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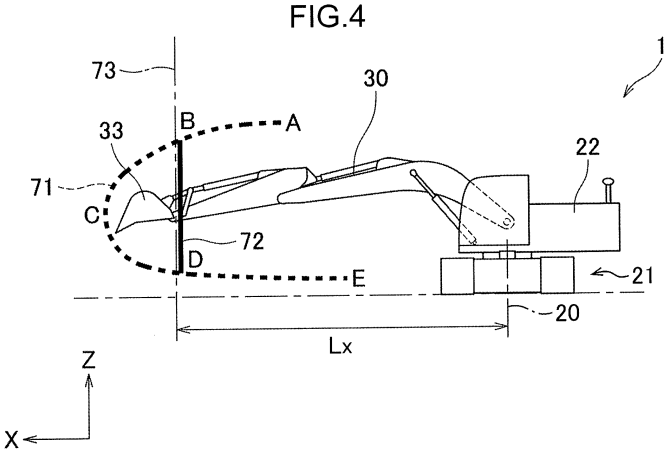
(54) **WORK MACHINE**

(57) Provided is a work machine (1) capable of automatic with reduced burden on a worker. The work machine (1) includes a controller that controls driving of an upper turning body (22) and a work device (30) to make the upper turning body (22) and the work device (30) perform a designated motion. The controller revises the designated motion, when a restriction target part of the work device (30) will be protruded beyond a preset allowable area during the designated motion, to keep the restriction target part from being protruded beyond the allowable area.

FIG.4



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Description

Technical Field

[0001] The present invention relates to a work machine capable of being automatically operated.

Background Art

[0002] Patent Literature 1 discloses a construction machine capable of being automatically operated. The construction machine is capable of automatically performing a motion that is taught by teaching (teaching operation), judging whether or not the position related to the motion taught by the teaching is within an allowable area in advance of the execution of the motion, and prompting re-teaching when the position is not within the allowable area.

[0003] The requirement for the re-teaching, however, increases the burden on the operator who performs the teaching.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Publication No. 2000-291077

Summary of Invention

[0005] It is an object of the present invention to provide a work machine capable of automatic operation within an allowable area without increase in the burden on an operator.

[0006] Provided is a work machine including a lower traveling body, an upper turning body, a work device, and a controller. The upper turning body is mounted on the lower traveling body capably of turning. The work device is attached to the upper turning body capably of performing a work motion. The controller controls driving of the upper turning body and the work device so as to make the upper turning body and the work device perform a designated motion that is designated in advance. The controller is configured to revise the designated motion, when a restriction target part of the work device will be protruded beyond an allowable area that is preset or there is a possibility that the restriction target part is protruded beyond the allowable area when the upper turning body and the work device performs the designated motion, so as to keep the restriction target part from being protruded beyond the allowable area.

Brief Description of Drawings

[0007]

FIG. 1 is a side view of a work machine according to a first embodiment of the present invention.
FIG. 2 is a circuit diagram of the work machine and a portable terminal.
FIG. 3 is a plan view showing a trajectory of the tip of a bucket involved by a designated motion in the work machine.
FIG. 4 is a side view showing the trajectory of the tip of the bucket in the designated motion.
FIG. 5A is a side view showing a first position for defining an allowable area as to the work machine.
FIG. 5B is a side view showing a second position for defining the allowable area.
FIG. 5C is a side view of a third position for defining the allowable area.
FIG. 5D is a side view of a fourth position for defining the allowable area.
FIG. 6 is a side view showing the allowable area defined based on the first to fourth positions.
FIG. 7 illustrates the allowable area that has not been yet updated.
FIG. 8 is a side view showing the allowable area that has been updated.
FIG. 9 is a side view showing a vessel of a dump truck and the lower boundary surface of the allowable area that is set above the vessel.
FIG. 10 is a side view showing an example in which two transit points are set between the start point and the terminal point of an excavation motion of a work machine according to a third embodiment.
FIG. 11 is a side view showing an example in which the transit point is set between the start point and the terminal point.
FIG. 12 is a side view showing an example in which a revision similar to that of the excavation motion according to the first embodiment has been performed in the work machine according to a fourth embodiment.
FIG. 13 is a side view showing an example of the revision of the excavation motion according to the fourth embodiment.
FIG. 14 is a side view showing another example of the revision of the excavation motion according to the fourth embodiment.

FIG. 15 is a side view showing an amount of a decrease in the excavation amount due to the revision shown in FIG. 14.
FIG. 16 is a side view showing a modification of excavation depth to compensate for the amount of the decrease in the excavation amount.
FIG. 17 is a flowchart illustrating a process executed by a control unit according to the fourth embodiment.
FIG. 18 is a side view showing a revision of the excavation motion performed in a work machine according to a fifth embodiment.
FIG. 19 is a side view of the bucket and the peripheral part therearound in the work machine shown in FIG. 18.
FIG. 20A is a side view showing the trajectory of the tip of the bucket according to the excavation motion on which the revision shown in FIG. 18 has not been yet performed.
FIG. 20B illustrates the trajectory of the tip of the bucket according to the excavation motion on which the revision shown in FIG. 18 has been performed.
FIG. 21 is a side view showing an example in which a part including the terminal point of the excavation motion has been revised in the work machine according to the fifth embodiment.
FIG. 22 is a view showing an example in which a region including the lowest point of the excavation motion has been revised in the work machine according to the fifth embodiment.

Detailed Description

[0008] Below will be described a preferred embodiment of the present invention with reference to the drawings.

[0009] FIG. 1 is a side view of a work machine 1 according to an embodiment of the present invention. The work machine 1 is a hydraulic excavator, provided with a machine body 25 including a lower traveling body 21 and an upper turning body 22, an attachment 30, and a work driving device 40.

[0010] The lower traveling body 21 includes a pair of crawlers, which are actuated to thereby enable the lower traveling body 21 to travel on the ground. The upper turning body 22 is mounted on the lower traveling body 21 through a turning device 24 capably of turning. The turning device 24 is a turning driving device for turning the upper turning body 22. The upper turning body 22 includes a cab (operation room) 23 located at the front of the upper turning body 22.

[0011] The attachment 30 is a work device, attached to the upper turning body 22 capably of performing a work motion including vertically rotational movement. The attachment 30 includes a boom 31, an arm 32, and a bucket 33. The boom 31 has a proximal end attached to the upper turning body 22 capably of vertically rotational movement (derricking) and a distal end opposite thereto. The arm 32 has a proximal end attached to the distal end of the boom 31 capably of vertically rotational movement with respect to the boom 31 and a distal end opposite thereto. The bucket 33 is a tip attachment that is the tip of the attachment 30, attached to the distal end of the arm 32 capably of rotational movement in the front-rear direction with respect to the arm 32. The bucket 33 has a shape capable of excavating, leveling, scooping and the like on an excavation object including soil and sand. The excavation object is not limited to soil and sand but allowed to be also a stone or a waste (industrial waste, etc.). Besides, the work machine according to the present invention is not limited to an excavation machine, so that the work object is not limited to an excavation object. For example, the tip attachment that forms the tip of the work device according to the present invention is not limited to the bucket 33 but allowed to be also a grapple or a lifting magnet that makes a gripping motion.

[0012] The work driving device 40 hydraulically actuates the attachment 30 to make the attachment 30 perform the work motion. In this embodiment, the work driving device 40 includes a plurality of extendable hydraulic cylinders, which include a boom cylinder 41, an arm cylinder 42, and a bucket cylinder 43.

[0013] The boom cylinder 41 rotationally moves the boom 31 with respect to the upper turning body 22. The boom cylinder 41 has a proximal end rotatably coupled to the upper turning body 22 and a distal end rotatably coupled to the boom 31.

[0014] The arm cylinder 42 rotationally moves the arm 32 with respect to the boom 31. The arm cylinder 42 has a proximal end rotatably coupled to the boom 31 and a distal end rotatably coupled to the arm 32.

[0015] The bucket cylinder 43 rotationally moves the bucket 33 with respect to the arm 32. The bucket cylinder 43 has a proximal end rotatably coupled to the arm 32 and a distal end rotatably coupled to a link member 34. The link member 34 is rotatably coupled to the bucket 33 to interconnect the bucket cylinder 43 and the bucket 33.

[0016] The work machine 1 further includes a turning angle sensor 52, which is a turning angle detector, and a working posture detector 60.

[0017] The turning angle sensor 52 detects the turning angle of the upper turning body 22 with respect to the lower traveling body 21. The turning angle sensor 52 is, for example, an encoder, a resolver, or a gyro sensor. In this embodiment, the turning angle of the upper turning body 22 is 0° when the frontward direction of the upper turning body 22 coincides with the frontward direction of the lower traveling body 21.

[0018] The working posture detector 60 detects a working posture that is the posture of the attachment 30, which is the work device. The working posture detector 60, in the present embodiment, includes a boom inclination sensor 61, an arm inclination sensor 62, and a bucket inclination sensor 63.

[0019] The boom inclination sensor 61 is attached to the boom 31 to detect a posture of the boom 31. The boom inclination sensor 61 acquires an inclination angle of the boom 31 to a horizontal line. The boom inclination sensor 61 is, for example, an inclination (acceleration) sensor. The posture detector 60 may include, instead of the boom inclination sensor 61, a rotation angle sensor for detecting a rotation angle of the boom 31 about a boom foot pin or a stroke sensor for detecting a stroke of the boom cylinder 41.

[0020] The arm inclination sensor 62 is attached to the arm 32 to detect the posture of the arm 32. The arm inclination sensor 62 acquires the inclination angle of the arm 32 to a horizontal line. The arm inclination sensor 62 is, for example, an inclination (acceleration) sensor. The working posture detector 60 may include, instead of the arm inclination sensor 62, a rotation angle sensor for detecting the rotation angle of the arm 32 about an arm connection pin or a stroke sensor for detecting the stroke of the arm cylinder 42.

[0021] The bucket inclination sensor 63 is attached to the link member 34 to detect a posture of the bucket 33. The bucket inclination sensor 63 acquires an inclination angle of the bucket 33 to a horizontal line. The bucket inclination sensor is, for example, an inclination (acceleration) sensor. The working posture detector 60 may include, instead of the bucket inclination sensor 63, a rotation angle sensor for detecting a rotation angle of the bucket 33 about a bucket connection pin or a stroke sensor for detecting a stroke of the bucket cylinder 43.

[0022] The work machine 1 further includes a GNS (Global Navigation Satellite System) sensor 26. The GNS sensor 26 is a GPS sensor or the like, provided in the upper turning body 22 to detect the coordinates of the position of the upper turning body 22 at the work site. The GNS sensor 26 may be provided in the lower traveling body 21 or the attachment 30. The GNS sensor 26 is a positioning sensor to acquire the coordinates of the position of the work machine 1 (the upper turning body 22) in the global coordinate system. The position detection device is not limited to the GNS sensor 26 but allowed to be also a region sensor such as a total station.

[0023] The work machine 1 further includes a LiDAR (Light Detection and Ranging or Laser Imaging Detection and Ranging) 27. The LiDAR 27 is provided on the upper turning body 22; however, it may be provided on the attachment 30 (for example, the boom 31). The LiDAR 27 is an acquisition device that acquires an ambient condition at a work site. Specifically, the LiDAR 27 acquires point group data indicating the distance from the position where the LiDAR 27 is placed to an object (dump car or obstacle) at the work site. The acquisition device is not limited to the LiDAR 27 but allowed to be also a stereo camera or a TOF (Time Of Flight) sensor.

[0024] The work machine 1 is capable of communication with the portable terminal 3 shown in FIGS. 1 and 2. The portable terminal 3 is a terminal to be carried and operated by an operator at a work site, for example, a tablet terminal. The operator who operates the portable terminal 3 is, for example, a person who manages the work machine 1. The portable terminal 3 may be a smartphone or the like.

[0025] FIG. 2 is a circuit diagram of the work machine 1 and the portable terminal 3. As shown in FIG. 2, the work machine 1 includes a control unit 11, a work-machine side communication device 12, and a storage device 13. The portable terminal 3 includes a portable-terminal side control unit 15, a portable-terminal side communication device 16, and a display 17.

[0026] To the control unit 11 are input turning angle information and working posture information. The turning angle information is information acquired by the turning angle sensor 52, that is, information on the turning angle (posture) of the upper turning body 22 with respect to the lower traveling body 21. The working posture information is information related to the working posture of the attachment 30, including: information on the posture of the boom 31 acquired by the boom inclination sensor 61; information on the posture of the arm 32 acquired by the arm inclination sensor 62; and information about the posture of the bucket 33 acquired by the bucket inclination sensor 63.

[0027] To the control unit 11 is input the coordinates of the position of the upper turning body 22 at a work site, the coordinates detected by the GNS sensor 26. Besides, to the control unit 11 is input information related to the ambient condition at the work site, the information acquired by the LiDAR 27.

[0028] The control unit 11 automatically controls the motions of the work machine 1. Specifically, the control unit 11 can serve as a control means for controlling the driving of the upper turning body 22 and the attachment 30 so as to make the upper turning body 22 and the attachment 30 perform a predetermined designated motion, namely, in this embodiment, a series of motions from excavation of soil and sand to removal thereof. The work machine 1 can thus be automatically operated. Specifically, the control unit 11 automatically operates the turning device 24 and the work driving device 40 based on the information detected by the turning angle sensor 52 and the working posture detector 60, respectively.

[0029] The storage device 13 stores the designated motion. The designated motion, in this embodiment, includes a series of motions, designated through teaching by an operator. The designated motion causes a distal part of the attachment 30, the tip of the bucket 33 in this embodiment, to trace a predetermined trajectory.

[0030] The work-machine side communication device 12 is capable of communication with the portable-terminal side communication device 16 of the portable terminal 3.

[0031] FIGS. 3 and 4 are plan and side views, respectively, showing a trajectory of the tip of the attachment 30 (in this embodiment, the tip of the bucket 33) in the series of motions. The tip of the bucket 33 turns with the upper turning

body 22 from a point A to a point C via a point B shown in FIGS. 3 and 4. Thereafter, the tip of the bucket 33 moves from the point C to a point E via a point D toward the upper turning body 22. In FIGS. 3 and 4, the trajectory of the tip of the bucket 33 designated by teaching is indicated by respective dotted lines. The control unit 11, thus, controls the driving of the upper turning body 22 and the attachment 30 so as to make the tip of the bucket 33 pass through the points A to E, which are a plurality of target points, sequentially to make the upper turning body 22 and the attachment 30 perform the series of motions.

[0032] As shown in FIG. 4, the point B and the point D are set to respective positions both of which are separated from the turning center axis 20 of the upper turning body 22 leftward of the lower traveling body 21 (leftward in FIG. 4; in X direction) by a distance Lx (for example, 6000 mm). The point C is set at a position separated from the turning center axis 20 of the upper turning body 22 in the X direction by a distance greater than the distance Lx, the larger distance being, for example, 7000 mm.

[0033] While the series of motions are designated by teaching as described above, there may be an obstacle or the like which interferes with the attachment 30 performing the designated motion at the work site. The control unit 11 according to this embodiment also serves as a setting means for setting an allowable area for the motion of the attachment 30 in order to prevent the obstacle or the like and the attachment 30 from interference with each other. For example, the control unit 11 sets the allowable area based on information on the obstacle or the like at the work site. In FIGS. 3 and 4, the front boundary surface 73 of the allowable area is shown in a dot chain line. The allowable area may be set either in a coordinate system based on the work machine 1, for example, a machine coordinate system with the turning center of the upper turning body 22 as the origin, or in a coordinate system based on a work site, for example, a global coordinate system.

[0034] In the example shown in FIGS. 3 and 4, to the allowable area is set an area on the inner side of the position that is separated from the turning center axis 20 of the upper turning body 22 in the X direction (leftward of the lower traveling body 21) by the distance Lx (for example, 6000 mm), the inner side being the side closer to the turning center axis 20, that is, the right side of the front side boundary surface 73 indicated by the dot chain line in FIGS. 3 and 4. The point C is out of the allowable area.

[0035] The control unit 11 revises the designated motion, in the case where the restriction target part, namely, the tip of the bucket 33, will be protruded beyond the allowable area (in the example shown in FIG. 4, projected frontward over the front boundary surface 73) when the attachment 30 performs the designated motion, namely, the series of motions, so as to keep the tip of the bucket 33 from being protruded beyond the allowable area (so as to confine the tip of the bucket 33 inside the front boundary surface 73). Although the restriction target part to be inhibited from the deviation from the allowable area in the attachment 30, according to the present embodiment, is the tip of the bucket 33, the restriction target part is not limited to the tip of the bucket 33 but allowed to be arbitrarily set.

[0036] For example, the control unit 11 changes respective positions of the point B, the point C, and the point D to positions to each of which the distance in the X direction from the turning center axis 20 is smaller than the distance Lx (e.g., 5900 mm). Such revision of the designated motion causes the trajectory 71 of the tip of the bucket 33 from the point B to the point D via the point C to be modified to a trajectory 72 as indicated by a solid line in FIGS. 3 and 4, i.e., a trajectory extending along the front boundary surface 73 just on or the rear side (the right side in FIGS. 3 and 4) of the front boundary surface 73 indicated by a dot chain line. The tip of the bucket 33 is thus restrained from deviating to the outside of the front boundary surface 73. This eliminates the time and effort of an operator for re-designating the designated motion by teaching or the like in order to keep the tip of the bucket 33 from being protruded beyond the allowable area, thereby reducing the burden on the operator.

[0037] The control unit 11 may revise the designated motion, also in the case where a specific part other than the tip of the bucket 33 in the attachment 30 will be protruded beyond the allowable area during at least a part of the designated motion, to keep the specific part from being protruded beyond the allowable area. In short, the restriction target part of the attachment 30 may be a part that is properly set in a region other than the tip of the bucket 33. For example, depending on the rotation angle of the bucket 33 with respect to the arm 32, there may be a case where the tip of the arm 32 is the furthest part from the upper turning body 22. Also, depending on the rotation angle of the arm 32 with respect to the boom 31, there may be a case where the tip of the boom 31 is the farthest part from the upper turning body 22. Even in such cases where the tip of the arm 32 or the tip of the boom 31 will be thus protruded beyond the allowable area, revising the designated motion so as to keep the tip from being protruded beyond the allowable area allows the tip to be kept from being protruded beyond the allowable area.

[0038] Next will be described an example of the setting of the allowable area by the control unit 11. In the example, the allowable area is set based on a plurality of positions at which the tip of the bucket 33 as the restriction target part of the attachment 30 can be located. Such setting is useful at a site where the allowable area is unable to be clearly defined or at a site where the environment around the work machine 1 varies. The restriction target part of the attachment 30 is not limited to the tip of the bucket 33 but allowed to be also, for example, the tip of the arm 32.

[0039] In the example, initially, the tip of the bucket 33 is positioned at a first position shown in FIG. 5A by an operator's operation or the like and the first position is stored in the control unit 11 by performance of a designation operation or

the like at the first position. The first position defines the upper end of an allowable area to be set. Similarly, the tip of the bucket 33 is positioned at the second position shown in FIG. 5B and the second position is stored in the control unit 11. The second position defines the lower end of the allowable area. Similarly, the tip of the bucket 33 is positioned at the third position shown in FIG. 5C and the third position is stored in the control unit 11. The third position defines the front end of the allowable area. Similarly, the tip of the bucket 33 is positioned at the fourth position shown in FIG. 5D and the fourth position is stored in the control unit 11. The fourth position defines the rear end of the allowable area. Based on the thus designated first to fourth positions, the control unit 11 sets an allowable area Ra as shown in FIG. 5D. Such setting of the allowable area Ra may be performed either in a coordinate system based on the work machine 1 (mechanical coordinate system) or in a coordinate system based on a work site (for example, a global coordinate system).

