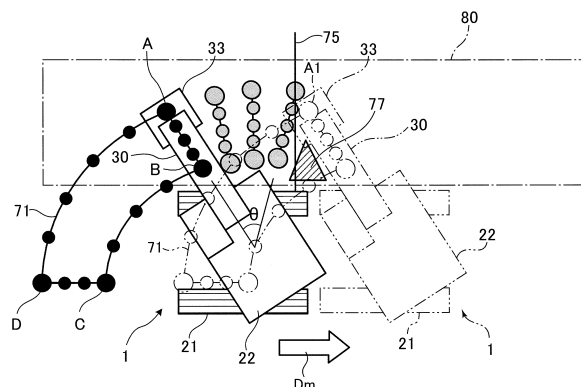


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Description

Technical Field

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

Background Art

[0002] Patent Literature 1 discloses an automatically-operated excavator by which work motions from excavation of earth and sand to removal thereof are automatically performed. Specifically, Patent Literature 1 discloses automatically shifting the next excavation position in the turning direction of an upper turning body when the excavation depth reaches a set value at a certain excavation position.

[0003] Even with the shift of the excavation position in the turning direction of the upper turning body, however, there remains a limit in the expansion of working area. An automatically-operated excavator is desired to continue work over a larger area.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Publication No. 2001-123479

Summary of Invention

[0005] It is an object of the present invention to provide a work machine capable of continuing work by automatic operation over a large area.

[0006] Provided is a work machine including a lower traveling body, an upper turning body, a work device, and a controller. The lower traveling body is capable of performing a traveling motion. The upper turning body is mounted on the lower traveling body capably of turning. The work device is rotatably attached to the upper turning body capably of performing a processing motion for processing an object. The controller controls driving of the upper turning body and the attachment so as to make the upper turning body and the work device perform a series of motions including the processing motion by the work device a plurality of times. The controller is configured to perform: shifting a start position of the processing motion included in the next series of motions in a turning direction of the upper turning body when work performed by the series of motions reaches a predetermined stage; making the lower traveling body perform an area change movement that is a movement for changing an area of processing work, which is work performed by the series of motions, when the processing work reaches the predetermined stage in a state where the start position has reached a predetermined shift limiting surface that defines a limit of the shift of the start position in the turning

direction; and setting an after-movement start position, which is a start position of the processing motion after the area change movement, so as to make the processing work after the area change movement and the processing work before the area change movement continued with each other.

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 block diagram showing a control unit installed on the work machine and elements connected thereto.

FIG. 3 is a plan view of the work machine to show a target trajectory of a tip of a bucket in a series of motions before and after an area change movement.

FIG. 4 is a plan view of the work machine to show a movement distance of the area change movement.

FIG. 5 is a plan view of the work machine to show an example of setting of a shift limiting surface.

FIG. 6 is a plan view of the work machine to show an area change movement for setting an after-movement start position upstream of the shift limiting surface with respect to a movement direction that is a direction of the area change movement.

FIG. 7 is a plan view of the work machine to show an example of setting of a movement distance of the area change movement for setting the after-movement start position shown in FIG. 6.

FIG. 8 is a plan view of the work machine to show the movement of the shift limiting surface upstream with respect to the traveling direction of the lower traveling body.

FIG. 9 is a plan view of the work machine to show work for moving earth and sand in the movement direction of the area change movement.

FIG. 10 is a plan view of the work machine to show work for forming a slope.

FIG. 11 is a flowchart showing a process to be performed by a controller of the work machine.

FIG. 12 is a plan view of a work machine according to a second embodiment of the present invention to show a state where the lower traveling body has performed an area change movement by a predetermined movement distance.

FIG. 13 is a plan view of the work machine according to the second embodiment of the present invention to show a state where the lower traveling body has moved by a distance different from the movement distance.

FIG. 14 is a plan view of the work machine according to the second embodiment of the present invention to show a state where the after-movement start position is deviated beyond the shift limiting surface by area change movement.

Detailed Description

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

[0009] FIG. 1 shows a work machine 1 according to a first embodiment of the present invention. The work machine 1 is capable of being automatically operated. The work machine 1 is a hydraulic excavator, including a machine body 25 including a lower traveling body 21 and an upper turning body 22, a turning device 24, an attachment 30, and a work driving device 40.

[0010] The lower traveling body 21 includes a pair of crawler, which is actuated to thereby enable the lower traveling body 21 to perform a traveling motion. The upper turning body 22 is mounted on the lower traveling body 21 capably of performing a turning motion of turning with respect to the lower traveling body 21. The turning device 24 is a turning driving device that causes the upper turning body 22 to perform the turning motion. The upper turning body 22 includes a cab (operation room) 23 which forms a front part 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. The work motion is a motion for processing an object, including a vertically rotational movement. The attachment 30 includes a boom 31, an arm 32, and a bucket 33. The boom 31 has a proximal end and a distal end opposite thereto, the proximal end being connected to the upper turning body 22 capably of vertically rotational movement (capably of being raised and lowered). The arm 32 has a proximal end and a distal end opposite thereto, the proximal end being connected to the distal end of the boom 31 capably of vertically rotational movement. The bucket 33 is a tip attachment, which is attached to the distal end of the arm 32 capably of rotational movement in a front-rear direction to form the tip of the attachment 30. The bucket 33 has a shape capable of performing work operation such as excavation, leveling, scooping, and the like, on an excavation object including earth and sand. The excavation object by the bucket 33 is not limited to earth 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 and, therefore, the work object is not limited to the excavation object. For example, the tip attachment to form the tip of the work apparatus according to the present invention is not limited to the bucket 33 for holding earth and sand as described above but allowed to be also a grapple for gripping a work object, a lifting magnet for attracting a work object to hold it, or the like.

