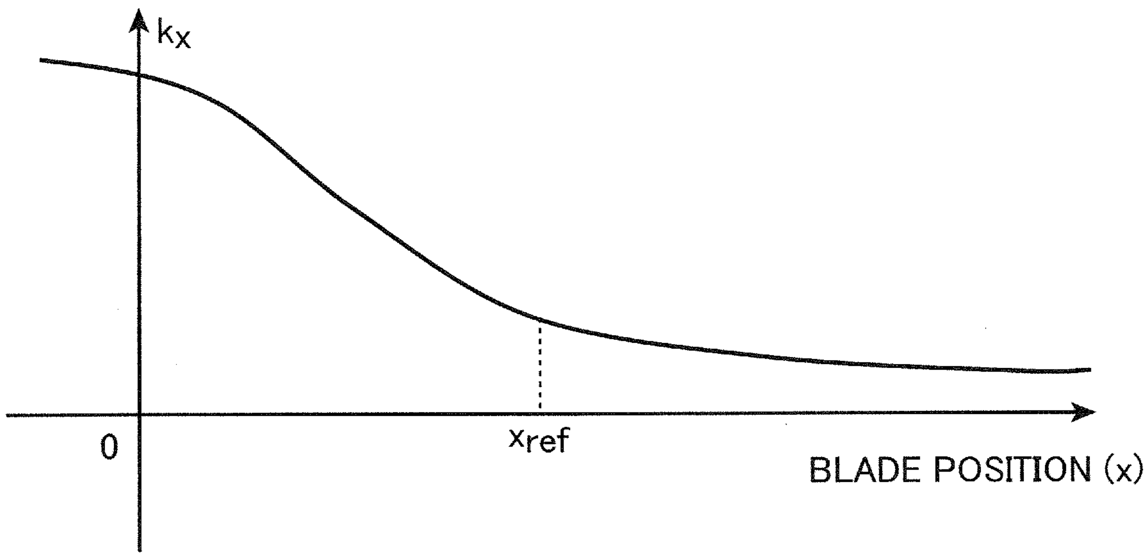


FIG. 12

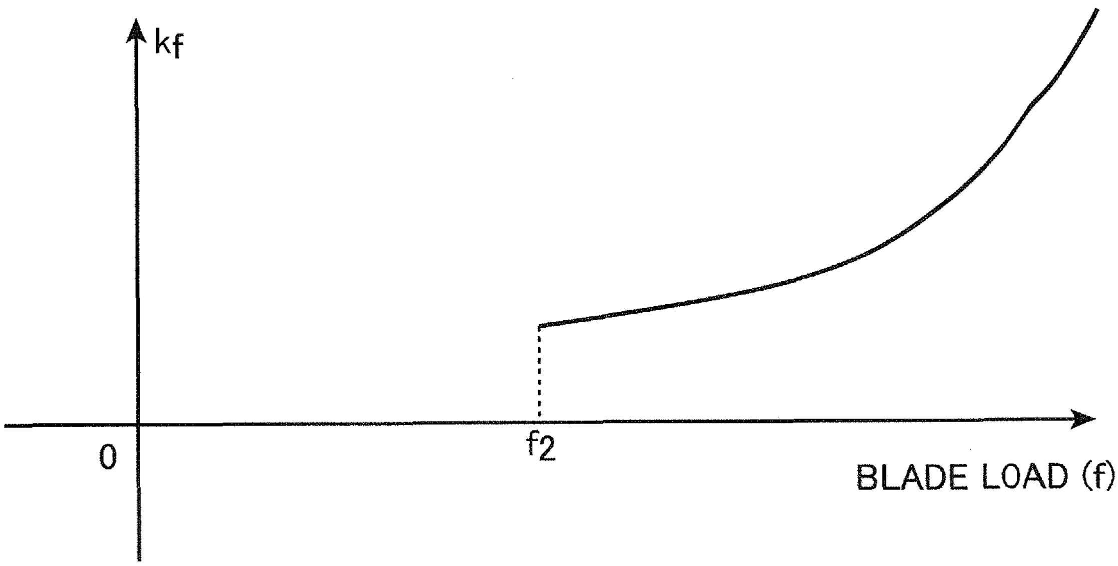
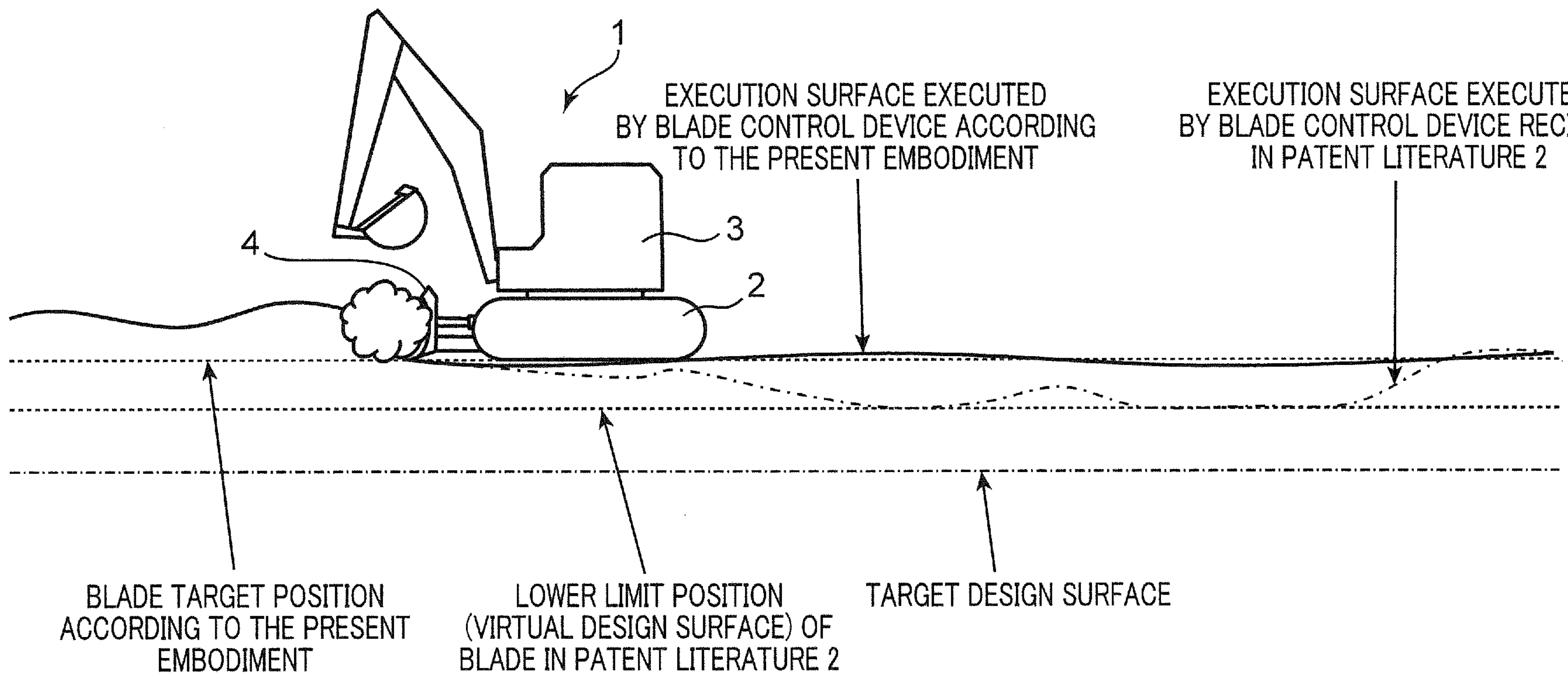


FIG. 13


1
2
3
4
EXECUTION SURFACE EXECUTED BY BLADE CONTROL DEVICE ACCORDING TO THE PRESENT EMBODIMENT
EXECUTION SURFACE EXECUTED BY BLADE CONTROL DEVICE RECITED IN PATENT LITERATURE 2
BLADE TARGET POSITION ACCORDING TO THE PRESENT EMBODIMENT
LOWER LIMIT POSITION (VIRTUAL DESIGN SURFACE) OF BLADE IN PATENT LITERATURE 2
TARGET DESIGN SURFACE

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/031265

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	1-8
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	1-8

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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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.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/031265

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 5285805 B1 (KOMATSU LTD.) 11 September 2013, paragraphs [0019]-[0078], fig. 1-9 & US 2015/0019086 A1, paragraphs [0027]-[0090], fig. 1-9 & WO 2014/064850 A1 & CN 103906877 A	1-8

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 3537182 B **[0005]**
- JP 5285805 B **[0005]**