[0040] By thus positioning the tip of the bucket 33 at a plurality of positions where the tip of the bucket 33 can be located, the allowable area Ra is allowed to be easily set even at a site, for example, where a restriction area cannot be clearly defined. Besides, even at a site where the environment around the work machine 1 varies, the allowable area Ra is allowed to be flexibly set.

[0041] Although the allowable area Ra shown in FIG. 5D is set on the front side of the work machine 1, there may be set, on not only the front side but also the rear side of the work machine 1, an allowable area, for example, an allowable area Rb as shown in FIG. 6. The allowable area Ra which is set on the front side of the work machine 1 is applied to the case where the turning angle of the upper turning body 22 is within the range of - 90° to 90° across 0°, and the allowable area Rb which is set on the rear side of the work machine 1 is applied to the case where the turning angle of the upper turning body 22 is within the range of - 90° to 90° across 180° (- 180°). The allowable area Rb shown in FIG. 6 is set only on the upper side of the upper turning body 22 to avoid obstacles behind the work machine 1, but it is not limited thereto.

[0042] The control unit 11 shown in FIG. 2 transmits to the portable terminal 3 that the control unit 11 itself revises the designated motion, namely, the series of motions, and the portable-terminal side control unit 15 of the portable terminal 3 executes a notification about the revision. The control unit 11 and the portable-terminal side control unit 15, thus, constitute a notification means. Specifically, the portable-terminal side control unit 15 performs at least one of making the display 17 of the portable terminal 3 to display a notification for the revision and making a sound for notification of the revision to be output from the speaker of the portable terminal 3. The notification enables an operator who manages the work machine 1 to recognize that the designated motion is revised.

[0043] There may be a case of difficulty for the control unit 11 of making the upper turning body 22 and the attachment 30 perform the designated motion that has been revised by the control unit 11. For example, if the revision of the designated motion involves the full stroke extension of the boom cylinder 41, the boom 31 cannot be rotationally moved upward any more. For such a case, preferably, the control unit 11 is configured to serve as a stop control means for stopping the motion of the upper turning body 22 and the attachment 30. This can restrain the upper turning body 22 and the attachment 30 from performing unreasonable motion.

[0044] When being set in a coordinate system based on the work machine 1 (machine coordinate system), the allowable area is shifted along with the movement of the work machine 1 in the traveling direction of the lower traveling body 21. On the other hand, when the allowable area is set in a coordinate system based on the work site (for example, a global coordinate system), the relative position of the allowable area to the work machine 1 is changed with the movement of the work machine 1 in the traveling direction.

[0045] When the allowable area is set in the coordinate system based on the work site, the control unit 11 updates the allowable area along with the movement of the work machine 1, based on the position of the upper turning body 22 detected by the GNS sensor 26, that is, the position in the coordinate system. For example, when the allowable area shown in FIG. 4, that is, the allowable area from the turning center axis 20 to the position separated from the turning center axis 20 leftward of the lower traveling body 21 (in X direction) by a distance Lx (for example, 6000 mm) is set in the coordinate system based on the work site, the control unit 11 updates the allowable area, with the movement of the work machine 1 in the X direction by a predetermined distance (e.g., 1000 mm) as shown in FIG. 8, so as to reduce the distance from the turning center axis 20 to the outer end of the allowable area (left end in FIG. 7) to a distance Lxr (e.g., 5000 mm) that is less than the distance Lx before the update.

[0046] Such update of the allowable area along with the movement of the work machine 1 enables the relative positional relationship between the attachment 30 and the like and the allowable area to be properly judged regardless of the movement of the work machine 1 in the coordinate system based on the work site. This allows an operator to be free from resetting the allowable area after the movement of the work machine 1, thereby reducing the burden on the operator.

[0047] The portable-terminal side communication device 16 of the portable terminal 3 shown in FIG. 2 is capable of communication with the work-machine side communication device 12 of the work machine 1. The portable-terminal side control unit 15 of the portable terminal 3 acquires trajectory information and allowable-area information from the work machine 1 through the portable-terminal side communication device 16. The trajectory information includes information about the trajectory 71 that the tip of the bucket 33 traces along with the designated motion and information about the

trajectory 72 of the tip of the bucket 33 that has been changed by the revision of the designated motion. The allowable-area information includes information about the allowable area that is set as described above and information about the relative positions of the upper turning body 22 and the attachment 30 to the allowable area.

[0048] The control unit 11 and the portable-terminal side control unit 15 serve as motion display control means for making a display 17, which is a motion information display device, display information about the designated motion and information about a result of the revision of the designated motion by the control unit 11. Specifically, displayed on the display 17 are respective trajectories indicated by the dotted line and the solid line in FIGS. 3 and 4, namely, the trajectory 71 that the tip of the bucket 33 traces along with the designated motion that has not yet been revised and the trajectory 72 that the tip of the bucket 33 traces along with the designated motion that has been already revised. The display provided by the display 17 enables an operator to compare the trajectories 71, 72 before and after the revision to accurately grasp the revised motion of the upper turning body 22 and the attachment 30 and further perform, when the revised motion has a problem, changing the condition of the revision or resetting the designated motion.

[0049] Besides, the control unit 11 and the portable-terminal side control unit 15 make a display 17, which is a position information display device, display the allowable area that has been set and the relative positions of the upper turning body 22 and the attachment 30 to the allowable area. For example, as shown in FIGS. 3 and 4, displayed on the display 17 are a front boundary surface 73 of the allowable area and respective figures that indicate the upper turning body 22 and the attachment 30. The display provided by the display 17 enables an operator to easily grasp the relative positions of the upper turning body 22 and the attachment 30 to the allowable area (e.g., the front boundary surface 73), and further to take an action such as moving the work machine 1 when the relative position has a problem.

[0050] Next will be described a work machine 101 according to a second embodiment with reference to the drawings. The configuration common to the first embodiment and the effect exhibited thereby will be omitted, and the points different from the first embodiment will be mainly described. The same member as that of the first embodiment is applied with the same sign as that of the first embodiment.

[0051] In the first embodiment, as shown in FIG. 5, the allowable area is set on the basis of a plurality of positions at which the tip of the bucket 33, which is the restriction target part of the attachment 30, can be located, whereas the control unit 11, which is the setting means according to the second embodiment, sets an allowable area based on the information about the ambient condition that is input from the management device 4 shown in FIG. 2. The management device 4 manages an ambient condition at a work site, for example, being a management server. The management device 4 manages information related to a position of an obstacle, a passage or the like at a work site.

[0052] The work-machine side communication device 12 of the work machine 101 shown in FIG. 2 is capable of communication with the management device 4. The control unit 11 acquires the ambient condition at the work site managed by the management device 4 from the management device 4. The use of the information managed by the management device 4, for example, allows an operator of the work machine 101 to be free from an operation to set an allowable area, thus allowing the allowable area to be easily set.

[0053] Specifically, the control unit 11, which is the setting means of the work machine 101 according to the second embodiment, sets the allowable area based on the ambient condition at the work site acquired by the LiDAR 27 shown in FIG. 2.

[0054] An example of the setting of the allowable area is described with reference to FIG. 9. FIG. 9 is a side view showing a vessel 6 of a dump truck 5 and the periphery therearound, illustrating work for removing soil and sand to the vessel 6. The setting of the allowable area is appliable to also work for leveling soil and sand loaded on the vessel 6 with the bucket 33.

[0055] The amount of soil and sand loaded on the vessel 6 is increased with an increase in the number of soil removal operations onto the vessel 6. This involves the variation in the ambient condition around the vessel 6 from moment to moment, which condition is acquired by the LiDAR 27.

[0056] Along with the motion designated for the soil removal work, the tip of the bucket 33 is moved from the left side to the right side in the FIG. while tracing a trajectory 71 indicated by a dotted line in FIG. 9.

[0057] The control unit 11 sets an allowable area above the soil and sand loaded on the vessel 6 based on the ambient condition at the work site acquired by the LiDAR 27. In FIG. 9, the lower boundary surface 73 of the allowable area is indicated by a dot chain line. The side closer to the vessel 6 than the lower boundary surface 73 (lower side in FIG. 9) is the outer side of the allowable area, and the side farther from the vessel 6 than the lower boundary surface 73 (upper side in FIG. 9) is a side on which the allowable area lies. The control unit 11 modifies the allowable area (the lower boundary surface 73) from time to moment in response to the change in the amount of soil and sand loaded on the vessel 6. Thus is allowed a proper allowable area to be set according to the variation in the ambient condition based on the acquired ambient condition.

[0058] When soil and sand is loaded on the vessel 6 in a shape as shown in FIG. 9, the movement of the tip of the bucket 33 to the front side (right side in FIG. 9) of the vessel 6 along the trajectory 71 indicated by the dotted line in FIG. 9 may bring the tip into collision with the soil and sand. To prevent such collision, the control unit 11 as a revision means revises the designated motion so as to make the tip of the bucket 33 trace a trajectory 72 indicated by a solid line in FIG. 9.

[0059] Next will be describe a work machine 201 according to a third embodiment with reference to FIGS. 10 and 11. The configuration common to the first embodiment and the effect exhibited thereby will be omitted, and the points different from the first embodiment will be mainly described. The same member as that of the first embodiment is applied with the same sign as that of the first embodiment.

[0060] In the third embodiment, the revision of a designated motion is performed when there is a possibility of protrusion of the tip of a bucket 33 beyond an allowable area during the designated motion. In the third embodiment, as shown in FIG. 10, there are set points A and B as target points at respective positions close to the front boundary surface (left boundary surface in FIG. 10) 73 indicated by the dot chain line in the allowable area. The point B is located downward of the point A and closer to the front boundary surface 73 of the allowable area than the point A. The interval between the point A and the point B is larger than the interval between the point A and the point B according to the first embodiment shown in FIG. 4.

[0061] The control unit 11, which is a control means of the work machine 201, controls the driving of the upper turning body 22 and the attachment 30 so as to make the tip of the bucket 33 pass through the point A and the point B in this order to thereby make the upper turning body 22 and the attachment 30 perform the designated motion. The path of the tip of the bucket 33 between the point A and the point B is not fixed but allowed to be any path between the point A and the point B. This generates a possibility of protrusion of the tip of the bucket 33 beyond the allowable area, depending on the path, such as the trajectory 71 indicated by the dotted lines (leftward projection over the front boundary surface 73 in FIGS. 10 and 11).

[0062] In such a case where there is a possibility of protrusion of the tip of the bucket 33 beyond the allowable area in a region between the point A and the point B during the unrevised designated motion that has not been revised yet, the control unit 11 sets at least one transit point at a position between the point A and the point B within the allowable area (a position on the right side of the front boundary surface 73 in FIGS. 10 and 11). The at least one transit point includes two transit points C1, C2 in the example shown in FIG. 10. The at least one transit point, however, may include one or more transit points.

[0063] In the example shown in FIG. 10, the control unit 11 sets the two transit points C1, C2 on a line L1 interconnecting the point A and the point B. The line L1 may be either a straight line or a curve. The line L1 illustrated in FIG. 10 is a straight line both when viewed sideward of the upper turning body 22 of the work machine 201 and when viewed in a direction along the turning axis of the upper turning body 22 (viewed from above the work machine 201). The two transit points C1, C2 may be set in any of the following manners: at equal intervals in the X-direction, which is the front-rear direction of the upper turning body 22; at equal intervals in the Z-direction, which is the vertical direction of the upper turning body 22: at respective positions that equally divides the line L1 itself. Setting the two transit points C1, C2 on the line L1, which is the straight line interconnecting the point A and the point B, as described above allows the arithmetic operation for the setting to be simplified.

[0064] The control unit 11 serves as a revision means that revises the designated motion so as to make the tip of the bucket 33 pass through the transit points C1 and C2. The revision reliably prevents the tip of the bucket 33 from being protruded beyond the allowable area, that is, crossing over the front boundary surface 73, even when the point A and the point B are close to the front boundary surface 73 of the allowable area.

[0065] FIG. 11 shows a second example of the setting of the transit point performed by the control unit 11. In the second example, the control unit 11 sets a transit point C at a position between two target points A and B within an allowable area (inside the front boundary surface 73, right side in FIG. 11). The point B is the final point of the unrevised designated motion, therefore being the downstream target point selected from the two target points A, B. The transit point C is set on a straight line L2 passing through the point B. The straight line L2 is inclined to the horizontal plane at an angle formed by the horizontal plane and the direction of the movement of the attachment 30, that is, the direction of the movement of the tip of the bucket 33 when the tip of the bucket 33 passes through the point B by the unrevised designated motion. In the present embodiment, the motion at the point B is an excavation motion. Such setting of the transit point C enables the attachment 30 to be made suitably perform the work (excavation work) by the designated motion at the point B.

[0066] The transit point C is located directly below the point A when viewed from the side of the upper turning body 22 as shown in FIG. 11 and between the point A and the point B when viewed in a direction along the turning center axis of the upper turning body 22 (when viewed from above).

[0067] The straight line L2 may be inclined to the horizontal plane at an angle formed between a horizontal plane and the direction of the movement of the attachment 30, specifically, the movement of the restriction target part (in the present embodiment, the tip of the bucket 33) when the attachment 30 performs predetermined work at the point B. In the embodiment, the predetermined work at the point B is excavation work. Also in this case, the attachment 30 can be made suitably perform the predetermined work (excavation work) at the point B.

[0068] Next will be described a work machine 301 according to a fourth embodiment with reference to FIGS. 12 to 17. The configuration common to the first embodiment and the effect exhibited thereby will be omitted, and the points different from the first embodiment will be mainly described. The same member as that of the first embodiment is applied with

the same sign as that of the first embodiment.

[0069] The designated motion according to the fourth embodiment is an excavation motion for excavating soil and sand, which is an excavation object, by the bucket 33 of the work machine 301, and the excavation motion is revised. The excavation object is not limited to soil and sand but allowed to be also stone, waste, or the like.

[0070] The excavation motion is to excavate soil and sand in an excavation area (rectangular area in FIG. 12) enclosed by a dashed line in FIG. 12, and the excavation area 80 is set on the front side (right side in FIG. 12) of the lower traveling body 21 of the work machine 301. The allowable area according to the fourth embodiment is defined by a plurality of boundary surfaces indicated by dashed lines in FIG. 12, which include a first boundary surface 73a, a second boundary surface 73b, a third boundary surface 73c, a fourth boundary surface 73d, and a fifth boundary surface 73e. The second boundary surface 73b is a vertical surface set at a position away from the work machine 301 frontward of the lower traveling body 21, and the first boundary surface 73a is a horizontal plane extending in a direction away from the work machine 401 beyond the upper end of the second boundary surface 73b. The start point A is an endpoint of the excavation motion, located at the height equal to the height of the soil surface and on the front side of the second boundary surface 73b (i.e., outside the allowable area). The third boundary surface 73c is a horizontal plane along the bottom surface of the excavation area 80, having a front end and a rear end that are connected to the second and fourth boundary surfaces 73b, 73d, respectively. The fourth boundary surface 73d is a vertical surface that crosses the soil and sand perpendicularly at a position on the frond side of the front end of the lower traveling body 21 of the work machine 301, connected to the rear end of the third boundary surface 73c. The fifth boundary surface 73e is a horizontal plane along the ground on which the work machine 301 lies, connected to the upper end of the fourth boundary surface 73d.

[0071] In the case of thus setting the allowable area, the performance of the excavation motion with making the tip of the bucket 33 trace the trajectory 71 indicated by the dashed line in FIG. 12 involves the protrusion of the tip of the bucket 33 beyond the allowable area at the start point A of the excavation motion. More specifically, the tip of the bucket 33 projects forward (rightward in FIG. 12) over the second boundary surface 73b. If a revision is performed to shift the start point A to a position on the second boundary surface 73b, similarly to the first embodiment, to prevent the above-described deviation of the tip of the bucket 33 from the allowable area, the tip of the bucket 33 will trace a trajectory 72 indicated by a solid line. In the trajectory 72, the penetration direction in which the bucket 33 is penetrated into the soil and sand is rendered substantially vertical, the tip of the bucket 33 difficultly following the trajectory 72.

[0072] To avoid such inconvenience, the control unit 11 as a revision means according to the fourth embodiment shifts the entire region of the excavation motion toward the work machine 301 (leftward in FIG. 13) so as to bring the start point X in the revised excavation motion to the height that is equal to the height of the soil surface within the allowable area, as indicated by the solid line in FIG. 13. The height of the soil surface can be acquired, for example, by the LiDAR (height detection device) 27 shown in FIG. 1. Such revision to horizontally shift the entire region of excavation motion allows the tip of the bucket 33 to be prevented from deviation from the allowable area while keeping a smooth excavation motion.

[0073] According to the revision shown in FIG. 13, the horizontal movement distance La from the start point A of the unrevised excavation motion to the start point X of the revised excavation motion and the horizontal movement distance Lb from the terminal point B of the unrevised excavation motion to the terminal point Y of the revised excavation motion are equal to each other.

[0074] Conversely to the example shown in FIG. 13, in the case of rearward deviation of the terminal point B of the excavation motion from the allowable area as shown in FIG. 14, specifically in the case where the terminal point B is located on the outer side of the fourth boundary surface 73d (left side in FIG. 14) that is the rear vertical boundary surface of the allowable area and, for example, located at the same height as the height of the soil surface, it is preferable to shift the entire region of excavation motions horizontally away from the work machine 301 and forward of the upper turning body 22.

[0075] In the example shown in FIG. 14, where the horizontal distance Lb from the terminal point B of the unrevised excavation motion to the point C at the same height on the fourth boundary surface 73d is larger than the horizontal distance La from the start point A of the unrevised excavation motion to the point D at the same height on the second boundary surface (front boundary surface) 73b, the shift of the entire region of the excavation motion in the front direction of the upper turning body 22 (rightward in FIG. 14) by the horizontal distance Lc would cause the start point X of the revised excavation motion to be protruded beyond the allowable area, that is, would cause the start point to project to the outside (right side in FIG. 14) of the second boundary surface 73b. Hence, in the present example, the entire region of the excavation motion is shifted by not the distance Lc but the distance La smaller than the distance Lc so as to keep the start point X of the revised excavation motion from being protruded beyond the allowable area. The start point X of the revised excavation motion is thus shifted to a point on the second boundary surface 73b. On the other hand, by the shift of the region of the excavation motion only by the distance La, the point B' corresponding to the non-shifted terminal point B cannot be made reach the fourth boundary surface 73d, still located outside the allowable area (on the rear side of the fourth boundary surface 73d); hence, to shift the terminal point B to the point Y on the fourth boundary surface 73d, a revision is made to modify the trajectory of the tip of the bucket 33 to the trajectory 74 shown in FIG. 14. The

shape of the part of the trajectory 74 from the start point X on the second boundary surface 73b to the transit point E on the third boundary surface 74d is equivalent to the trajectory 71 before the revision, but the part from the transit point E to the terminal point Y is such a trajectory that the tip of the bucket 33 rises substantially vertically. The transit point E, therefore, is the intersection point of a vertical boundary surface on the side closer to the work machine 301 among the boundary surfaces defining the allowable area, namely, the fourth boundary surface 73d, and a trajectory 72 that is provided by the frontward shift of the trajectory 71 of the bucket 33 before the revision in parallel by the distance La.