[0012] The work drive device 40 is capable of making the attachment 30 perform the work motion by hydraulic actuation of the attachment 30. The work drive device 40 includes a plurality of hydraulic cylinders, each of which is capable of performing expansion and contraction motions, the plurality of hydraulic cylinders including a boom cylinder 41, an arm cylinder 42, and a bucket cylinder 43.

[0013] The boom cylinder 41 is arranged so as to actuate the boom 31 vertically rotationally in rising and falling directions (vertical direction) with respect to the upper turning body 22 by performing the expansion and contraction motions. The boom cylinder 41 has a proximal end to be rotatably connected to the upper turning body 22 and a distal end to be rotatably connected to the boom 31.

[0014] The arm cylinder 42 is arranged so as to actuate the arm 32 vertically rotationally with respect to the boom 31 by performing the expansion and contraction motions. The arm cylinder 42 has a proximal end to be rotationally connected to the boom 31 and a distal end to be rotationally connected to the arm 32.

[0015] The bucket cylinder 43 is arranged so as to actuate the bucket 33 rotationally with respect to the arm 32 by performing the expansion and contraction motions. The bucket cylinder 43 has a proximal end to be rotationally connected to the arm 32 and a distal end to be rotationally connected to a link member 34. The link member 34 is rotationally connected 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 a 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 the present embodiment, the turning angle of the upper turning body 22 at which the frontward direction of the upper turning body 22 coincides with the frontward direction of the lower traveling body 21 is fixed to 0°.

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

[0019] The boom inclination sensor 61 is attached to the boom 31 to detect the posture of the boom 31. The boom inclination sensor 61 is, specifically, a sensor that acquires the inclination angle of the boom 31 to a horizontal line, for example, an inclination (acceleration) sensor. The working posture detector 60 may include, instead of the boom inclination sensor 61, a rotation angle sensor that detects a rotation angle of the boom 31 around a boom foot pin, which is a support shaft of the proximal end of the boom 31, or a stroke sensor that detects 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 is, specifically, a sensor that acquires the inclination angle of the arm 32 to a horizontal line, for example, an inclination (acceleration) sensor. The working posture detector 60 may include, instead of the arm inclination sensor 62, a rotation angle sensor that detects a rotation angle of the arm 32 around an arm connection pin that is a support shaft of the proximal end

of the arm 32, or a stroke sensor that detects a stroke of the arm cylinder 42.

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

[0022] The work machine 1 further includes an imaging device 26. The imaging device 26 is attached to the upper turning body 22. The imaging device 26, alternatively, may be located remote from the work machine 1. The imaging device 26 according to the present embodiment is a LIDAR. If the work machine according to the present invention includes means for imaging, however, the means may be a camera, an ultrasonic sensor, a millimeter wave radar, a stereo camera, a distance image sensor, an infrared sensor, or the like.

[0023] The following description is made about the case of excavating earth and sand using the bucket 33.

[0024] As shown in FIG. 2, the work machine 1 includes a control unit 11 and a storage device 13.

[0025] To the control unit 11 is input turning posture information and working posture information. The turning posture information is information detected by the turning angle sensor 52, that is, information about the turning angle (turning posture) of the upper turning body 22 with respect to the lower traveling body 21. The working posture information is information about the posture detected by the working posture detector 60, that is, the posture of the attachment 30 as the work device. The working posture information contains: information detected by the boom inclination sensor 61, that is, information on the posture of the boom 31; information detected by the arm inclination sensor 62, that is, information on the posture of the arm 32; and information detected by the bucket inclination sensor 63, that is, information on the posture of the bucket 33.

[0026] The control unit 11 according to the present embodiment automatically controls motions of the work machine 1. The control unit 11 serves as a control means of 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 series of motions. The work machine 1 is, thus, automatically operated. Specifically, the control unit 11 automatically controls the driving of the upper turning body 22 by the turning device 24 and the driving of the attachment 30 by the work driving device 40 based on the information detected by the turning angle sensor 52 and the working posture detector 60. In the present embodiment, the series of motions are motions for excavating earth and sand and discharging it. The series of motions, therefore, includes an excava-

tion motion for excavating earth and sand by the bucket 33. The excavation motion is an example of a processing motion of processing an object by the attachment 30 as the work device.

[0027] The control unit 11 makes the upper turning body 22 and the attachment 30 perform the series of motions a plurality of times. The control unit 11 according to the present embodiment makes the series of motions repeated with a change of the height of the tip of the bucket 33 during the excavation motion. The series of motions from excavation of earth and sand to earth removal are thereby repeated at the same excavation place with the change of the depth of excavation of earth and sand.

[0028] The storage device 13, which constitutes a controller in association with the control unit 11, stores the series of motions. The series of motions are set, for example, by means of teaching by an operator. The series of motions causes the tip of the attachment 30 i.e., the tip of the bucket 33, to trace a predetermined trajectory. As described later, a part of the trajectory may be corrected along with the movement of the lower traveling body 21.

[0029] FIG. 3 shows a target trajectory 71 of the tip of the bucket 33 in the series of motions. The series of motions include an excavation motion, a lifting and turning motion, an earth removal motion, and a return turning motion. The excavation motion involves the movement of the tip of the bucket 33 from a point A to a point B. The lifting and turning motion involves the turn of the tip of the bucket 33 from the point B to a point C. The lifting and turning motion is performed with earth and sand held in the bucket 33. The earth removal motion involves the movement of the tip of the bucket 33 from the point C to a point D and the rotation of the bucket 33 in the opening direction during the movement, the rotation of the bucket 33 causing the earth and sand to be discharged to a vessel of a dump truck or the like. The earth removal position is located in an area from the point C to the point D. The return turning motion involves the turn of the tip of the bucket 33 in a return direction from the point D to the point A. The control target part of the attachment 30 according to the present embodiment is the tip of the bucket 30, the target trajectory of which is graphically shown. The control target part, however, is not limited to the tip of the bucket 33.