[0076] In the trajectory 74 which has been modified as described above, the terminal point Y in the trajectory 74 is located on the front side of the terminal point B', involving an decrease in the excavation amount of the soil and sand by the area S 1 of the region indicated by the oblique lines in FIG. 15, that is, by the area of the substantially triangular shape in the side view having the point Y, the point B', and the point E as vertices, compared with the trajectory 72 that has not been modified yet. For such a case that the modification from the trajectory 72 to the trajectory 74 involves a decrease in the excavation amount, it is preferable that the control unit 11 is configured to make further modification of trajectory to increase the excavation depth so as to compensate for the amount of the decrease in the excavation amount.

[0077] FIG. 16 shows an example of the further modification of the trajectory. In the present example, the trajectory 74 shown in FIG. 15 is modified to a trajectory 75 below the trajectory 74. Specifically, the part from the lowest point D to the transit point E on the trajectory 74 is shifted downward. The lowest point D is the point that is located on the lowermost side of the points included in the trajectory 74. In the case where the trajectory 74 includes a plurality of lowest points, any lowest point from among the plurality of lowest points is selected. In the example shown in FIG. 16, the lowest point D is changed to the point (changed lowest point) F directly therebelow, and the transit point E is changed to the point (changed transit point on the fourth boundary surface 73d) G directly therebelow. The trajectory 75 is provided by modifying the curve part interconnecting the final common point H, the lowest point D, and the transit point E shown in FIG. 16 of the trajectory 74 to the curved portion interconnecting the final common point H, the changed lowest point F, and the changed transit point G, wherein the final common point H is the most downstream point of the common part of the trajectory 75 with the trajectory 74. Such revision makes it possible to compensate for the excavation amount by the area sandwiched between the unrevised curved part that interconnects the points H, D, E and the revised curved part that interconnects the points H, F, G, namely, the area S2 indicated by oblique lines in FIG. 16. If the changed lowest point F and the changed transit point G are set so as to render the area S2 equal to the area S1 (the area corresponding to the amount of the decrease in the excavation amount due to the change of the terminal point from the point B' to the point Y), the amount of the decrease in the excavation amount due to the revision shown in FIG. 15 will be fully compensated by the further revision shown in FIG. 16.

[0078] The final common point H is set so as to reduce the step that is caused, in the trajectory 75, by respective changes of the lowest point D and the transit point E to the changed lowest point F and the changed transit point G to secure the smooth motion of the bucket 33. In the example shown in FIG. 16, the final common point H is set at the position upstream of the lowest point D by a distance Lh in the trajectory 74, and the trajectory 75 after the further revision is defined by interconnecting the final common point H and the changed lowest point F through a straight line. Setting the final common point H so as to render the difference between the inclination of the straight line and the inclination of the trajectory 74 at the final common point H, preferably so as to render both the inclinations equal to each other, allows the trajectory 75 to be smoothed.

[0079] In the example shown in FIGS. 12 to 16, the changed lowest point F is required to be set at a position having a height equal to that of the second boundary surface 73b, which is the lower boundary surface of the allowable area, or a position on the upper side thereof. Accordingly, the compensation for the excavation amount by the downward change from the lowest point D to the changed lowest point F is performed within the allowable area inside the third boundary surface 73c.

[0080] FIG. 17 is a flowchart showing a process executed by the control unit 11 to make the revision according to the fourth embodiment.

[0081] The control unit 11 initially judges whether or not at least one of the two endpoints of the unrevised excavation motion (the start point A and the terminal point B) is outside the allowable area, more specifically, whether or not deviated horizontally from the allowable area (step S1). Only when judging at least one of the endpoints of the unrevised excavation is outside the allowable area (YES in step S1), the control unit 11 shifts the entire region of the excavation motion horizontally so as to confine the at least one endpoint into the allowable area (Step S2). For example, when the trajectory before the revision is the trajectory 71 in which the terminal point B significantly deviates from the allowable area as shown in FIG. 14, the start point A of the trajectory 71 is shifted horizontally within a range for keeping the start point A of the trajectory 71 from deviating from the allowable area (by a horizontal distance La in the drawing) to make the shift to the trajectory 72. In the case of judging that both of the endpoints of the unrevised excavation motion is within the allowable area (NO in step S1), where the horizontal shift of the region of the excavation motion is not required, the processing of the step S2 and the following steps S3 to S6 are skipped.

[0082] Next, the control unit 11 judges whether or not the endpoint of the excavation motion having been horizontally shifted is still outside the allowable area (step S3). For example, in the example shown in FIG. 14, it is judged whether

or not the point B' that has been horizontally shifted from the terminal point B is still outside the allowable area.

[0083] When judging the endpoint to be outside the allowable area (YES in step S3), the control unit 11 modifies the trajectory to confine the endpoint that is lying outside the allowable area into the allowable area (step S4). For example, if the terminal point B' that has been shifted as described above is outside the allowable area, as shown in FIG. 14, the trajectory 72 is modified to the trajectory 74 that rises substantially vertically from the transit point E to the terminal point Y as shown in FIGS. 14 and 15 in order to change the terminal point B' to the point Y on the fourth boundary surface 73d of the allowable area.

[0084] Next, the control unit 11 judges whether or not the modification of the trajectory involves a decrease in the excavation amount (step S5). Only when judging that the excavation amount will decrease (YES in step S5), the control unit 11 further modifies the trajectory so as to compensate for the amount of the decrease in the excavation amount (step S6). For example, if the excavation amount will decrease by an area S1 as shown in FIGS. 15 and 16, the control unit 11 changes the trajectory of the tip of the bucket 33 downward from the trajectory 74 passing through the lowest point D and the transit point E to the trajectory 75 passing through the changed lowest point F and the changed through point G as shown in FIG. 16.

[0085] Next, the control unit 11 judges whether or not the lowest point of the trajectory of the tip of the bucket 33 is outside the allowable area (step S7). Only when judging the lowest point to be outside the allowable area (YES in step S7), the control unit 11 revises the lowest point (step S8). For example, if the lowest point F shown in FIG. 16 is lower than the third boundary surface 73c of the allowable area, the lowest point F is revised upward so as to be confined within the allowable area.

[0086] The control unit 11 controls the driving of the attachment 30 so as to make the attachment 30 perform the excavation motion, which is the designated motion finally determined through the above-described processes of step S1 to S8 (Step S9).

[0087] Next will be described a work machine 401 according to a fifth embodiment with reference to FIGS. 18 to 22. The configuration common to the first embodiment and the effect exhibited thereby will be omitted, and the points different from the first embodiment will be mainly described. The same member as that of the first embodiment has the same sign as that of the first embodiment.

[0088] In the fifth embodiment, as in the fourth embodiment, an excavation motion for excavating soil and sand with the bucket 33 is revised. Specifically, there are a series of motions in the fifth embodiment, the motions being the designated motion and including an excavation motion for excavating soil and sand with the bucket 33. Also in the fifth embodiment, the height of the soil surface is detected by the LiDAR (height detection device) 27 shown in FIG. 1.

[0089] In FIG. 18, an allowable area is set, defined by a plurality of boundary surfaces indicated by dot chain lines, to excavate soil and sand having a soil surface 82 indicated by dashed lines. The plurality of boundary surfaces include a first boundary surface 73a, a second boundary surface 73b, a third boundary surface 73c, a fourth boundary surface 73d and a fifth boundary surface 73e, which surfaces are similar to the first to fifth boundary surfaces 73a to 73e shown in FIGS. 12 to 16, respectively. The start point A of the excavation motion is the intersection point of the trajectory 71 of the movement of the tip of the bucket 33 involved by the excavation motion and the soil surface 82, located on the front side of the first boundary surface 73a, which is the front boundary surface in the example shown in FIG. 18, i.e., outside the allowable area, and located at a height equivalent to the height of the soil surface 82. At the start point A, therefore, the tip of the bucket 33 is protruded beyond the allowable area.

[0090] If a revision is made to shift the start point A to a position on the second boundary surface 73b, which is the front-side boundary surface of the allowable area, similarly to the first embodiment, in order to confine the tip of the bucket 33 into the allowable area, the trajectory 71 of the tip of the bucket 33 will be changed to the trajectory 72, and the part of the trajectory 71 that had lied beyond the allowable area will be made a surface along the second boundary surface 73b as indicated by a solid line, and the revised start point X is located on the second boundary surface 73b. The revision of the excavation motion, thus, involves the modification of the trajectory of the tip of the bucket 33, thereby changing the ground angle θ of the bucket 33 at least at the starting part of the excavation motion. The ground angle θ is the angle of the upper surface 33a of the bucket 33 to the vertical plane, as shown in FIG. 19. The ground angle θ at which the upper surface 33a extends vertically is 0°.

[0091] The increase in the ground angle θ of the bucket 33 in the soil increases excavation resistance to hinder soil and sand from being well excavated. To prevent it, the control unit 11 as a revision means according to the fifth embodiment sets a ground angle θc of the bucket 33 after the revision on the basis of a preset angle θs, which is a preset ground angle θ of the bucket 33, upon the revision of the excavation motion. The set angle θs, i.e., the preset ground angle of the bucket 33, is a ground angle set by teaching or numerical input, etc.

[0092] Specifically, the control unit 11 sets the ground angle θ of the bucket 33 at which the bucket 33 is penetrated into soil and sand, which is an excavating object (work object), to the ground angle θ of the bucket 33 at which the bucket 33 is penetrated into the soil and sand by the unrevised excavation motion. The ground angle θ of the bucket 33 at which the bucket 33 is penetrated into the soil and sand is the ground angle of the bucket 33 at respective start points A, X of the unrevised and revised excavation motions. Thus rendering the ground angle θ of the bucket 33 at the time of the

penetration during the revised excavation motion equal to the ground angle θ of the bucket 33 during the unrevised excavation motion enables the bucket 33 to be reliably penetrated into the ground.

[0093] Similarly, the control unit 11 sets the ground angle θ of the bucket 33 at which the bucket 33 is extracted from soil and sand to the ground angle θ of the bucket 33 at which the bucket 33 is extracted from the soil and sand by the unrevised excavation motion. The ground angle θ of the bucket 33 when the bucket 33 is extracted from soil and sand is the ground angle θ of the bucket 33 at respective terminal points B, Y of the unrevised and revised excavation motions. In the example shown in FIG. 18, the terminal points B, Y before and after the revision are coincident with each other. Thus rendering the ground angle θ of the bucket 33 when the bucket 33 is extracted from the soil and sand during the revised excavation motion equal to the ground angle θ of the bucket 33 during the unrevised excavation motion enables soil and sand to be restrained from pilling out of the bucket 33.

[0094] The control unit 11 further, in at least a part of the excavation motion, sets the ground angle θ of the bucket 33 in the revised excavation motion on the basis of respective ground angles θa, θb of the bucket 33 at the start point A and the terminal point B of the unrevised excavation motion, and respective path lengths of the trajectories 71, 72 of the tip of the bucket 33 in the unrevised and revised excavation motions. The target in the present embodiment is all of the excavation motion, i.e., all of the region between the start point X and the terminal point Y; however, the target may be a part of the excavation motion, i.e., a part of the region between the start point X and the terminal point Y.

[0095] FIG. 20A shows the trajectory 71 of the tip of the bucket 33 by the unrevised excavation motion, and FIG. 20B shows the trajectory 72 of the tip of the bucket 33 by the revised excavation motion. The ground angle θa of the bucket 33 at the start point A of the unrevised excavation motion and the ground angle θx of the bucket 33 at the start point X of the revised excavation motion are equal to each other, and also the ground angle θb of the bucket 33 at the terminal point B of the unrevised excavation motion and the ground angle θy of the bucket 33 at the terminal point Y of the revised excavation motion are equal to each other. The path length Lab of the trajectory 71 of the tip of the bucket 33 before the revision is changed to the path length Lxy of the trajectory 72 of the tip of the bucket 33 after the revision. The control unit 11 calculates the ground angle θz of the bucket 33 at any position between the start point X and the terminal point Y on the trajectory 72 by the following equation (1) based on the path length Lac from the start point A to the above any position in the trajectory 71 before the revision. Here, any position on the trajectory 72 corresponds to any position between the start point A and the terminal point B on the trajectory 71.

$$\theta z = \theta x + (\theta y - \theta x) \times (Lac/Lab) \times Lxy \ldots (1)$$

[0096] The setting of the ground angle θz of the bucket 33 based on the above equation (1) allows the ground angle of the bucket 33 after the revision to be also appropriate when the ground angle θ of the bucket 33 before revision is appropriate. This restrains excavation resistance from being increased by a change in the trajectory of the tip of the bucket 33 due to the revision of the excavation motion, thereby allowing soil and sand to be suitably excavated.

[0097] The ground angle θz of the bucket 33 at any position between the start point X and the terminal point Y on the trajectory 72 may be calculated by use of the following equation (2) in place of the equation (1).

$$\theta z = \theta x + (\theta y - \theta x) \times (Dac/Dab) \times Dxy \ldots (2)$$

[0098] The equation (2) includes horizontal distances Dab, Dxy, Dac. The horizontal distance Dab is the horizontal distance between the start point A and the terminal point B in the unrevised excavation motion, the horizontal distance Dxy is the horizontal distance between the start point X and the terminal point Y in the revised excavation motion, and the horizontal distance Dac is the horizontal distance between the start point A and the any position on the trajectory 71.

[0099] Setting the ground angle θz of the bucket 33 based on equation (2) also allows the ground angle of the bucket 33 after the revision to be appropriate when the ground angle of the bucket 33 before the revision is appropriate.

[0100] In the case of setting a transit point D, as shown in FIG. 18, at a position directly below the start point X after the revision on the second boundary surface 73b, which is the front boundary surface of the allowable area, it is also considerable that the ground angle θ from the start point X to the transit point D is set based on equation (1) or equation (2) while the ground angle from the transit point D to the terminal point Y is set to the ground angle before revision. Besides, the ground angle θ from the start point X to the transit point D may be kept the ground angle θx at the start point X.

[0101] FIG. 21 shows a case where soil and sand having a soil surface 82 indicated by a dotted line is excavated by the work machine 401 and the fourth boundary surface 73d, which is a vertical surface close to the work machine 401, out of the first to fifth boundary surfaces 73a to 73e that define an allowable area similarly to the first to fifth boundary surfaces 73a to 73e shown in FIG. 18, is located farther from the work machine 401 than the terminal point B of the excavation motion included in the designated motion, in other words, the terminal point B is located on the rear side (left side in FIG. 21) of the fourth boundary surface 73d thereover, that is, located outside the allowable area. The terminal

point B is located at a height equal to the height of the soil surface 82. In this case, the performance of the excavation motion to move the tip of the bucket 33 along the trajectory including the terminal point B, i.e., the trajectory 71 including the part indicated by the broken line in FIG. 21, involves the protrusion of the tip of the bucket 33 beyond the allowable area, at least at the terminal point B.

[0102] If a revision of the excavation motion is made so as to change the terminal point B to a terminal point Y located on the fourth boundary surface 73d as in the first embodiment in order to confine the terminal point B into the allowable area and modify the trajectory 71 to the trajectory 72 along the fourth boundary surface 73d as indicated by the solid line, the ground angle of the bucket 33 is varied in at least a part including the terminal point Y in the excavation motion. Also in this revision, the start point A before the revision and the start point X after the revision are the same.

[0103] Also regarding such revision, setting the ground angle θ of the bucket 33 in a manner equivalent to that described by use of FIGS. 18 and 20 can restrain excavation resistance from being increased.

[0104] FIG. 22 shows a case where a third boundary surface 73c, which is the lower boundary surface among first to fifth boundary surfaces 73a to 73e that define an allowable area similarly to the first to fifth boundary surfaces 73a to 73e shown in FIG. 18, is located on the upper side of the lowest point on the trajectory 71 of the movement of the tip of the bucket 33 in an excavation motion included in the designated motion, in other words, a case where the lowest point is located outside (on the lower side of) the third boundary surface 73c thereover. In this case, the performance of the excavation motion based on the trajectory 71 including the lowest point as indicated by a dashed line involves the protrusion of the tip of the bucket 33 beyond the allowable area at the lowest point and in the region across the lowest point.

[0105] If a revision of the excavation motion is made so as to change the lowest point upward to a point on the third boundary surface 73c in order to confine the lowest point into the allowable area and change to the trajectory 72 in which the region across the lowest point extends horizontally along the third boundary surface 73c, the ground angle θ of the bucket 33 is varied in at least a region including the lowest point (a horizontal region along the third boundary surface 73c) in the excavation motion. Such a variation in the ground angle θ may increase excavation resistance to hinder soil and sand from being well excavated.

[0106] To reduce the increase in the excavation resistance, the control unit 11 as a revision means sets the ground angle of the bucket 33 at the lowest point on the trajectory 72 to an angle equal to or less than the ground angle at which the bottom surface 33b (see FIG. 19) of the bucket 33 is horizontal. To the lowest point on the trajectory 72 correspond all points in the region between the two transit points E, F shown in FIG. 22 on the trajectory 72. The two transit points E, F are the intersections of the trajectory 71 before the revision and the third boundary surface 73c, respectively, and the region between the two transit points E, F is a region extending horizontally along the third boundary surface 73c.

[0107] Setting the ground angle θ of the bucket 33 at the lowest point on the trajectory 72 to an angle equal to or less than the ground angle at which the bottom surface 33b is horizontal reduces the excavation resistance at the lowest point to allow the soil and sand to be well excavated.

[0108] The above-described embodiments are just illustrative, not intended to limit the invention. The specific configuration disclosed can be designed as appropriate. Also, the effects and advantages described with respect to embodiments of the invention have only enumerated the most preferred effects arising from the present invention, not intended to limit the effects and advantages of the present invention.

[0109] Thus, there is provided a work machine capable of automatic operation within an allowable area without increase in the burden on an operator. The work machine includes a lower traveling body, an upper turning body, a work device, and a controller. The upper turning body is mounted on the lower traveling body capably of turning. The work device is attached to the upper turning body capably of performing a work motion. The controller controls driving of the upper turning body and the work device so as to make the upper turning body and the work device perform a designated motion that is designated in advance. The controller is configured to revise the designated motion, when a restriction target part of the work device will be protruded beyond an allowable area that is preset during the designated motion, so as to keep the restriction target part from being protruded beyond the allowable area.

[0110] The controller, which revises the designated motion to prevent the restriction target part from being protruded beyond the allowable area when the restriction target part will be protruded beyond the allowable area or there is a possibility of the protrusion during the designated motion, allows an operator to be free from resetting the designated motion by teaching or the like, thereby reducing the burden on the operator.

[0111] The allowable area may be predetermined and stored in the controller, or the controller may be configured to set the allowable area. For the latter case, it is preferable that the controller is configured to set the allowable area based on a plurality of positions at which a predetermined part of the work device can be located. This allows the allowable area to be easily set by positioning the predetermined part at the plurality of positions. For example, even at a site where the allowable area is not clearly defined, the allowable area can be easily set. Besides, even at a site where the environment around the work machine varies, the allowable area can be flexibly set.

[0112] Preferably, the controller is configured to set the allowable area based on information about an ambient condition at a work site. This reduces the burden on an operator for performing operations to set the allowable area, allowing the allowable area to be easily set.

[0113] The controller is, for example, preferably configured to set the allowable area based on the ambient condition managed by a management device that monitors the ambient condition at the work site. This allows the allowable area to be easily set by effective utilization of the information managed by the management device.