[0030] The control unit 11 sets a depth limit. The depth limit is a limit value set for excavation depth, which is the depth by which earth and sand is excavated by the bucket 33. As described above, the series of motions from the excavation of earth and sand to the earth removal are repeated with the change of the excavation depth.

[0031] The control unit 11 judges that the work performed by the repetition of the series of motions has reached a predetermined stage at the time when the excavation depth in the excavation motion reaches the depth limit. When judging that the work by the repetition of the series of motions has reached the predetermined

stage, the control unit 11 terminates the repetition of the series of motions at the same excavation place.

[0032] It is also desirable that the control unit 11 or the storage device 13 stores a target number of repetitions that is the number of times by which the series of motions is to be repeated and the control unit 11 is configured to judge that the work by the repetition of the series of motions has reached a predetermined stage at the time when the number of times by which the series of motions are repeated reaches the target number of repetitions.

[0033] The control unit 11 serves as a start position shifting means of shifting the start point of the excavation motion in the next series of motions in the turning direction of the upper turning body 22 from the point A. Specifically, the start position is shifted in the turning direction from the point A by means of turning the upper turning body 22. The start position is shifted to the position separated from the point A by a predetermined angle in a direction of separating from the point D in the turning direction (the reverse direction to that of the lifting and turning motion, i.e., the rightward direction in FIG. 3). Along with the shift of the start point from the point A, the terminal point of the excavation motion is also shifted from the point B by the same angle in the same direction.

[0034] After shifting the start position of the excavation motion from the point A to a new position, the control unit 11 makes the upper turning body 22 and the attachment 30 perform the next series of motions. Thus is performed processing work by the next series of motions at the new excavation place.

[0035] In FIG. 3, the initial posture of the upper turning body 22 is indicated by a solid line. The initial posture is the posture of the upper turning body 22 corresponding to the point A, which is the start position of the excavation motion in the first series of motions, more specifically, such a posture of the upper turning body 22 with respect to the lower traveling body 21 as to locate the tip of the bucket 33 that is the control target part at the start position, and the upper turning body 22 in the initial posture is located at such a position that the tip of the bucket 33 is separated from the earth removal position between the point C and the point D by an initial angle in the turning direction. Along with the shift of the start position of the excavation motion from the point A, the posture of the upper turning body 22 with respect to the lower traveling body 21 (turning posture) at the start of the excavation motion is also gradually changed from the initial posture. Each time the start position is thus shifted, the series of motions are started from the shifted start position.

[0036] The control unit 11 serves as a limiting surface setting means of setting a shift limiting surface 75 shown in FIG. 3. The shift limiting surface 75 defines the limit of the shift of the start position in the turning direction. The shift limiting surface 75 is a surface perpendicular to a movement direction, which is the direction of a below-described area change movement of the lower traveling body, indicated by a straight line perpendicular to the movement direction, as shown in FIG. 3 when viewed in

a direction along the turning center axis of the upper turning body 22 (vertically in general). The shift limiting surface 75 may be set in advance and stored in the control unit 11.

[0037] By the repetition of the series of motions with the shift of the start position of the excavation motion in the turning direction, the start position is shifted from the point A to eventually reach the shift limiting surface 75. The control unit 11 serves as a lower-traveling-body moving means of making the lower traveling body 21 perform the traveling motion to thereby move the lower traveling body 21 in the traveling direction when the work by the repetition of the series of motions reaches a predetermined stage in a state where the start position has reached the shift limiting surface 75, that is, when the excavation depth in the shift limiting surface 75 reaches the depth limit. The movement of the lower traveling body 21 is the area change movement for changing the area of the processing work by the series of motions. Preferably, the area change movement is a movement in a direction of making the after-movement posture of the upper turning body 22 closer to the initial posture. The after-movement posture is the posture of the upper turning body 22 with respect to the lower traveling body 21 (turning posture) corresponding to an after-movement start position, which is the start position of the excavation motion in the first series of motions after the area change movement. The initial posture is the posture of the upper turning body 22 with respect to the lower traveling body 21 corresponding to the start position of the processing motion included in the first series of motions. FIG. 3 shows an arrow Dm, which indicates the movement direction that is the direction of the area change movement, and the position of the work machine 1 after the area change movement is indicated by a two-dot chained line. Moreover, the control unit 11 sets the start position of the excavation motion after the area change movement, namely, the after-movement start position, so as to make the processing work by the series of motions started immediately after the area change movement continued with the processing work by the series of motions immediately before the area change movement.

[0038] The control unit 11 according to the present embodiment sets a movement distance L as shown in FIG. 4 so as to make the processing work after the area change movement continued with the processing work before the area change movement. The movement distance L is a target movement distance of the area change movement of the lower traveling body 21, being the sum of a start position distance L1 and a limiting surface distance L2 shown in FIG. 4 in the present embodiment. The start position distance L1 is the distance in the movement direction, from the start position (point A) to the turning center axis 20 of the upper turning body 22 in the work machine 1 where the upper turning body 22 is in the initial posture. The limiting surface distance L2 is the distance in the movement direction, from the turning center axis 20 to the shift limiting surface 75.

[0039] As described below, when the movement distance L of the lower traveling body 21 is smaller than the sum of the start position distance L1 and the limiting surface distance L2, the start position of the excavation motion included in the series of motions after the area change movement, namely, the after-movement start position, is located upstream of the shift limiting surface 75 with respect to the movement direction.