[0114] Alternatively, it is also preferable that the work machine further includes an acquisition device that acquires information about the ambient condition at the work site, wherein the controller is configured to set the allowable area on the basis of the ambient condition acquired by the acquisition device. This allows the allowable area to be set suitably in accordance with variation in the ambient condition from moment to moment.

[0115] The controller may be configured to control driving of the upper turning body and the work device so as to make the restriction target part pass through a plurality of target points sequentially to make the upper turning body and the work device perform the designated motion; preferably, for the case where there is a possibility that the restriction target part of the work device is protruded beyond the allowable area between two target points selected from among the plurality of target points in the designated motion that is unrevised, the controller is configured to set a transit point between the two target points within the allowable area and to revise the designated motion so as to make the restriction target part pass through the transit point. Even if there is a section in which the space between the target points is so large that there is a possibility of the protrusion of the restriction target part beyond the allowable area between the target points, the controller can prevent the restriction target part from being protruded beyond the allowable area by setting the transit point located between the two target points within the allowable area and revising the designated motion so as to make the restriction target part pass through the transit point.

[0116] The controller can easily set the transit point by, for example, setting the transit point on a line L1 interconnecting the two target points.

[0117] The controller, alternatively, may be configured to set the transit point on a straight line passing through a downstream target point. The downstream target point is a target point on the downstream side in the designated motion that is unrevised, selected from the two target points, and the straight line is a straight line inclined to a horizontal plane at an angle formed between the horizontal plane and a direction of the motion of the work device when the restriction target part passes through the downstream target point by the designated motion that is unrevised. Setting the transit point on such a straight line allows the work device to suitably perform work by the designated motion at the downstream target point.

[0118] The straight line, alternatively, may be a straight line inclined to a horizontal plane at an angle formed between the horizontal plane and a direction of the motion of the work device, specifically, a direction of movement of the restriction target part, when the work device performs a predetermined work motion. Setting the transit point on such a straight line allows the work device to suitably perform the predetermined work at the downstream target point.

[0119] In the case where the work device includes a bucket including the restriction target part and the designated motion includes an excavation motion for excavating an excavation object with the bucket, it is preferable that the work machine further includes a height detection device that detects a height of a surface of the excavation object and the controller is configured to horizontally shift a region in which the excavation motion is performed, when at least one of a start point and a terminal point of the excavation motion that is unrevised is an endpoint located at a height equivalent to a height of the surface and outside the allowable area, so as to locate the endpoint in the excavation motion that is unrevised at a height equivalent to the height of the surface within the allowable area. Such a revision as to horizontally shift the region in which the excavation motion is performed makes it possible to keep the motion of the bucket before the revision to secure a smooth excavation motion.

[0120] In this aspect, it is preferable that the controller is configured to revise the excavation motion, when the horizontal shift of the region of the excavation motion involves a decrease in an excavation amount by the excavation motion, to increase an excavation depth so as to compensate for an amount of the decrease in the excavation amount. The revision, which increases the excavation depth, i.e., the depth by which the excavation object is excavated by the bucket, to compensate for the amount of the decrease in the excavation amount, can restrain work efficiency from being lowered by the revision.

[0121] Moreover, it is preferable that the controller is configured to modify the trajectory of the bucket in a direction for smoothing the trajectory with increasing the excavation depth. The modification can restrain smooth motion of the bucket from being hindered by, for example, occurrence of a step in the trajectory of the bucket because of the increase in the depth of excavation.

[0122] Preferably, the controller is configured to set a ground angle of the bucket in the revised excavation motion based on a set angle that is a preset ground angle of the bucket. This restrains excavation resistance from being increased by a change in the ground angle of the bucket, in spite of the change in the trajectory of the tip of the bucket due to the revision of the excavation motion, allowing good excavation to be performed.

[0123] For example, the controller is preferably configured to set the ground angle of the bucket at which the bucket is penetrated into the excavation object in the revised excavation motion to an angle equal to a ground angle of the bucket at which the bucket is penetrated into the excavation object by the excavation motion that is unrevised. Thus applying the ground angle according to the unrevised excavation motion as the ground angle at which the bucket is

penetrated into the excavating object in the revised excavation motion allows the bucket to be reliably penetrated into the excavating object regardless of the revision.

[0124] Also, the controller is preferably configured to set the ground angle of the bucket at which the bucket is extracted from the excavation object in the revised excavation motion to an angle equal to a ground angle of the bucket at which the bucket is extracted from the excavation object in the unrevised excavation motion. Thus applying the angle equivalent to the ground angle in the unrevised excavation motion as the ground angle of the bucket extracted from the excavation object in the revised excavation motion makes it possible to restrain the excavation object from spilling from the bucket.

[0125] Preferably, the controller is configured to set a ground angle of the bucket in at least a part of the revised excavation motion based on respective ground angles of the bucket at a start point and a terminal point of the unrevised excavation motion and respective path lengths of the trajectories of the tip of the bucket in the unrevised excavation motion and the revised excavation motion. Thus setting the ground angle of the bucket allows the ground angle of the bucket after the revision to be also appropriate if the ground angle of the bucket before the revision is appropriate, thereby restraining the change in the trajectory of the tip of the bucket due to the revision of the excavation motion from increasing the excavation resistance to allow good excavation to be performed.

[0126] Also, the controller is preferably configured to set a ground angle of the bucket in at least a part of the revised excavation motion based on respective ground angles of the bucket at a start point and a terminal point of the unrevised excavation motion and a horizontal distance between the start point and the terminal point in each of the unrevised excavation motion and the revised excavation motion. Thus setting the ground angle of the bucket also allows the ground angle of the bucket after the revision to be appropriate if the ground angle of the bucket before the revision is appropriate, thereby restraining the change in the trajectory of the tip of the bucket due to the revision of the excavation motion from increasing the excavation resistance to allow good excavation to be performed.

[0127] Preferably, the controller is configured to set the ground angle of the bucket at the lowest point of the trajectory of the tip of the bucket to an angle equal to or less than a ground angle at which the bottom surface of the bucket is horizontal. This reduces the excavation resistance at the lowest point to allow good excavation to be performed.

[0128] Preferably, the controller is configured to make a notification device notify the revision of the designated motion. The notification can inform a worker managing the work machine of the revision of the designated motion.

[0129] Preferably, the controller is configured to stop respective motions of the upper turning body and the work device when judging it difficult to make the upper turning body and the work device perform the revised designated motion. The situation where it is difficult to make the upper turning body and the work device perform the revised designated motion is, for example, a situation where the revised designated motion exceeds the motion range of the upper turning body or the work device. Stopping the motion of the upper turning body and the work device in such a situation can restrain the upper turning body and the work device from performing unreasonable motion.

[0130] Preferably, the work machine further includes a position detection device that detects a coordinate of a position of at least one of the lower traveling body, the upper turning body and the work device in a coordinate system of the work site, and the controller is configured to set the allowable area in the coordinate system of the work site and to update the allowable area based on a change in the coordinate of the position detected by the position detection device. Such an update allows the positional relationship between the restriction target part and the allowable area to be properly judged without requiring an operator to reset the allowable area with the movement of the work machine in spite of the change in the relative positional relationship of the allowable area to the position of the work machine in the coordinate system of the work site, thereby reducing the burden on the operator.

[0131] The preferable restriction target part of the work device is, for example, a tip of the work device. The restriction target part, alternatively, may be a part other than the tip of the work device. In any case, by the revision of the designated motion, the controller can prevent the restricted target part of the work device from being protruded beyond the allowable area in the designated motion.

[0132] Preferably, the controller is configured to make a motion information display device display information about the designated motion and information about a result of the revision. This allows an operator looking at the display provided by the motion information display device to grasp the revised motion of the upper turning body and the work device by referring to both of the information about the designated motion and the information about the result of the revision, thereby enabling, for example, changing the revision condition or resetting the designated motion when there is a problem in the movement after the revision, to be performed.

[0133] Also, the controller is preferably configured to make a position information display device: display information about the allowable area and information about respective relative positions of the upper and work devices relative to the allowable area. This allows an operator looking at the display provided by the position information display to grasp the relative positions of the upper turning body and the work device to the allowable area, thereby enabling handling such as moving the work machine to be performed when there is a problem in the relative position.

Claims

1. A work machine comprising:

   a lower traveling body;
   an upper turning body mounted on the lower traveling body capably of turning;
   a work device attached to the upper turning body capably of performing a work motion; and
   a controller that controls driving of the upper turning body and the work device so as to make the upper turning body and the work device perform a designated motion that is designated in advance, wherein
   the controller is configured to revise the designated motion, when a restriction target part of the work device will be protruded beyond an allowable area that is preset or there is a possibility that the restriction target part is protruded beyond the allowable area when the upper turning body and the work device performs the designated motion, so as to keep the restriction target part from being protruded beyond the allowable area.

2. The work machine according to claim 1, wherein the controller is configured to set the allowable area.

3. The work machine according to claim 2, wherein the controller is configured to set the allowable area based on a plurality of positions at which a predetermined part of the work device can be located.

4. The work machine according to claim 1, wherein the controller is configured to set the allowable area based on information about an ambient condition at a work site.

5. The work machine according to claim 4, wherein the controller is configured to set the allowable area based on information about the ambient condition that is managed by a management device that manages ambient condition at the work site.

6. The work machine according to claim 4, further comprising an acquisition device that acquires information about an ambient condition of the work site, wherein the controller sets the allowable area based on information about the ambient condition acquired by the acquisition device.

7. The work machine according to any one of claims 1 to 6, wherein the controller is configured to perform: controlling driving of the upper turning body and the work device so as to make the restriction target part pass through a plurality of target points sequentially to make the upper turning body and the work device perform the designated motion; setting a transit point, when there is a possibility that the restriction target part of the work device is protruded beyond the allowable area between two target points selected from among the plurality of target points in the designated motion that is unrevised, between the two target points within the allowable area; and revising the designated motion so as to make the restriction target part pass through the transit point.

8. The work machine according to claim 7, wherein the controller is configured to set the transit point on a line interconnecting the two target points.

9. The work machine according to claim 7, wherein the controller is configured to set the transit point on a straight line passing through a downstream target point, which is a target point on a downstream side in the designated motion that is unrevised, selected from the two target points, the straight line being inclined to a horizontal plane at an angle formed between the horizontal plane and a direction of movement of the work device when the restriction target part passes through the downstream target point by the designated motion that is unrevised.

10. The work machine according to claim 7, wherein the controller is configured to set the transit point on a straight line passing through a downstream target point, which is a target point on a downstream side in the designated motion that is unrevised, selected from the two target points, the straight line being inclined to a horizontal plane at an angle formed between the horizontal plane and a direction of movement of the restriction target part when the work device performs a predetermined word motion.

11. The work machine according to any one of claims 1 to 4, wherein the work device includes a bucket, which includes the restriction target part, and the designated motion includes an excavation motion for excavating an excavation object with the bucket, the work machine further comprising a height detection device that detects a height of a surface of the excavation object, wherein the controller is configured to horizontally shift a region in which the excavation motion is performed, when at least one of a start point and a terminal point of the excavation motion that

is unrevised is an endpoint that is located at a height equivalent to a height of the surface and outside the allowable area, so as to locate the endpoint in the excavation motion that is revised at a height equivalent to the height of the surface.

12. The work machine according to claim 11, wherein the controller is configured to revise the excavation motion, when a horizontal shift of the region of the excavation motion involves a decrease in an excavation amount by the excavation motion, to increase an excavation depth so as to compensate for an amount of the decrease in the excavation amount, the excavation depth being a depth by which the excavation object is excavated by the bucket.

13. The work machine according to claim 12, wherein the controller is configured to modify a trajectory of the bucket in a direction for smoothing the trajectory with increasing the excavation depth.

14. The work machine according to any one of claims 1 to 6, wherein: the work machine includes a bucket; the designated motion includes an excavation motion for excavating an excavation object with the bucket; and the controller is configured to set a ground angle of the bucket in the excavation motion that is revised, on the basis of a set angle that is a preset ground angle of the bucket, with a revision of the excavation motion.

15. The work machine according to claim 14, wherein the controller is configured to set the ground angle of the bucket at which the bucket is penetrated into the excavation object in the excavation motion that is revised to an angle equal to a ground angle of the bucket at which the bucket is penetrated into the excavation object by the excavation motion that is unrevised.

16. The work machine according to claim 14, wherein the controller is configured to set the ground angle of the bucket at which the bucket is extracted from the excavation object in the excavation motion that is revised to an angle equal to a ground angle of the bucket at which the bucket is extracted from the excavation object in the excavation motion that is unrevised.

17. The work machine according to claim 14, wherein the controller is configured to set the ground angle of the bucket in at least a part of the excavation motion that is revised, based on respective ground angles of the bucket at a start point and a terminal point of the excavation motion that is unrevised and respective path lengths of trajectories of a tip of the bucket in the excavation motion that is unrevised and the excavation motion that is revised.

18. The work machine according to claim 14, wherein the controller is configured to set the ground angle of the bucket in at least a part of the excavation motion that is revised, based on respective ground angles of the bucket at a start point and a terminal point of the excavation motion that is unrevised and a horizontal distance between the start point and the terminal point in each of the excavation motion that is unrevised and the excavation motion that is revised.

19. The work machine according to claim 14, wherein the controller is configured to set the ground angle of the bucket at a lowest point of a trajectory of a tip of the bucket to an angle equal to or less than a ground angle at which a bottom surface of the bucket is horizontal.

20. The work machine according to any one of claims 1 to 6, wherein the controller is configured to make a notification device notify a revision of the designated motion.

21. The work machine according to any one of claims 1 to 6, wherein the controller is configured to stop respective motions of the upper turning body and the work device when judging it difficult to make the upper turning body and the work device perform the revised designated motion.

22. The work machine according to any one of claims 1 to 6, further comprising a position detection device that detects a coordinate of a position of at least one of the lower traveling body, the upper turning body and the work device in a coordinate system of a work site, wherein the controller is configured to set the allowable area in the coordinate system of the work site and to update the allowable area based on a change in the coordinate of the position detected by the position detection device.

23. The work machine according to any one of claims 1 to 6, wherein the restriction target part is a tip of the work device.

24. The work machine according to any one of claims 1 to 6, wherein the controller is configured to make a motion information display device display information about the designated motion and information about a result of the

revision.

25. The work machine according to any one of claims 1 to 6, wherein the controller is configured to make the position information display device display information about the allowable area and information about relative positions of the upper and work devices relative to the allowable area.

FIG.1

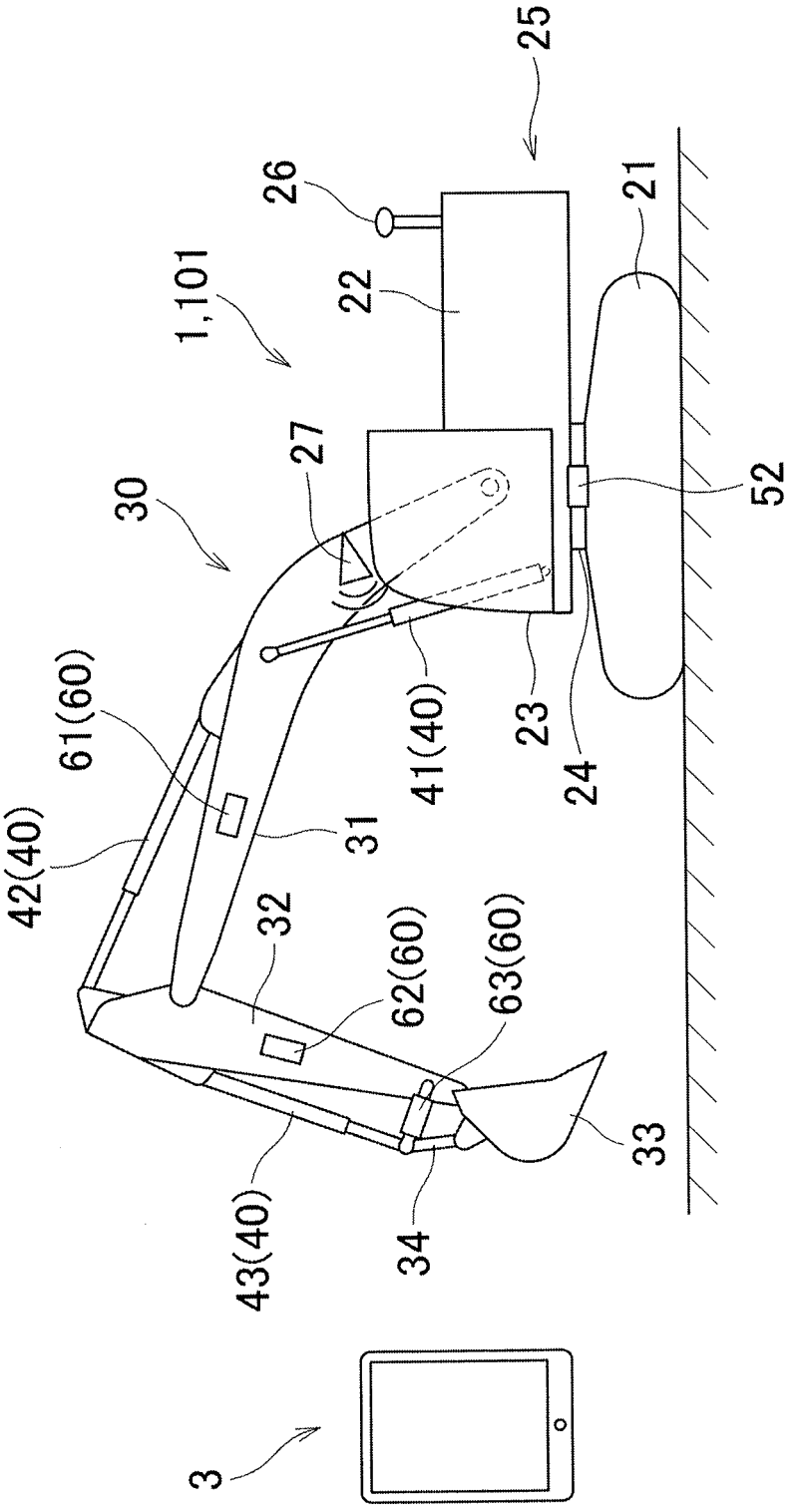

25
26
21
1,101
22
27
52
30
61(60)
41(40)
23
24
42(40)
31
32
62(60)
63(60)
33
43(40)
34
3