[0040] As shown in the arrow Dm, the movement direction which is the direction of the area change movement of the lower traveling body 21 is rightward in FIG. 3, being the same direction as the direction in which the start position of the series of motions is shifted before the area change movement, that is, the same direction as the direction in which the area of the repeated series of motions is gradually shifted.

[0041] The control unit 11 serves as a posture setting means of setting the after-movement posture of the upper turning body 22 to the same posture as the initial posture. The after-movement posture is the turning posture of the upper turning body 22 corresponding to the start position of the excavation motion included in the series of motions after the area change movement, namely, the after-movement start position, being, in the present embodiment, the posture of the upper turning body 22 with respect to the lower traveling body 21 for locating the tip of the bucket 33 as the control target part at the after-movement start position. The after-movement posture of the upper turning body 22, therefore, is returned to the same posture as the initial posture, that is, the posture where the turning angle of the upper turning body 22 with respect to the lower traveling body 21 is equal to the initial turning angle. The control unit 11 makes the series of motions restarted and thereafter repeated by the upper turning body 22 and the attachment 30 in the thus same posture as the initial posture. The processing motion by the series of motions is thereby repeated at a new excavation place. This allows the processing work from the posture after the area change movement to be continued with the processing work before the area change movement. In addition, performing not only the shift of the start position of the excavation motion before the area change movement in the turning direction but also making the lower traveling body 21 perform the area change movement enables the process work to be continued over a larger area.

[0042] The control unit 11 serves as a working area setting means of setting a working area 80 as shown in FIG. 3. The working area 80 is an area within which the attachment 30 is allowed to move for performing the processing motion. As shown in FIG. 3, the control unit 11 makes the shift of the start position of the excavation motion within the working area 80 to thereby prevent the attachment 30 from being deviated from the working area 80 in the series of motions regardless of the shift of the start position. Furthermore, the control unit 11 sets the after-movement start position within the working area 80 so as to make the processing work after the area change

movement continued with the processing work before the area change movement. This prevents the attachment 30 from being deviated from the working area 80 by the series of motions even after the area change movement, thereby allowing the attachment 30 to be prevented from interference with obstacles, etc. lying outside the working area 80.

[0043] As shown in FIG. 3, the shift limiting surface 75 is set to a surface passing through the position of the tip of the bucket 33 in a state where the upper turning body 22 has been turned in a direction of separating from the point D, i.e., in a direction reverse to the direction of the lifting and turning motion, by a preset limit angle θ from a posture where the tip of the bucket 33 is located at the start position of the first excavation motion. Alternatively, the surface passing through the start position that has been shifted by a preset allowable number of shift times may be set to the shift limiting surface 75.

[0044] The shift limiting surface 75, alternatively, may be set as a downstream boundary surface of a soil-amount detection area 81 as shown in FIG. 5. The soil-amount detection area 81 is set in the working area 80. The downstream side boundary surface is the surface that defines a boundary of the soil-amount detection area 81 on the downstream side (right side in FIG. 5) in the movement direction of the lower traveling body 21, being perpendicular to the movement direction. The control unit 11 detects the amount of soil in the soil-amount detection area 81 from the image information acquired by the imaging device 26, and performs control to make the lower traveling body 21 perform the area change movement at the time when the detected soil amount, which is the detected amount of soil, becomes equal to or less than a predetermined amount.

[0045] If the series of motions after the area change movement of the lower traveling body 21 is performed at a position deviated beyond the shift limiting surface 75 in the movement direction, for example, when the work machine 1 performs the series of motions at a position indicated by a two-dot chained line in FIG. 3, there occurs a non-working area 77 as shown in FIG. 3. The non-working area 77 is an area where neither the processing work before the area change movement nor the processing work after the area change movement is performed. To reduce such a non-working area 77, the control unit 11 is preferably configured to, for example, as shown in FIG. 6, set an after-movement start position, which is the start position of the excavation motion in the series of motions immediately after the area change movement (the point A1 in FIG. 6), on the upstream side (left side in FIG. 6) of the shift limiting surface 75 with respect to the movement direction of the lower traveling body 21.

[0046] For the setting of the after-movement start position (point A1) as shown in FIG. 6, it is preferable to set a movement distance, which is the distance of the area change movement of the lower traveling body 21, for example, as shown in FIG. 7. The details are as follows.

(i) A shift termination surface 78 is set as shown in FIG. 7. The shift termination surface 78 is the surface that passes through the terminal position of the excavation motion (point B2 in FIG. 7) at a start position maximum shift time point and perpendicular to the movement direction of the area change movement of the lower traveling body 21. The start position maximum shift time point is the point in time when the start position of the excavation motion has been maximumly shifted before the area change movement, specifically, the point in time when the start position has been shifted to a position on the shift limiting surface 75 like the point A2 shown in FIG. 7. The start position maximum shift time point, alternatively, may be either a point in time when the shift angle from the initial start position A to the latest start position (an angle corresponding to the turning angle of the upper turning body 22) reaches a preset limit angle θ or a point in time when the number of shift times of the start position reaches a preset number of times.

(ii) A movement termination surface 79 is set as shown in FIG. 7. The movement termination surface 79 is the surface that is perpendicular to the movement direction and passes through such a start position of an immediately-after-movement excavation motion that the terminal point of the immediately-after-movement excavation motion (the point B1 in FIG. 7) is on the shift termination surface 78, the immediately-after-movement excavation motion being an excavation motion in the first series of motions after the area change movement (the start position is the point A1 in FIG. 7).

(iii) The distance by which the start position of the immediately-after-movement excavation motion (point A1) is shifted to reach the movement termination surface 79 is set to the movement distance.