FIG.2

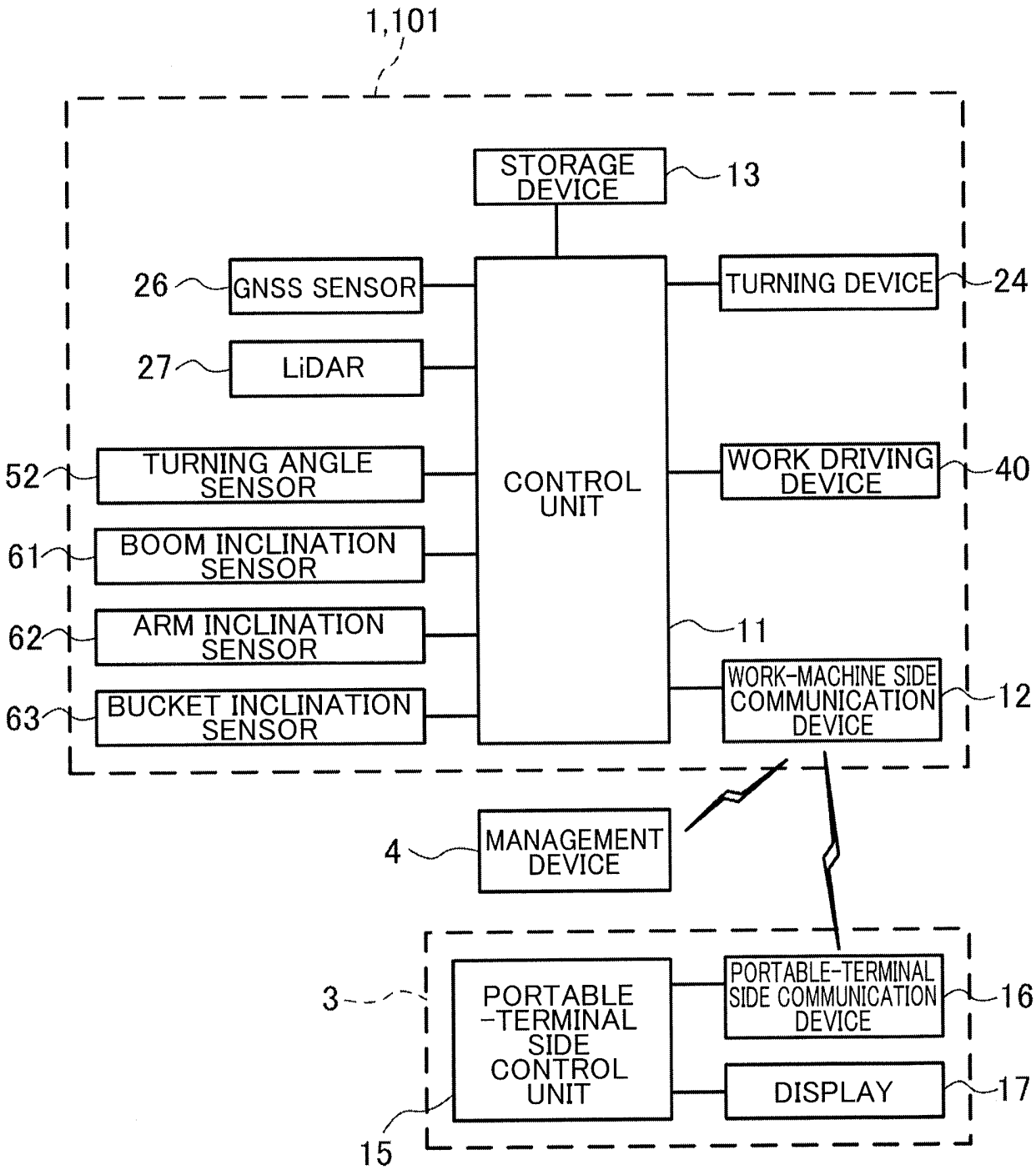

1,101
STORAGE DEVICE
13
26
GNSS SENSOR
27
LiDAR
52
TURNING ANGLE SENSOR
61
BOOM INCLINATION SENSOR
62
ARM INCLINATION SENSOR
63
BUCKET INCLINATION SENSOR
CONTROL UNIT
TURNING DEVICE
24
WORK DRIVING DEVICE
40
11
WORK-MACHINE SIDE COMMUNICATION DEVICE
12
4
MANAGEMENT DEVICE
3
PORTABLE -TERMINAL SIDE CONTROL UNIT
15
PORTABLE-TERMINAL SIDE COMMUNICATION DEVICE
16
DISPLAY
17