[0047] The control unit 11 determines the amount of soil at the earth removal position between the point C and the point D, from the image information captured by the imaging device 26. The control unit 11, thus, serves as a soil amount detector in association with the imaging device 26. The control unit 11 moves the shift limiting surface 75 in a direction reverse to the movement direction of the area change movement as indicated by arrow Dr shown in FIG. 8 when the detected soil amount is equal to or more than a preset allowable amount. This advances the timing of the start of the area change movement, thereby allowing the lower traveling body 21 to be moved to change the area of the processing work before the excess of the soil amount at the earth removal position.

[0048] The earth removal position between the point C and the point D shown in FIG. 3 and FIGS. 6 to 8, i.e., the position to which the earth and sand excavated by the bucket 33 is to be discharged, is outside the working area 80. However, like the modification shown in FIG. 9,

the earth and sand excavated by the bucket 33 may be discharged to the earth removal position in the working area 80. The control unit 11 according to the present modification sets the start position of the excavation motion immediately after the area change movement, namely, the after-movement start position, so as to allow the earth and sand discharged to the earth removal position before the area change movement to be excavated by the excavation motion after the area change movement. The movement direction of the area change movement is the leftward direction in FIG. 9 as indicated by arrow Dm. The control according to the present modification enables the work machine 1 to repeat the motion of excavating earth and sand that is discharged to the earth removal position before the area change movement, after the area change movement, and then discharging the excavated earth and sand to a new earth removal position. This motion allows the earth and sand to be moved in a larger area with respect to the same direction as the movement direction.

[0049] The processing motion of processing an object by the attachment 30 is not limited to the excavation motion of excavating earth and sand with the bucket 33 as described above. The processing motion may be, for example, a motion of scraping an inclined surface 85 with the bucket 33 as shown in FIG. 10. The inclined surface 85 can be scraped into a slope. The motion of scraping the inclined surface 85 may be performed either only once or more than two times in the same place of the inclined surface 85. In the case of performing the motion of scraping the inclination surface 85 two or more times in the same place of the slope 85, the motions may be repeated with a change of the height of the tip of the bucket 33. The area in which processing work including such a processing motion is performed also can be enlarged by the area change movement of the lower traveling body 21.

[0050] Next will now be described processing for motion control performed by the control unit 11 with reference to the flowchart of FIG. 11.

[0051] The control unit 11 sets the shift limiting surface 75 in the working area 80 (step S1). The control unit 11 renders the posture of the upper turning body 22 the initial posture (step S2). The control unit 11 makes the upper turning body 22 and the attachment 30 perform a series of motions from the initial posture (step S3).

[0052] Next, the control unit 11 judges whether or not the excavation depth has reached a depth limit (step S4). If judging the excavation depth has not reached the depth limit (NO in step S4), the control unit 11 changes the excavation depth (step S5) and makes the next series of motions performed by the changed excavation depth (step S3). The series of motions are, thus, repeated with the change of the height of the tip of the bucket 33 during the excavation motion.

[0053] At the time of judging that the excavation depth has reached the depth limit (YES in step S4), the control unit 11 judges whether or not the amount of soil at the

earth removal position is equal to or more than a predetermined amount (YES in step S6), and only when judging the amount of soil at the earth removal position to be equal to or more than the predetermined amount (YES in step S6), the control unit 11 moves the shift limiting surface 75 in a direction reverse to the movement direction of the lower traveling body 21 (step S7).

[0054] The control unit 11 judges whether or not the start position of the excavation motion gradually changed in the above-described manner has reached the shift limiting surface 75 (step S8). If judging that the start position has not yet reached the shift limiting surface 75 (NO in step S8), the control unit 11 makes the upper turning body 22 turned by a predetermined turning angle to thereby shift the start position of the excavation motion in the turning direction of the upper turning body 22 (Step S9). The series of motions is thereby repeated in a new excavation place.

[0055] At the time of judging that the start position of the excavation motion which is gradually shifted as described above reaches the shift limiting surface 75 (YES in step S8), the control unit 11 makes the lower traveling body 21 perform an area change movement (step S10). The area change movement is controlled so as to make the processing work by the series of motions after the area change movement continued with the processing work before the area change movement, and the turning posture of the upper turning body 22 is returned to the same posture as the initial posture (step S2). Even after the area change movement, the processing in the step S3 and the following steps are repeated.

[0056] Next will be described a second embodiment of the present invention with reference to FIGS. 12 to 14. 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 the first embodiment has the same sign as that of the first embodiment.

[0057] FIGS. 12 to 14 show a work machine 101 according to the second embodiment. It is the same as the first embodiment that the control unit 11 according to the present embodiment serves as a lower-traveling-body moving means of making the lower traveling body 21 perform an area change movement when the work by a series of motions reaches a predetermined stage in a state where the start position has reached the shift limiting surface 75, whereas the movement distance of the area change movement is different from the movement distance L according to the first embodiment, that is, such a distance that the after-movement posture for matching the start position of the excavation motion immediately before the area change movement with the start position of the excavation motion immediately after the area change movement is the same posture as the initial posture. The control unit 11 according to the present embodiment sets an after-movement posture that is the orientation of the upper turning body 22 with respect to the lower traveling body 21 (turning posture) after the area

change movement so as to make the processing motion by the series of motions after the area change movement continued with the processing work before the area change movement.

[0058] As shown in FIG. 12, when the movement distance of the area change movement is larger than the movement distance L that is set in the first embodiment as shown in FIG. 4, the control unit 11 changes the after-movement posture from the initial posture to a posture where the upper turning body 22 has been turned in a direction reverse to the movement direction (leftward direction in the figure) from the initial posture so as to render the start position of the excavation motion in the first series of motions after the area change movement of the lower traveling body 21, namely, the after-movement start position (point A1), a position on the shift limiting surface 75.