FIG.3

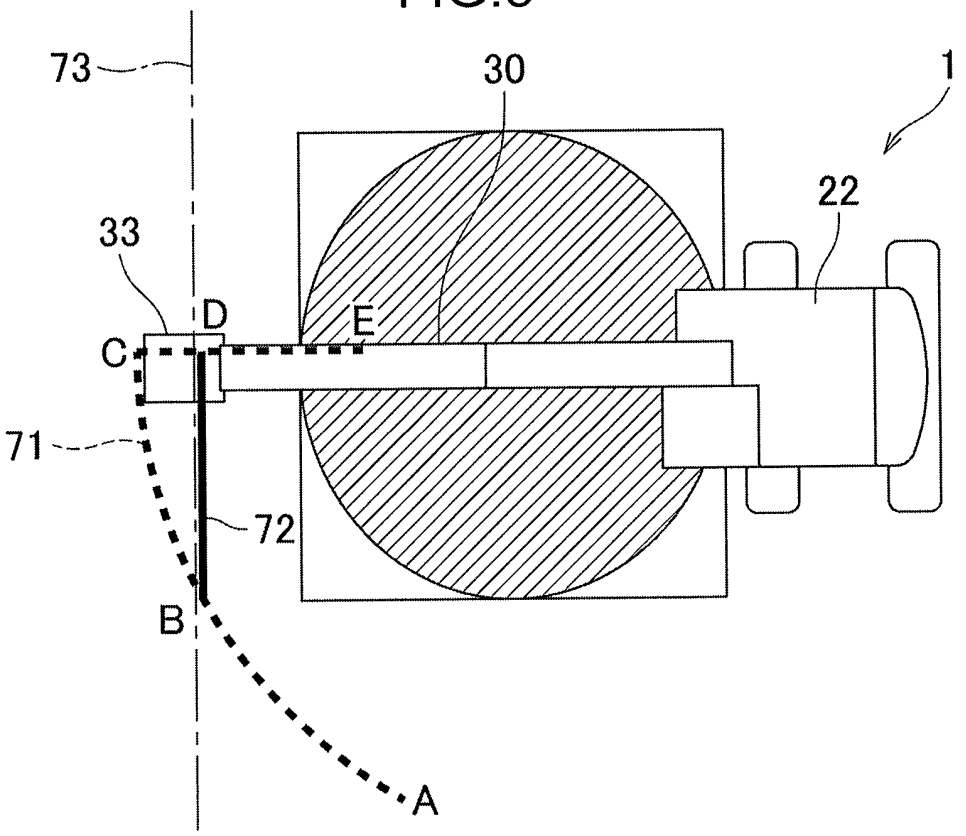


FIG.4

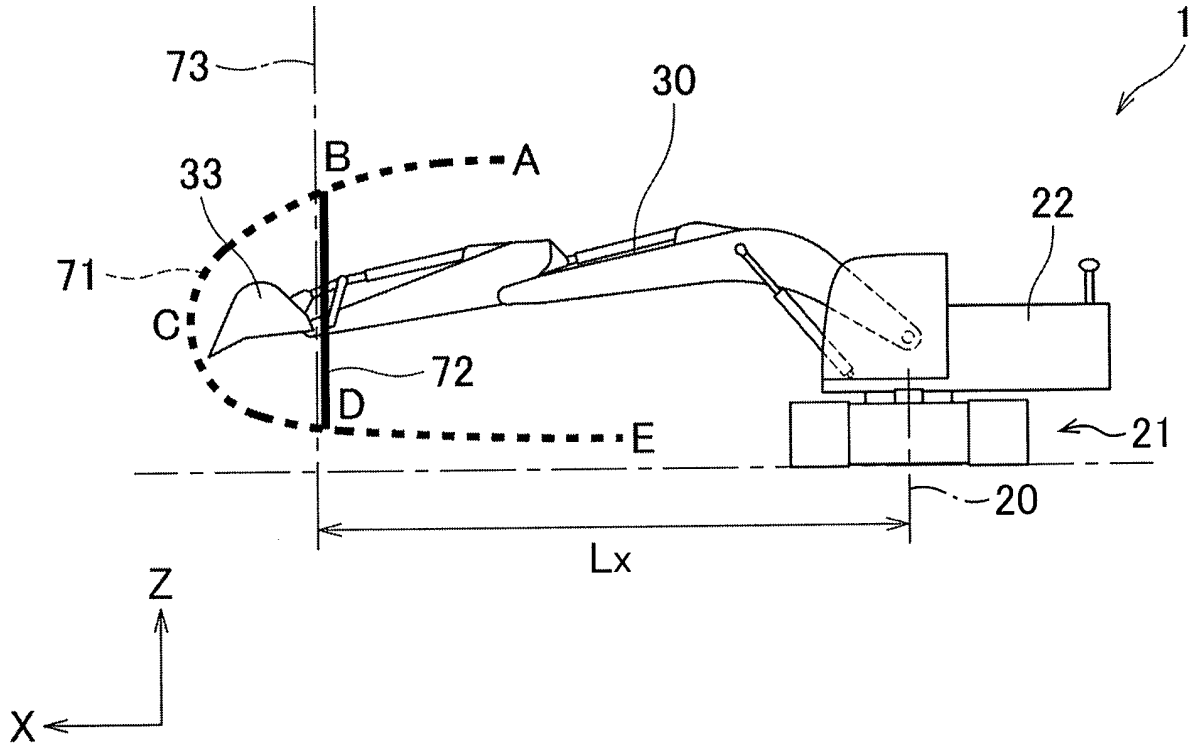


FIG.5A

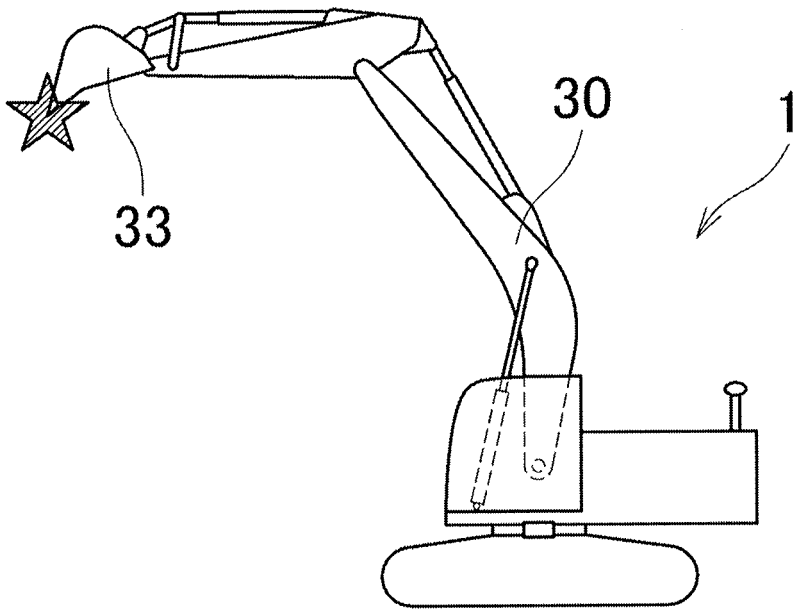


FIG.5B

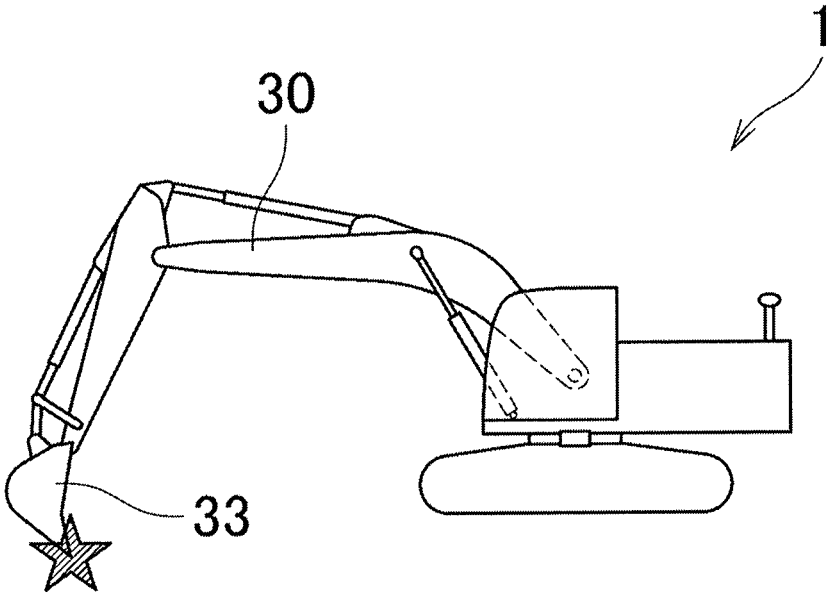


FIG.5C

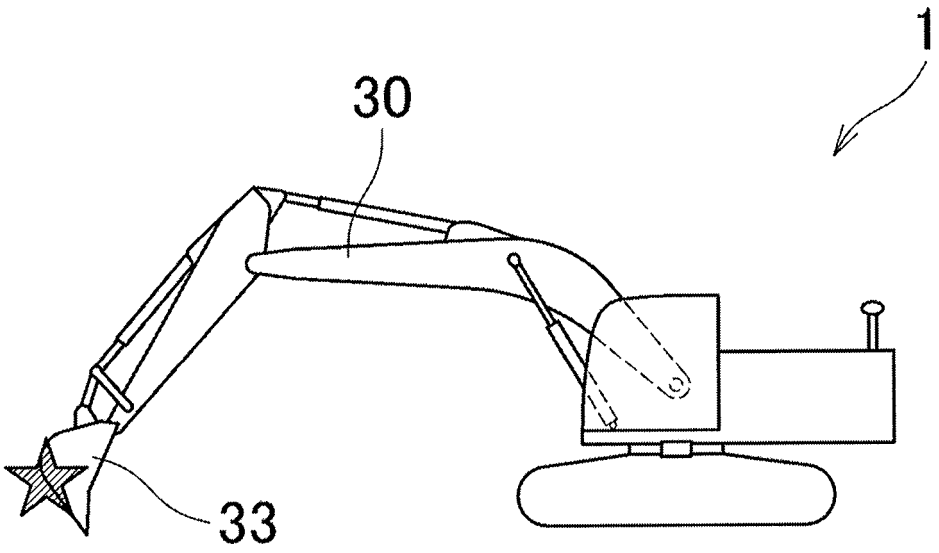


FIG.5D

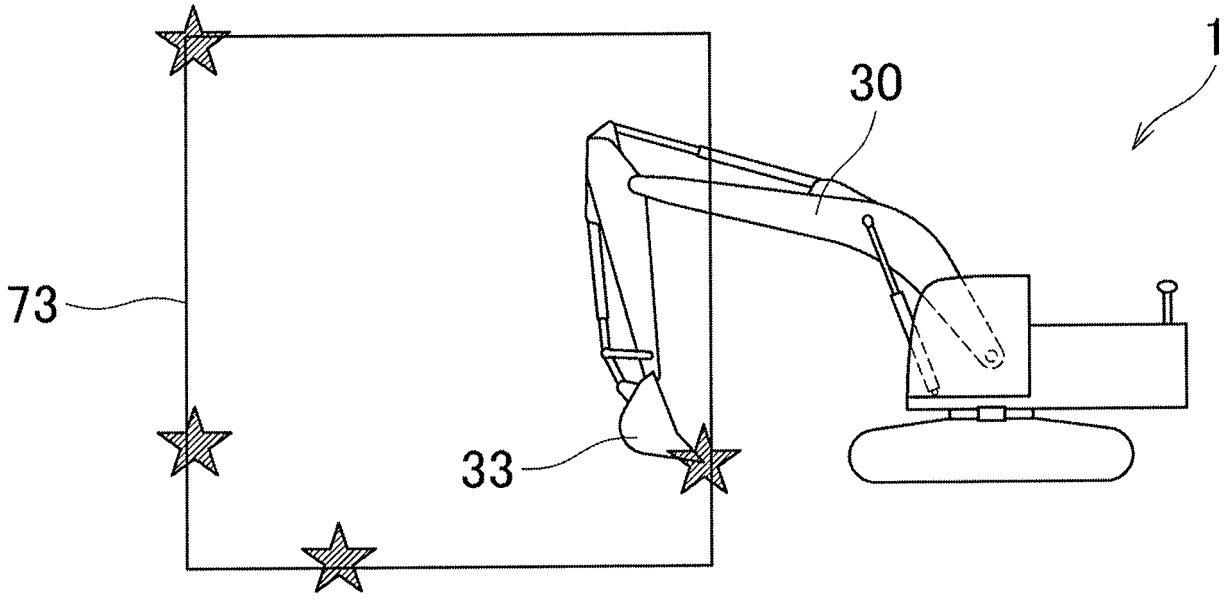


FIG.6

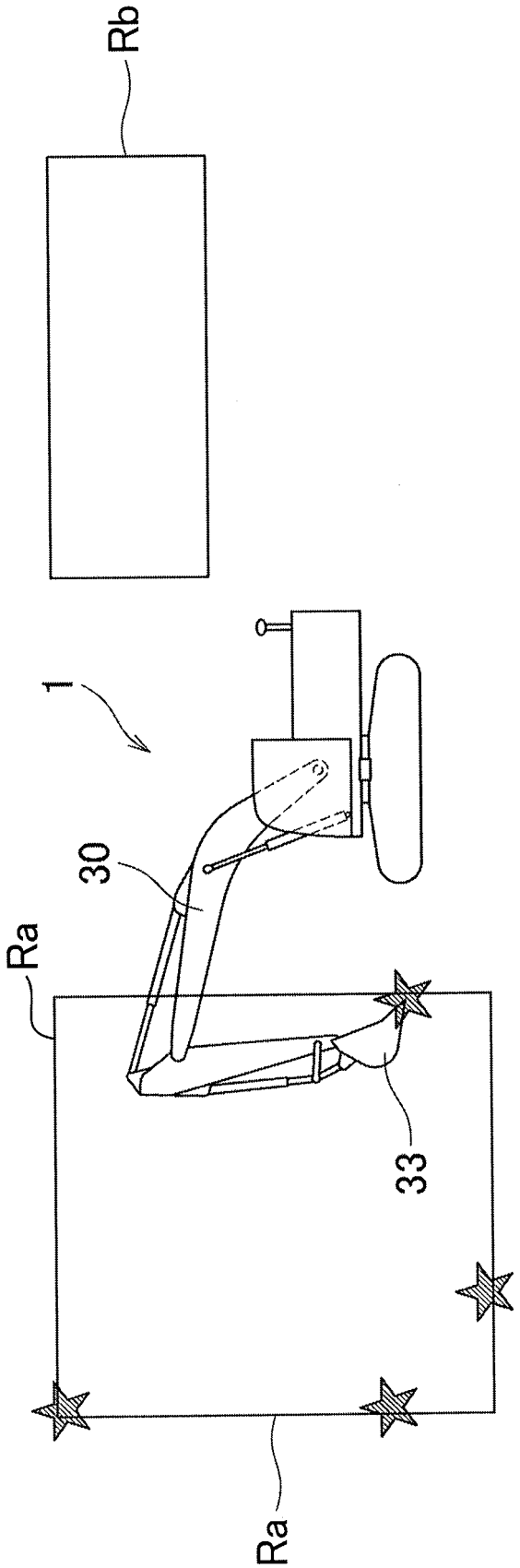


FIG.7

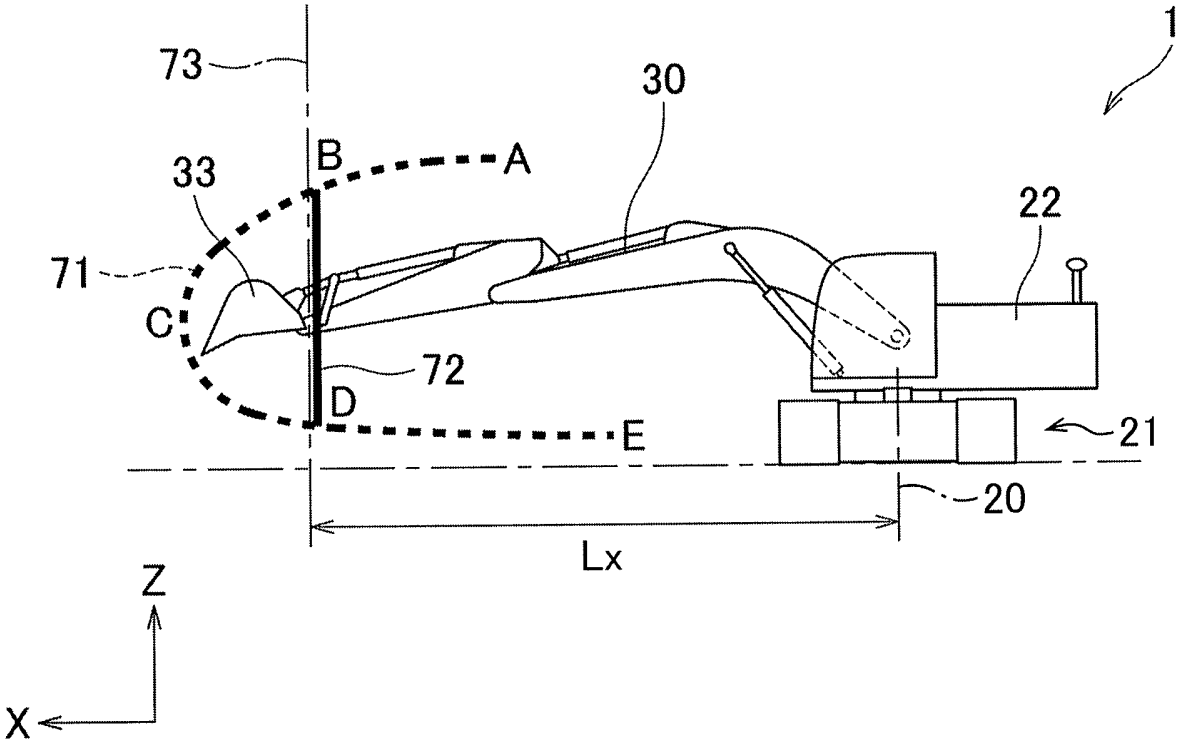

1
73
30
B
A
33
22
71
C
72
D
E
21
20
Lx
Z
X

FIG.8

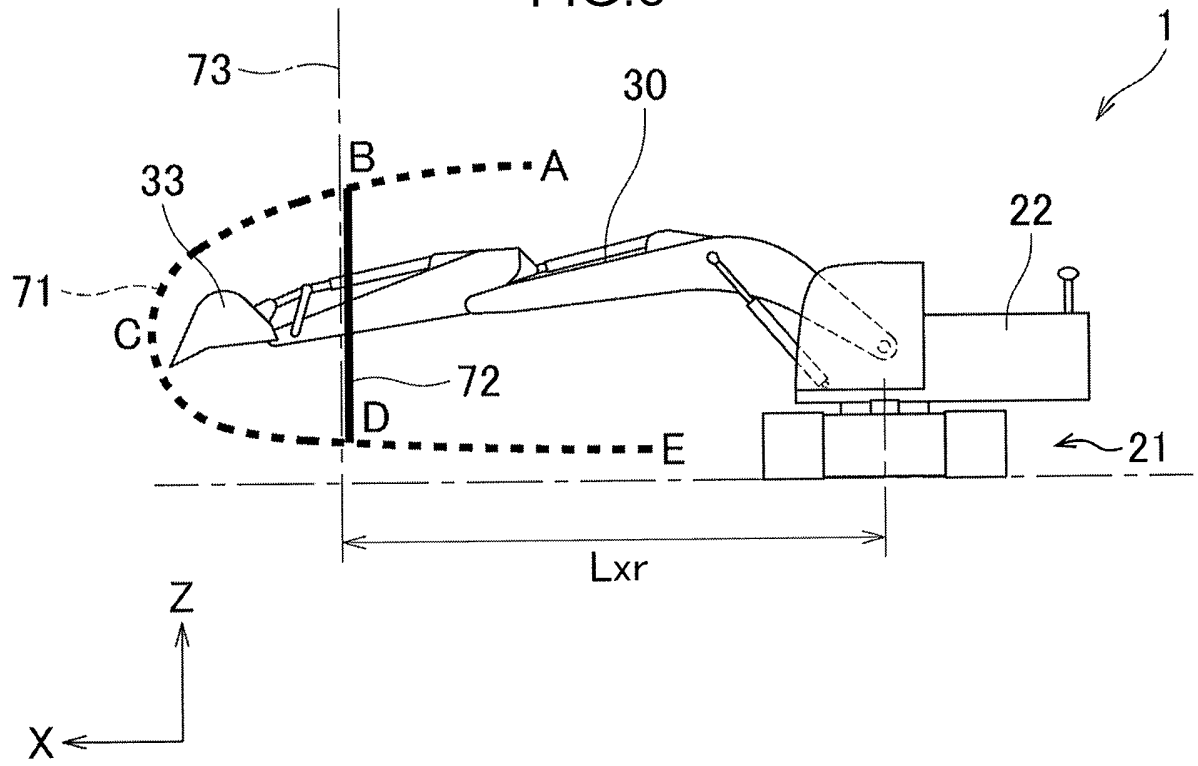

1
73
30
B
A
33
22
71
C
72
D
E
21
Lxr
Z
X

FIG.9

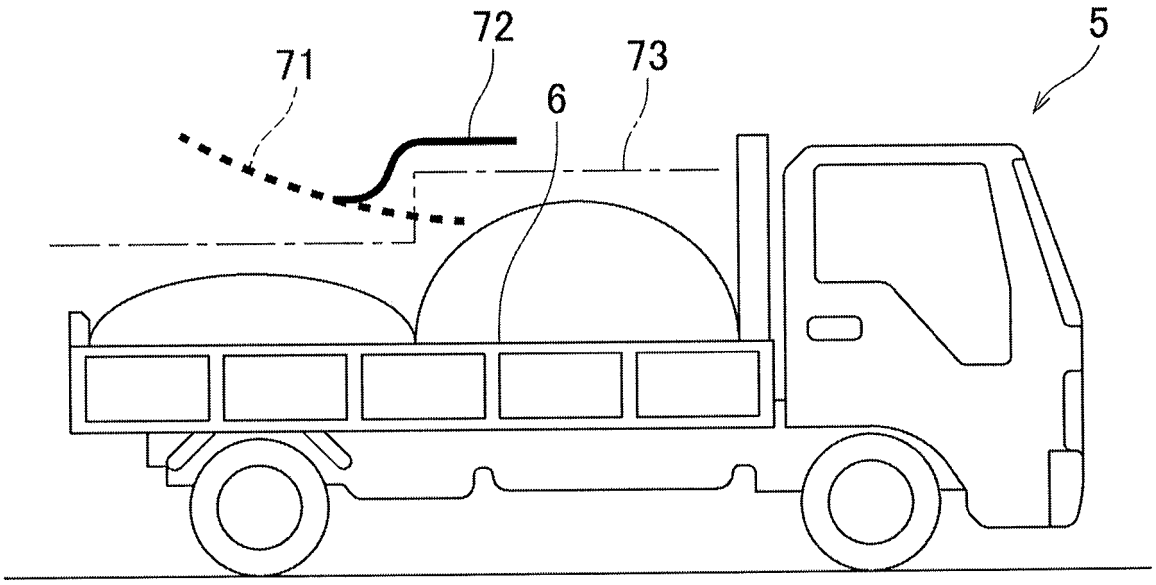


FIG.10

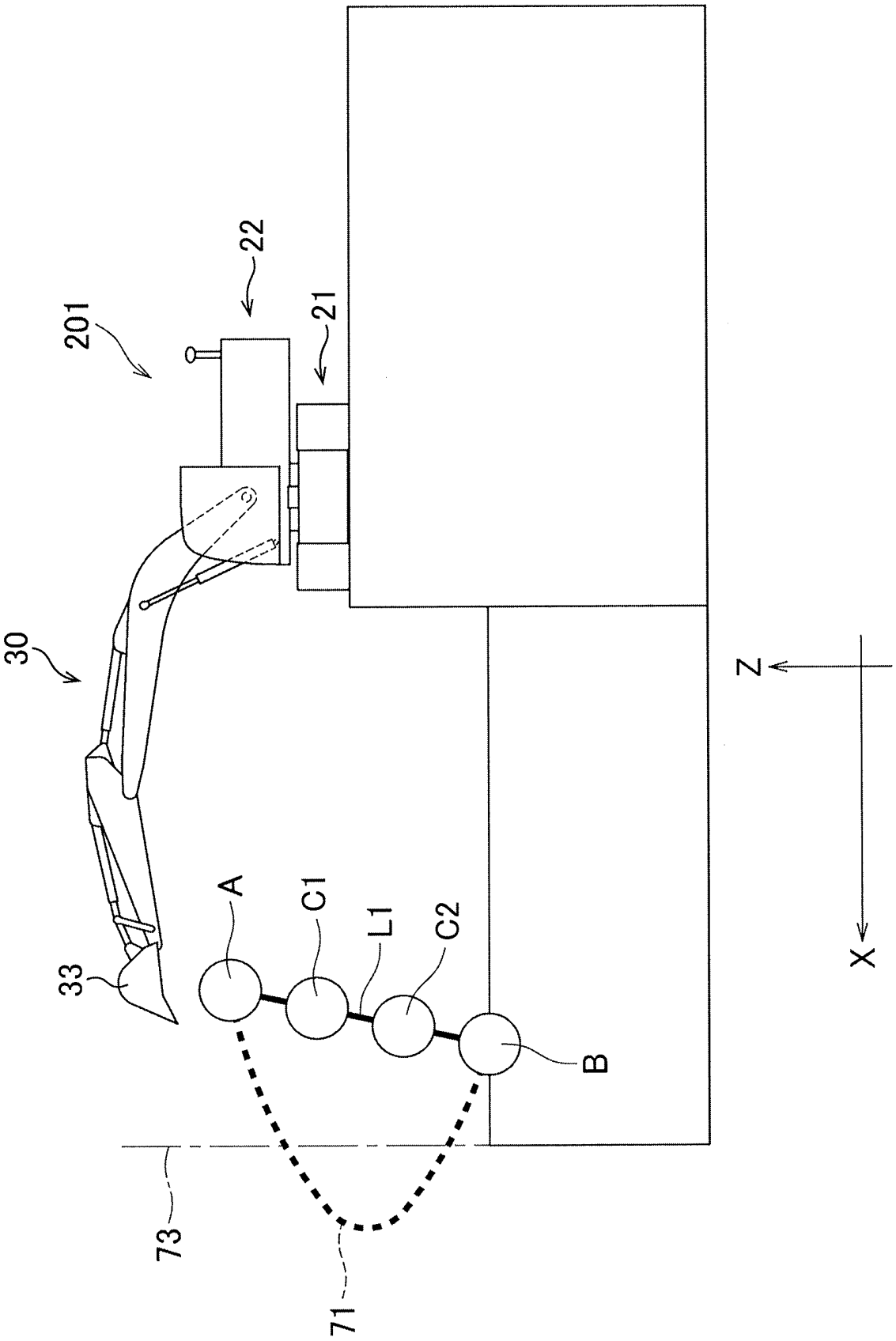


FIG.11

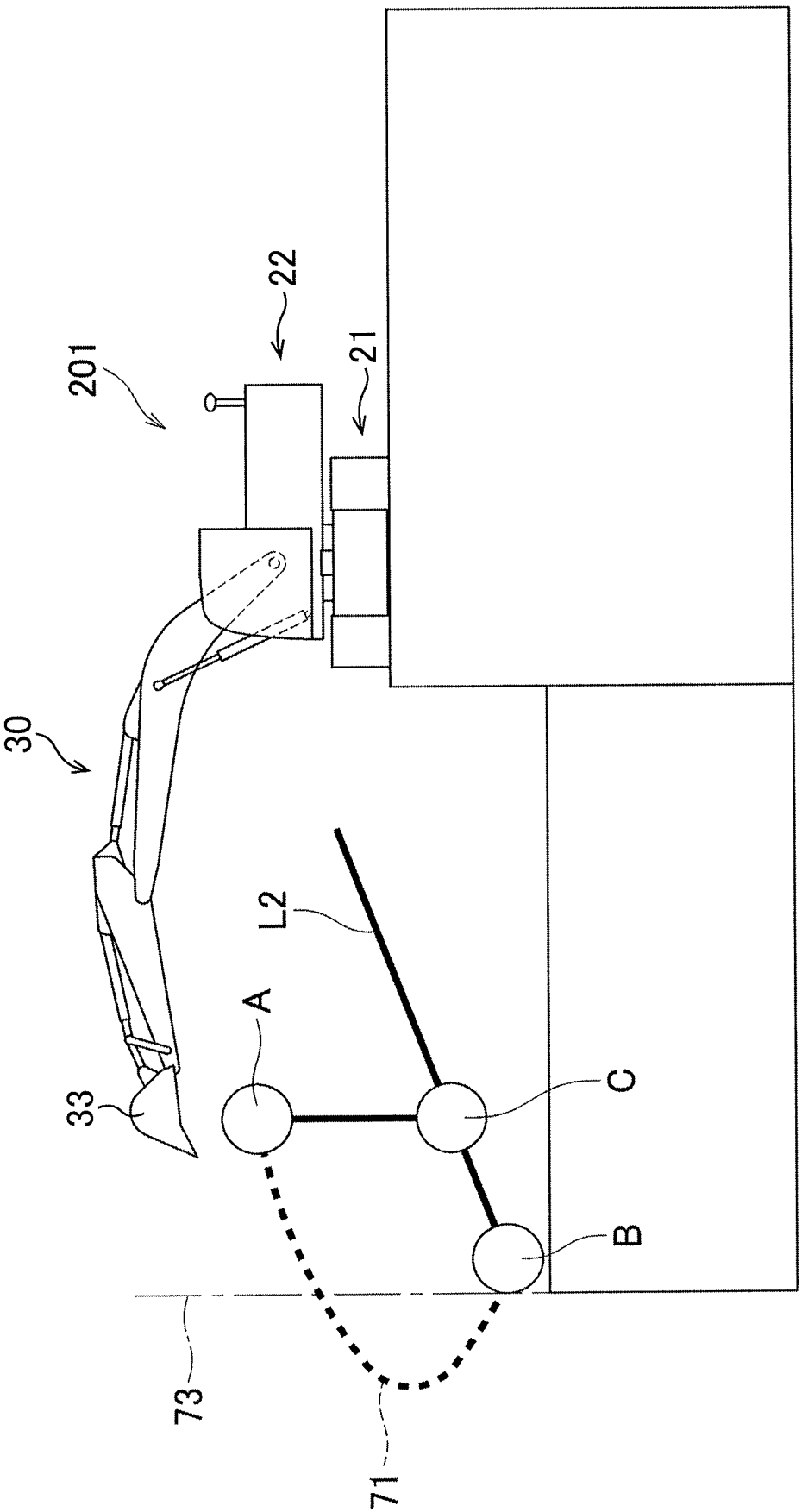


FIG.12

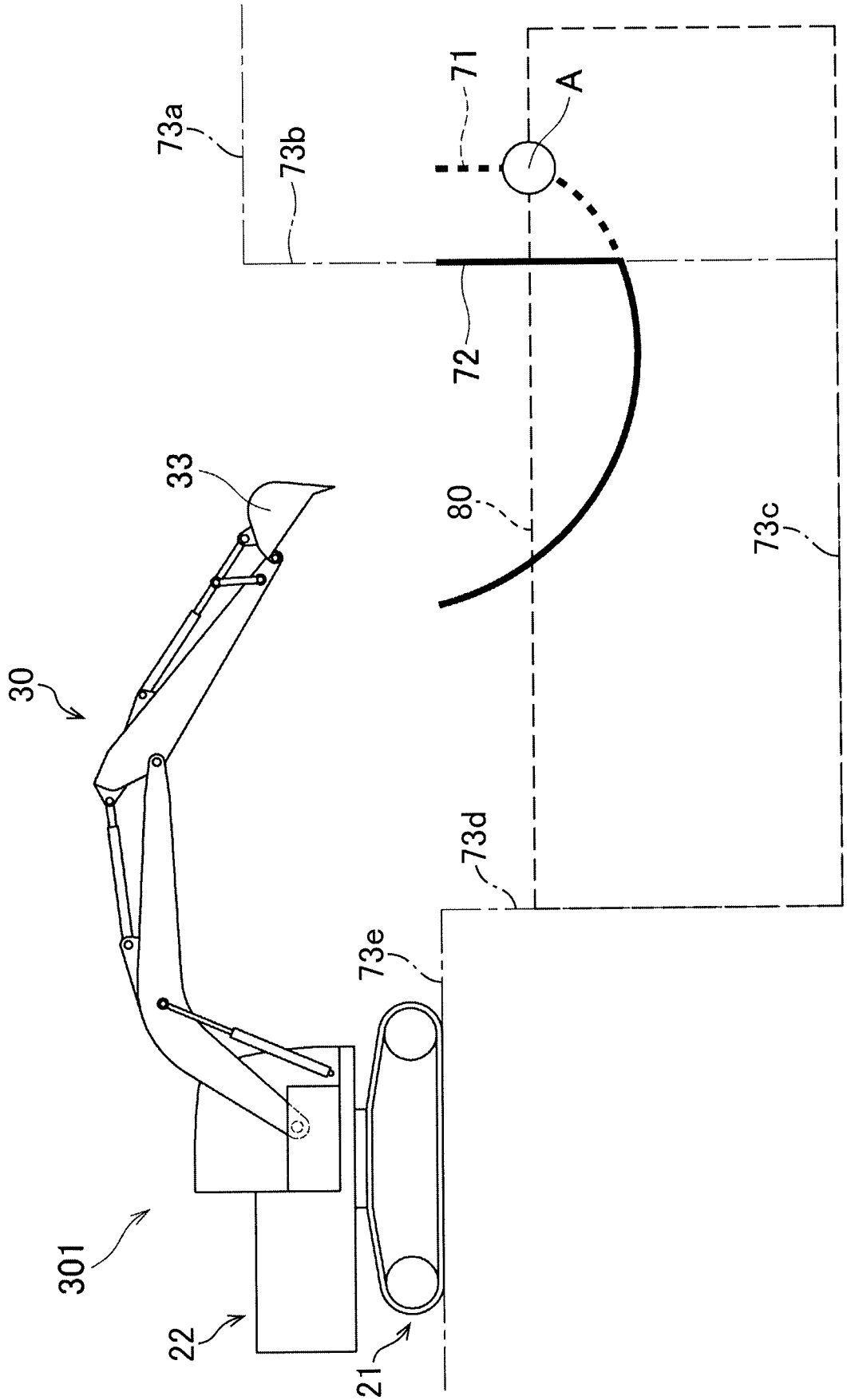


FIG.13

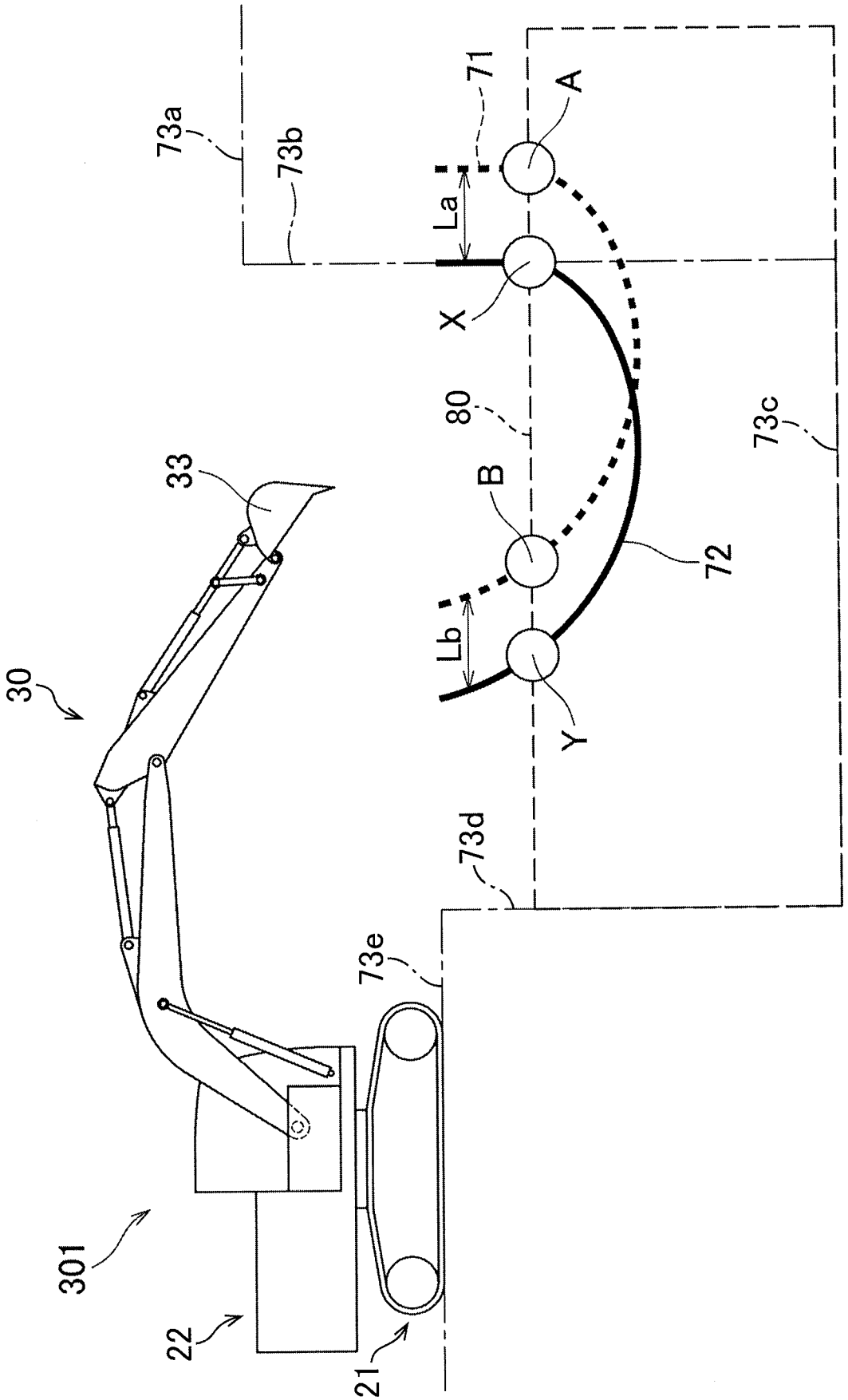


FIG.14

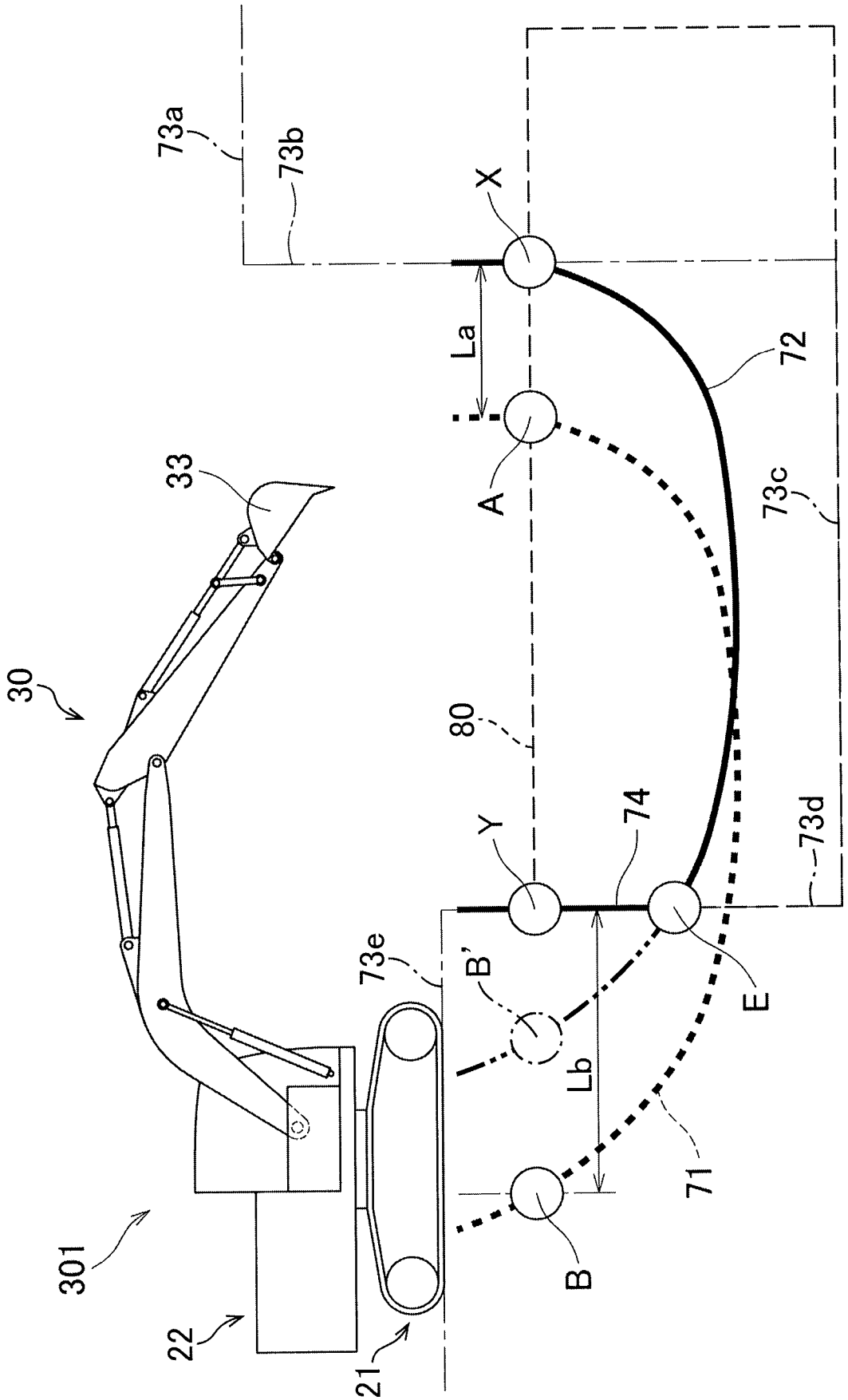


FIG.15

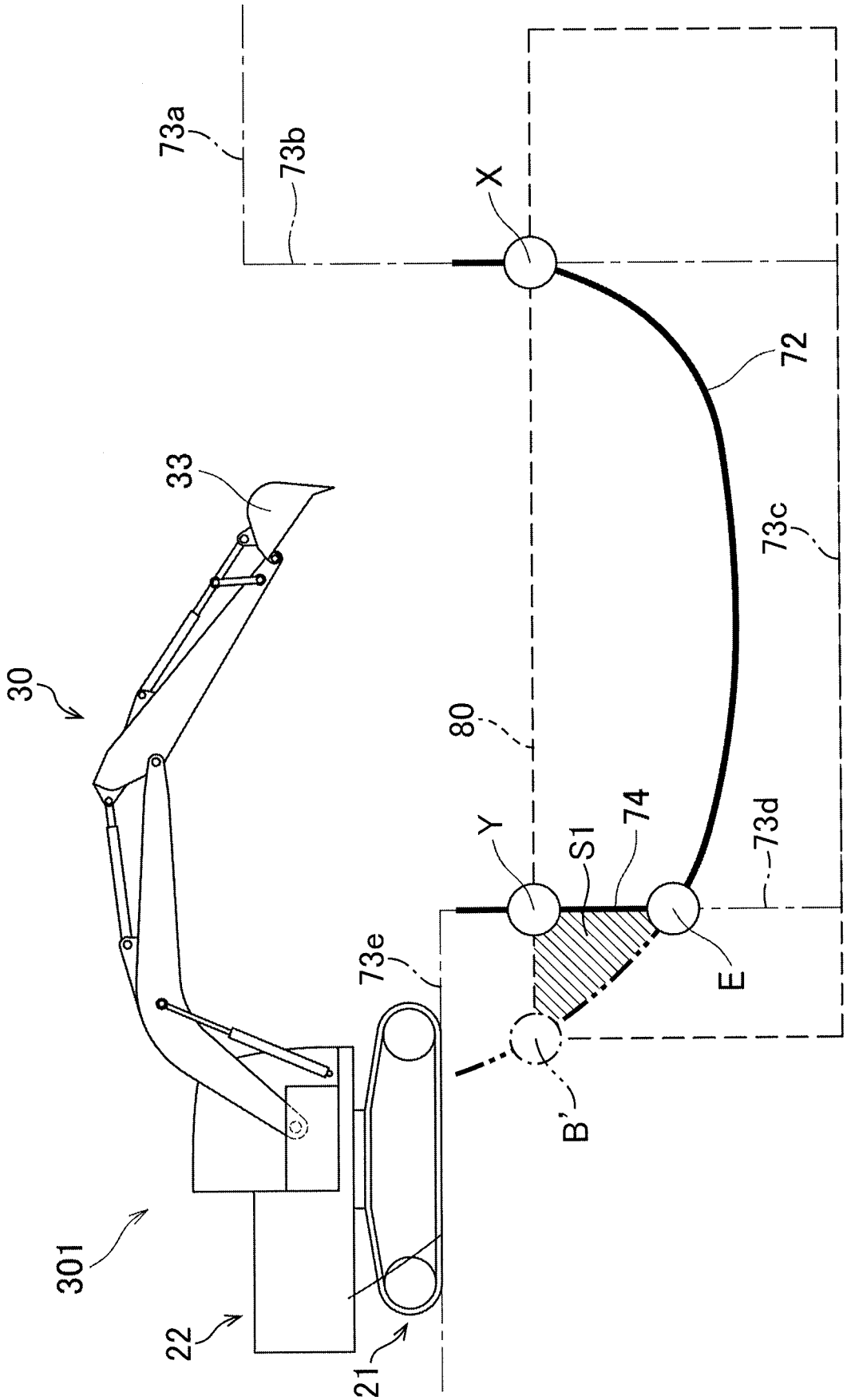


FIG.16

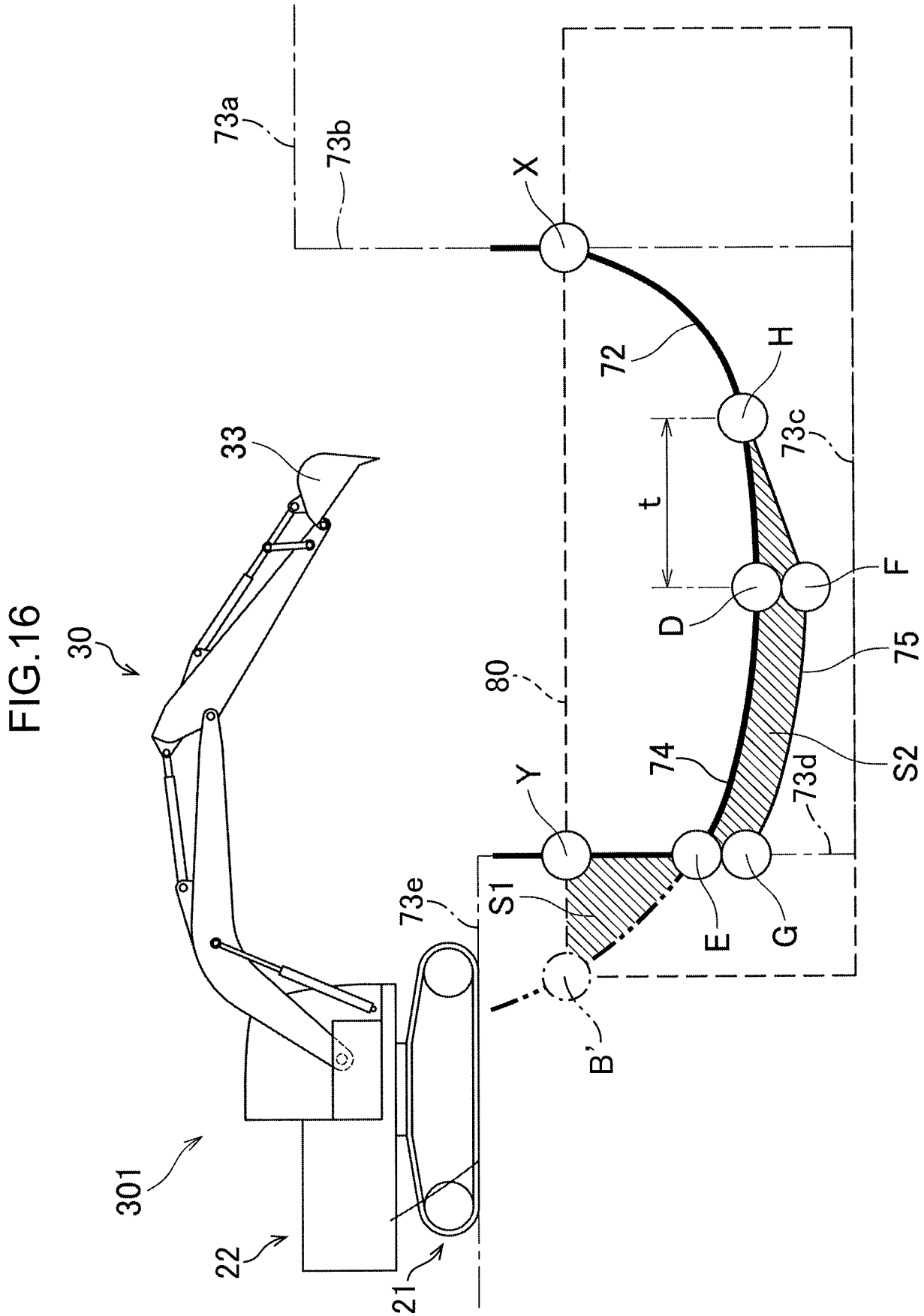


FIG.17

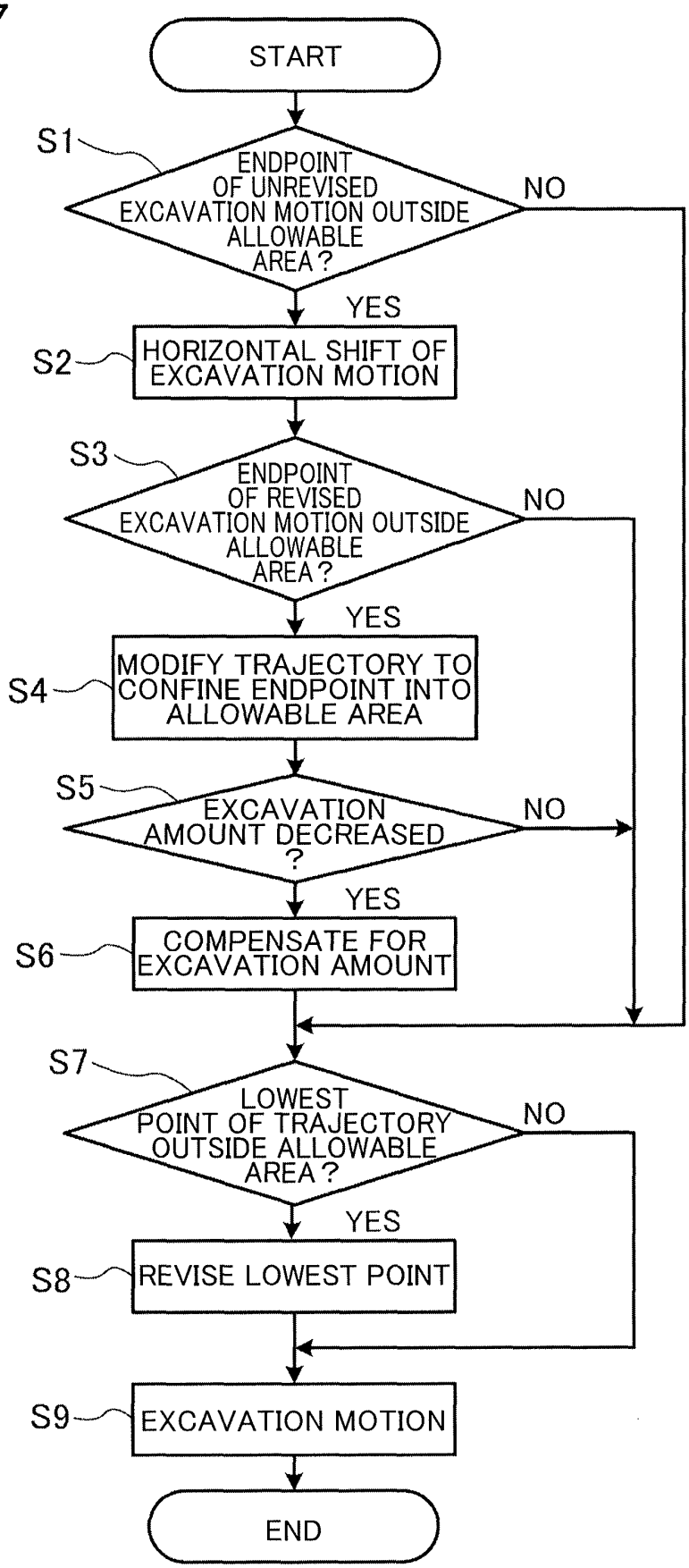

START
S1
ENDPOINT OF UNREVISED EXCAVATION MOTION OUTSIDE ALLOWABLE AREA?
NO
YES
S2
HORIZONTAL SHIFT OF EXCAVATION MOTION
S3
ENDPOINT OF REVISED EXCAVATION MOTION OUTSIDE ALLOWABLE AREA?
NO
YES
S4
MODIFY TRAJECTORY TO CONFINE ENDPOINT INTO ALLOWABLE AREA
S5
EXCAVATION AMOUNT DECREASED ?
NO
YES
S6
COMPENSATE FOR EXCAVATION AMOUNT
S7
LOWEST POINT OF TRAJECTORY OUTSIDE ALLOWABLE AREA?
NO
YES
S8
REVISE LOWEST POINT
S9
EXCAVATION MOTION
END