[0059] On the other hand, as shown in FIG. 13, when the movement distance is smaller than the movement distance L shown in FIG. 4, the control unit 11 changes the after-movement posture of the upper turning body 22 from the initial posture to a posture where the upper turning body 22 has been turned in the same direction as the movement direction (rightward direction in the drawing) so as to render the after-movement start position (point A1) a position on the shift limiting surface 75.

[0060] FIGS. 12 and 13 show a posture change angle θ_c in each case, and the after-movement posture is set to a posture where the upper turning body 22 has been turned in the direction reverse to the movement direction (leftward direction in FIG. 12) with respect to the lower traveling body 21 by the posture change angle θ_c from the turning posture immediately before the area change movement. In summary, the control of turning the upper turning body 22 by the posture changing angle θ_c after the area change movement is performed, and the start position is determined in the posture of the upper turning body 22 after the turning. Before the area change movement, the turning posture of the upper turning body 22 is changed by a predetermined turning angle each time the work by the repetition of the series of motions reaches a predetermined stage. This causes also the start position of the excavation motion to be gradually shifted from the first position A. As shown in FIG. 12, when the movement distance of the area change movement of the lower traveling body 21 is larger than the movement distance L shown in FIG. 4, the posture change angle θ_c corresponding to the area change movement is larger than the posture change angle of the upper turning body 22 from the initial posture to the turning posture immediately before the area change movement. In contrast, as shown in FIG. 13, when the movement distance of the area change movement is smaller than the movement distance L shown in FIG. 4, the posture change angle θ_c is smaller than the posture change angle of the upper turning body 22 from the initial posture to the turning posture immediately before the area change movement.

[0061] Furthermore, in the present embodiment, the

trajectory that the tip of the attachment 30 (the tip of the bucket 33) is to trace is corrected in accordance with the after-movement posture of the upper turning body 22.

[0062] The setting of the after-movement posture setting enables the processing work by the series of motions after the area change movement to be suitably continued with the processing work before the area change movement.

[0063] The control unit 11 according to the present embodiment serves as a movement limit setting means of setting a movement limiting position 88 of the lower traveling body 21. In the present embodiment, the movement limiting position 88 is set to such a position that the processing work after the area change movement of the lower traveling body 21 stopped at the movement limiting position 88 is continued with the processing work before the area change movement. More specifically, the movement limiting position 88 is set so as to render the start position of the excavation motion in the first series of motions in a state where the area change movement of the lower traveling body 21 is stopped at the movement limiting position 88, namely, the after-movement start position (point A1), a position on the shift limiting surface 75. The control unit 11 serves as a lower-traveling-body moving means of making the lower traveling body 21 perform the area change movement and stopping the area change movement at the time when the lower traveling body 21 reaches the movement limiting position 88. Such control of the area change movement enables the processing work after the area change movement to be suitably continued with the processing work before the area change movement.

[0064] The movement limiting position 88 may be set based on a work plan. For example, setting the movement limiting position 88 on the boundary of the area in which the work is planned allows work to be restrained from deviating from the work plan. The movement limiting position 88, alternatively, may be set based on the position of an obstacle or the like imaged by the imaging device 26. Setting the movement limiting position 88 on the front side of the position of the obstacle or the like prevents the attachment 30 from interfering with the obstacle or the like.

[0065] If the movement limiting position 88 is not set and thereby the movement distance of the area change movement of the lower traveling body 21 is permitted to be excessively large, the after-movement start position (point A1), which is the start position of the excavation motion after the area change movement, may be deviated beyond the shift limiting surface 75 in the movement direction, for example, as shown in FIG. 14.

[0066] For this case, it is preferable that the control unit 11 serves as a notification means of making a notification device notify that the after-movement start position has been deviated beyond the shift limiting surface 75. Specifically, it is preferable that the control unit 11 is configured to make a display device display the deviation or make a warning sound, etc. indicating the deviation out-

put from the speaker, in a portable terminal (tablet terminal, smartphone, etc.) carried by an administrator who manages the operation of the work machine 101. That is because the start of the excavation motion at a position beyond the shift limiting surface 75 would enlarge a non-working area where the processing work is not performed either before or after the area change movement. Notifying such a situation to an administrator or the like of the work machine 1 can call attention to the administrator or the like so as to prevent the excavation motion from being performed at a start position deviated beyond the shift limiting surface 75.

[0067] Preferably, the control unit 11 serves as a reverse traveling control means of moving the lower traveling body 21 in the direction reverse to the movement direction of the area change movement to make the after-movement start position closer to the shift limiting surface 75 as indicated by arrow Db shown in FIG. 14 when such an area change movement as to deviate the after-movement start position (point A1) beyond the shift limiting surface 75 as shown in FIG. 14 is performed. The movement of the lower traveling body 21 in the reverse direction makes it possible to reduce an area in which neither the processing work before the area change movement nor the processing work after the area change movement is performed, namely, the non-working area.

[0068] Also in the second embodiment, it is preferable that a working area 80 is set as shown in FIGS. 12, 13 and 14. In the present embodiment, the turning posture of the upper turning body 22 with respect to the lower traveling body 21 is set so as to confine the tip of the bucket 33 within the working area 80.

[0069] Also in the second embodiment, similarly to the configuration shown in FIG. 6, the after-movement start position (point A1) may be set so as to locate the after-movement start position (point A1) upstream of the shift limiting surface 75 in the movement direction (left side in FIG. 6) in order to reduce a non-working area similar to the non-working area 77 shown in FIG. 3. Specifically, in the second embodiment, the after-movement posture, which is the orientation of the upper turning body 22 with respect to the lower traveling body 21 (turning posture) for providing the after-movement start position, is set so as to locate the after-movement start position (point A1) upstream (left side in the drawing) of the shift limiting surface 75 in the movement direction of the lower traveling body 21.