FIG.18

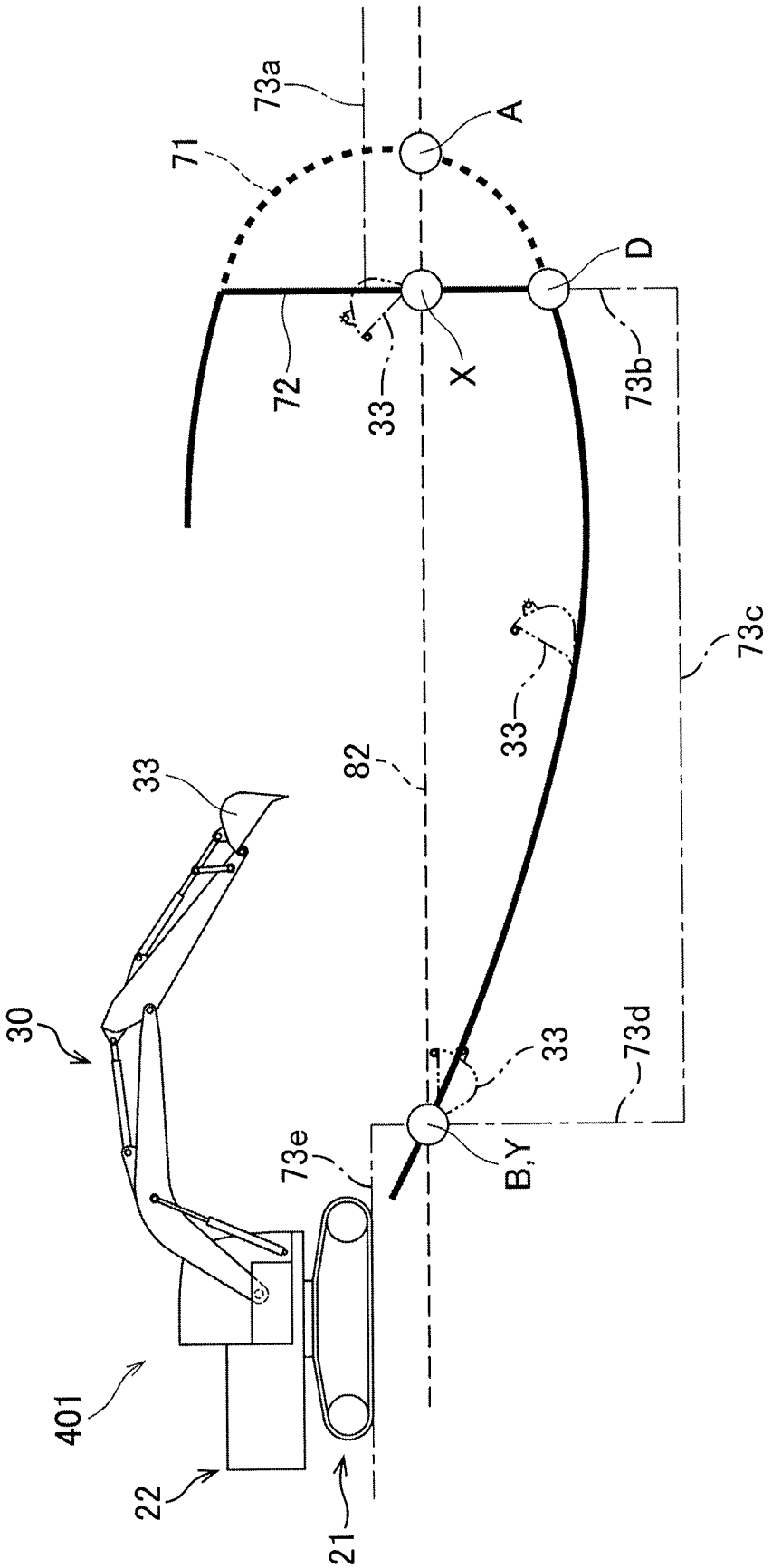


FIG.19

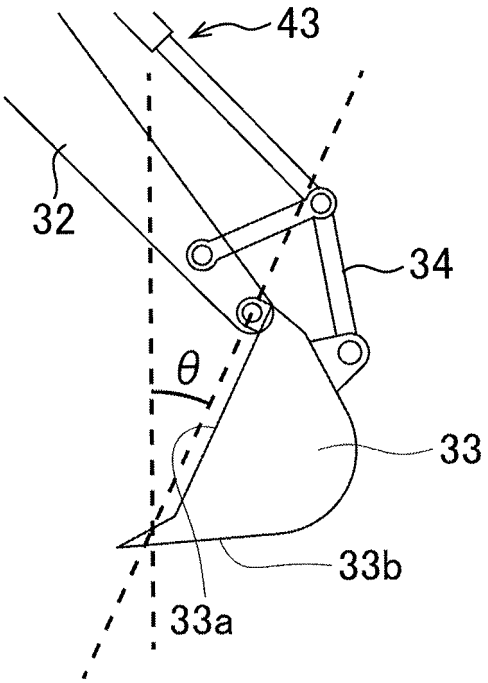


FIG.20A

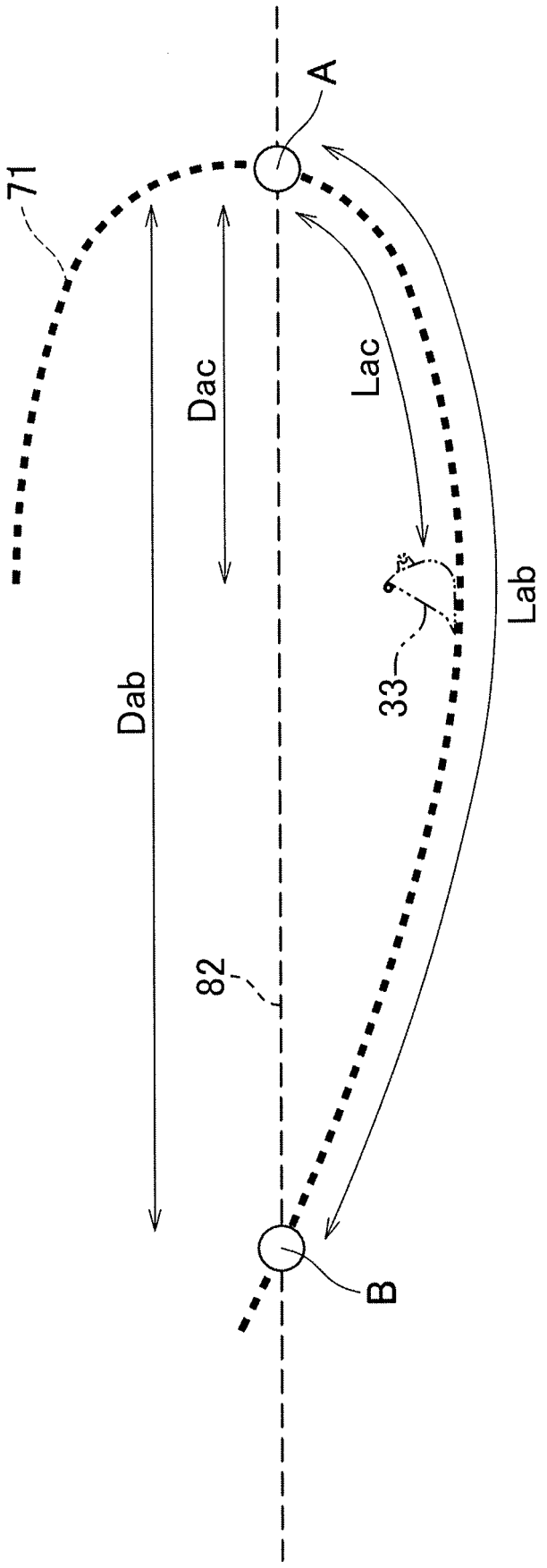


FIG.20B

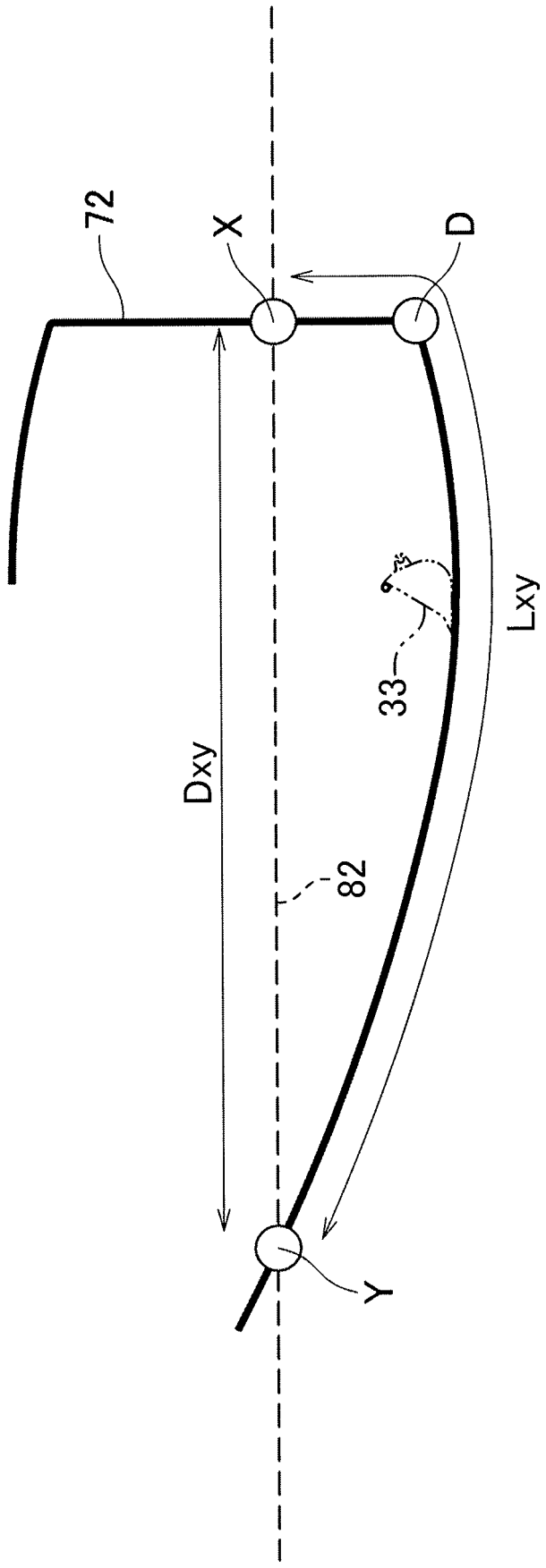


FIG.21

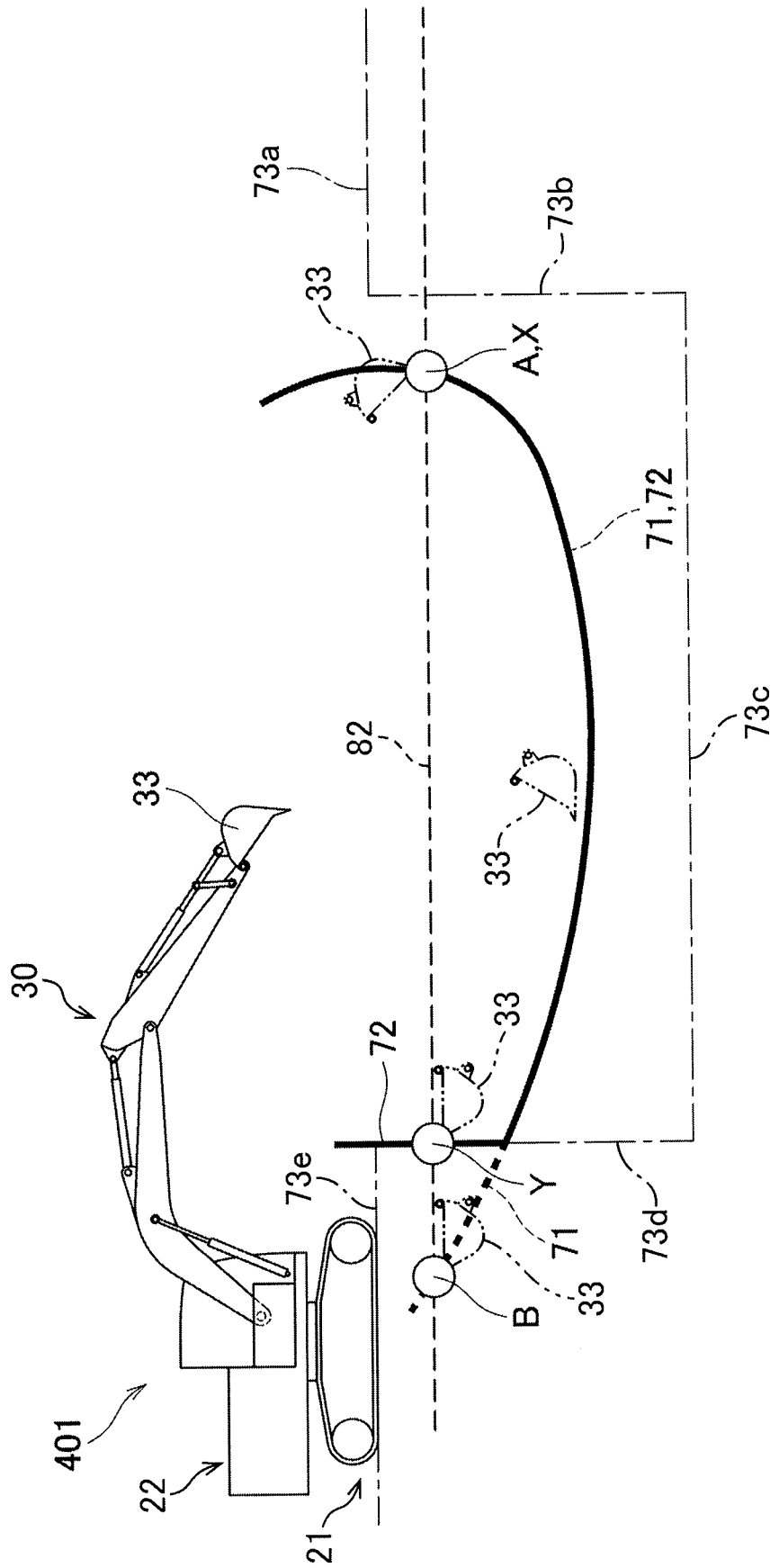
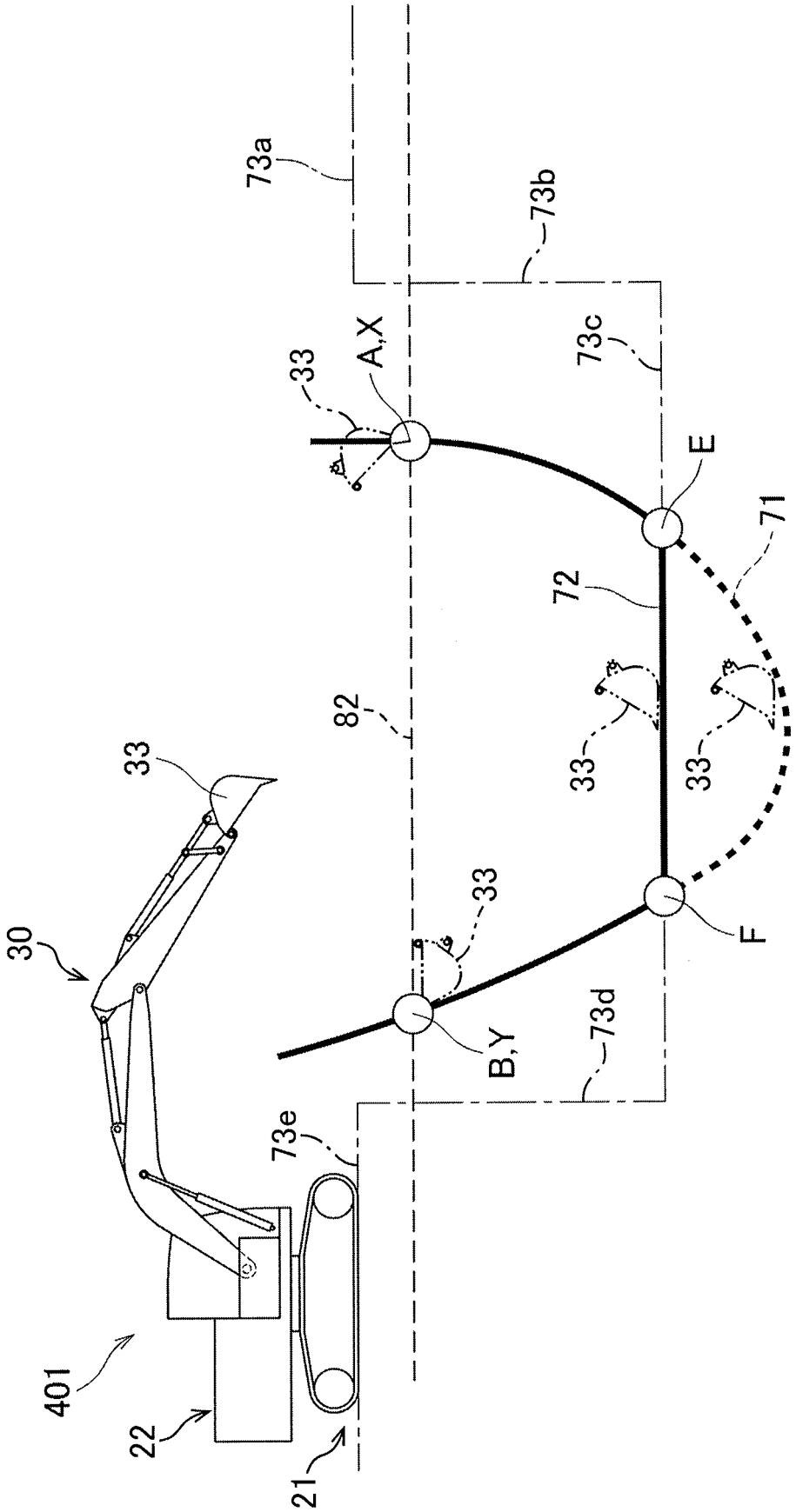


FIG.22



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/034600

A. CLASSIFICATION OF SUBJECT MATTER

E02F 3/43(2006.01)i; ***E02F 9/20***(2006.01)i; ***E02F 9/24***(2006.01)i; ***E02F 9/26***(2006.01)i
FI: E02F9/20 Q; E02F9/24 B; E02F3/43 C; E02F9/26 B; E02F3/43 A

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E02F3/43; E02F9/20; E02F9/24; E02F9/26

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2019-183382 A (SUMITOMO (SHI) CONSTRUCTION MACHINERY CO., LTD.) 24 October 2019 (2019-10-24) paragraphs [0001], [0112]-[0162], fig. 6-12	1-5
Y		6, 20-21, 23-25
A		7-19, 22
Y	WO 2019/189013 A1 (SUMITOMO (SHI) CONSTRUCTION MACHINERY CO., LTD.) 03 October 2019 (2019-10-03) paragraphs [0205]-[0220], fig. 15	6, 20-21, 23-25
Y	JP 2021-152307 A (HITACHI CONSTR. MACH. CO., LTD.) 30 September 2021 (2021-09-30) paragraphs [0062]-[0063], fig. 18	25
A	JP 2021-025258 A (SUMITOMO HEAVY IND., LTD.) 22 February 2021 (2021-02-22) entire text, all drawings	1-25
A	US 2017/0191246 A1 (CATEPILLAR INC.) 06 July 2017 (2017-07-06) entire text, all drawings	1-25

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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
31 October 2022	**15 November 2022**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/034600

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2019-183382 A	24 October 2019	(Family: none)	
WO 2019/189013 A1	03 October 2019	US 2021/0002852 A1 paragraphs [0233]-[0248], fig. 15 EP 3779070 A1 CN 111919003 A KR 10-2020-0132890 A	
JP 2021-152307 A	30 September 2021	(Family: none)	
JP 2021-025258 A	22 February 2021	(Family: none)	
US 2017/0191246 A1	06 July 2017	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2000291077 A **[0004]**