[0070] Also in the second embodiment, similarly to the configuration shown in FIG. 9, a control may be performed so as to make motions of excavating the earth and sand discharged to the earth removal position and discharging it to a new earth removal position repeated. In the second embodiment, the orientation of the upper turning body 22 with respect to the lower traveling body 21 (turning posture) is set so as to allow the earth and sand that has been discharged to the earth removal position to be excavated after the movement of the lower

traveling body 21. Also in the second embodiment, the processing motion is not limited to the excavation motion by the bucket 33 but allowed to be also, for example, as shown in FIG. 10, a motion of scraping the inclined surface 85 with the bucket 33.

[0071] While embodiments of the present invention have been described above, specific examples are illustrative only and, in particular, without limiting the invention, specific configurations and the like can be appropriately designed. Also, the effects and effects described in the embodiments of the invention have only enumerated the most preferred effects and effects arising from the present invention, and the effects and advantages of the present invention are not limited to those described in embodiments of the invention.

[0072] As has been described, provided is a work machine capable of continuing work by automatic operation over a large area. 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 rotatably attached to the upper turning body capably of performing a processing motion for processing an object. The controller controls driving of the upper turning body and the attachment so as to make the upper turning body and the work device perform a series of motions including the processing motion by the work device a plurality of times. The controller shifts a start position of the processing motion included in the next series of motions in a turning direction of the upper turning body when work performed by the series of motions reaches a predetermined stage. The work by the series of motions are thereby performed with a change of the start position of the excavation motion. Moreover, the controller makes the lower traveling body perform an area change movement for changing an area in which processing work which is work performed by the series of motions is performed, when the processing work reaches the predetermined stage in a state where the start position has reached a predetermined shift limiting surface that defines a limit of the shift of the start position in the turning direction, and sets an after-movement start position, which is a start position of the processing motion after the area change movement, so as to make the processing work after the area change movement and the processing work before the area change movement continued with each other. The area change movement enables work to be continued over a large area with the continuity of the processing work after the area change movement with the processing work before the area change movement.

[0073] Preferably, the area change movement is a movement in a direction of making an after-movement posture which is a posture of the upper turning body with respect to the lower traveling body at the after-movement start position closer to an initial posture which is the posture of the upper turning body with respect to the lower traveling body at the start position of the processing mo-

tion included in the first series of motions. Thus making the after-movement posture, which is the posture of the upper turning body corresponding to the start position immediately after the area change movement, closer to the initial posture enables the processing work to be performed over a large area even after the area change movement while making the processing work after the area change movement continued with the processing work before the area change movement.

[0074] Preferably, the controller is configured to perform setting the after-movement posture to the same posture as the initial posture and setting a distance of the area change movement so as to make the processing work after the area change movement continued with the processing work before the area change movement. The thus set movement distance enables the processing work by the series of motions after the area change movement to be suitably continued with the processing work before the area change movement, in spite of the return of the posture of the upper turning body after the area change movement (after-movement posture) to the same posture as the initial posture.

[0075] Preferably, the controller is configured to make the lower traveling body perform the area change movement by a preset movement distance, and configured to set the after-movement posture (i.e., the orientation of the upper turning body with respect to the lower traveling body after the area change movement) so as to make the processing work by the series of motions after the area change movement continued with the processing work before the area change movement. This enables the processing work after the area change movement to be suitably continued with the processing work before the area change movement by the setting of the turning posture (orientation) of the upper turning body with respect to the lower traveling body while performing the area change movement by simple control of only moving the lower traveling body by a preset movement distance.

[0076] Preferably, the controller is configured to make a notification device notify that the after-movement start position is deviated beyond the shift limiting surface by the area change movement by the movement distance. The notification can prompt an administrator of the work machine or the like to prevent the excavation motion from being performed from the after-movement start position deviated beyond the shift limiting surface, thereby restraining a non-working area from occurring.

[0077] Preferably, the controller is configured to move the lower traveling body in a direction reverse to a movement direction of the area change movement when the after-movement start position is deviated beyond the shift limiting surface by the area change movement. The reverse movement of the lower traveling body allows the after-movement start position deviated beyond the shift limiting surface to be corrected in a direction of approaching the shift limiting surface, thereby effectively reducing the non-working area, i.e., the area where neither the processing work before the area change movement nor

the processing work after the area change movement is performed.

[0078] The controller is preferably configured to stop the area change movement when the lower traveling body is made reach a preset movement limiting position by the area change movement. This enables proper control of the area change movement to be performed by a simple process of only comparing the actual position of the lower traveling body with the preset movement limiting position. For example, in the case of setting the movement limiting position based on a work plan, the stop of the area change movement of the lower traveling body at the movement limiting position can effectively restrain the work from being performed with deviation from the work plan. Besides, in the case of setting the movement limiting position on the front side of an obstacle or the like, the stop of the area change movement of the lower traveling body at the movement limiting position can restrain the work machine and the obstacle or the like from interfering with each other.

[0079] The controller preferably makes the shift of the start position within a preset working area. This can prevent the work device from being deviated from the working area by the series of motions after the change of the start position. Furthermore, it is preferable that the controller sets the after-movement start position within the working area so as to make the processing work after the area change movement continued with the processing work before the area change movement, which can also prevent the work device from being deviated from the working area by the series of motions after the area change movement. For example, in the case of presence of an obstacle or the like outside the working area, the work device can be prevented from being into interference with the obstacle or the like by the series of motions either after the shift of the start position or after the area change movement.

[0080] Preferably, the controller is configured to set the after-movement start position to a position upstream of the shift limiting surface in the movement direction. This makes it possible to prevent a non-working area (area in which neither the processing work before the area change movement nor the processing work after the area change movement is performed) from being caused by the start of the processing motion at a position deviated beyond the shift limiting surface (downstream position) after the area change movement.

[0081] For the case where the processing motion is an excavation motion of excavating earth and sand, it is preferable that the controller is configured to make the upper turning body and the work device repeat the series of motions with a change of a height of a tip of the work device in the processing motion. In this case, the area change movement of the lower traveling body enables excavation work to be performed over a large area.

[0082] For the case where the series of motions includes an earth removal motion of discharging earth and sand to an earth removal position, it is preferable that the

work machine further includes a soil amount detector that detects an amount of soil at the earth removal position and the controller is configured to move the shift limiting surface in a direction reverse to the movement direction when the amount of soil at the earth removal position detected by the soil amount detector is equal to or greater than a preset allowable amount. The movement of the shift limiting surface advances the timing of the start of the area change movement to thereby enable the area of the processing work to be changed by the area change movement before the excess of the amount of soil at the earth removal position.

[0083] Besides, for the case where the processing motion is a motion of excavating earth and sand and the series of motions includes an earth removal motion of discharging earth and sand to the earth removal position, it is preferable that the controller is configured to set the after-movement start position so as to allow the earth and sand that has been discharged to the earth removal position to be excavated by the processing motion after the area change movement. This enables the motions of excavating the earth and sand that has been discharged to the earth removal position after the area change movement and discharging it to a new earth removal position to be repeated, thereby enabling the work for moving the earth and sand in the movement direction of the area change movement to be performed over a large area.

[0084] The processing motion, alternatively, may be a motion of scraping an inclined surface. Also in this case, the area change movement of the lower traveling body enables the work of forming a slope to be performed over a large area.

Claims

1. A work machine comprising:

- a lower traveling body capable of performing a traveling motion;
- an upper turning body mounted on the lower traveling body capably of turning with respect to the lower traveling body;
- a work device rotatably attached to the upper turning body capably of performing a processing motion of processing an object; 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 series of motions including the processing motion by the work device a plurality of times, wherein:
 - the controller is configured to perform: shifting a start position of the processing motion included in the next series of motions in a turning direction of the upper turning body when processing work which is work performed by the series of motions reaches a predetermined stage;

- making the lower traveling body perform an area change movement that is a movement for changing an area in which the processing work is performed when the processing work reaches the predetermined stage in a state where the start position has reached a predetermined shift limiting surface that defines a limit of the shift of the start position in the turning direction; and setting an after-movement start position, which is a start position of the processing motion after the area change movement, so as to make the processing work after the area change movement and the processing work before the area change movement continued with each other.
2. The work machine according to claim 1, wherein the area change movement is a movement in a direction of making an after-movement posture which is a posture of the upper turning body with respect to the lower traveling body at the after-movement start position closer to an initial posture which is a posture of the upper turning body with respect to the lower traveling body at the start position of the processing motion included in the first series of motions.
 3. The work machine according to claim 2, wherein the controller is configured to perform setting the after-movement posture to the same posture as the initial posture and setting a distance of the area change movement so as to make the processing work after the area change movement continued with the processing work before the area change movement.
 4. The work machine according to claim 2, wherein the controller is configured to make the lower traveling body perform the area change movement by a preset movement distance and configured to set the after-movement posture so as to make the processing work by the series of motions after the area change movement continued with the processing work before the area change movement.
 5. The work machine according to claim 4, wherein the controller is configured to make a notification device notify that the after-movement start position is deviated beyond the shift limiting surface by the area change movement by the movement distance.
 6. The work machine according to claim 4 or 5, wherein the controller is configured to move the lower traveling body in a direction reverse to a direction of the area change movement when the after-movement start position is deviated beyond the shift limiting surface by the area change movement by the movement distance.
 7. The work machine according to any of claims 1 to 3, wherein the controller is configured to stop the area change movement when the lower traveling body is made reach a preset movement limiting position by the area change movement.
 8. The work machine according to any of claims 1 to 7, wherein the controller is configured to shift the start position within a preset working area and configured to set the after-movement start position within the working area so as to make the processing work after the area change movement continued with the processing work before the area change movement.
 9. The work machine according to any of claims 1 to 8, wherein the controller is configured to set the after-movement start position to a position upstream of the shift limiting surface in a direction of the area change movement.
 10. The work machine according to any of claims 1 to 9, wherein the processing motion is an excavation motion of excavating earth and sand, and the controller is configured to make the upper turning body and the work device repeat the series of motions with a change of a height of a tip of the work device in the processing motion.
 11. The work machine according to claim 10, wherein the series of motions includes an earth removal motion of discharging earth and sand to an earth removal position, the work machine further comprising a soil amount detector that detects an amount of soil at the earth removal position, wherein the controller is configured to move the shift limiting surface in a direction reverse to a direction of the area change movement when the amount of soil at the earth removal position detected by the soil amount detector is equal to or greater than a preset allowable amount.
 12. The work machine according to any of claims 1 to 9, wherein: the processing motion is a motion of excavating earth and sand; the series of motions includes an earth removal motion of discharging earth and sand to the earth removal position; and the controller is configured to set the after-movement start position so as to allow the earth and sand that has been discharged to the earth removal position to be excavated by the processing motion after the area change movement.
 13. The work machine according to any of claims 1 to 9, wherein the processing motion is a motion of scraping an inclined surface.

FIG.1

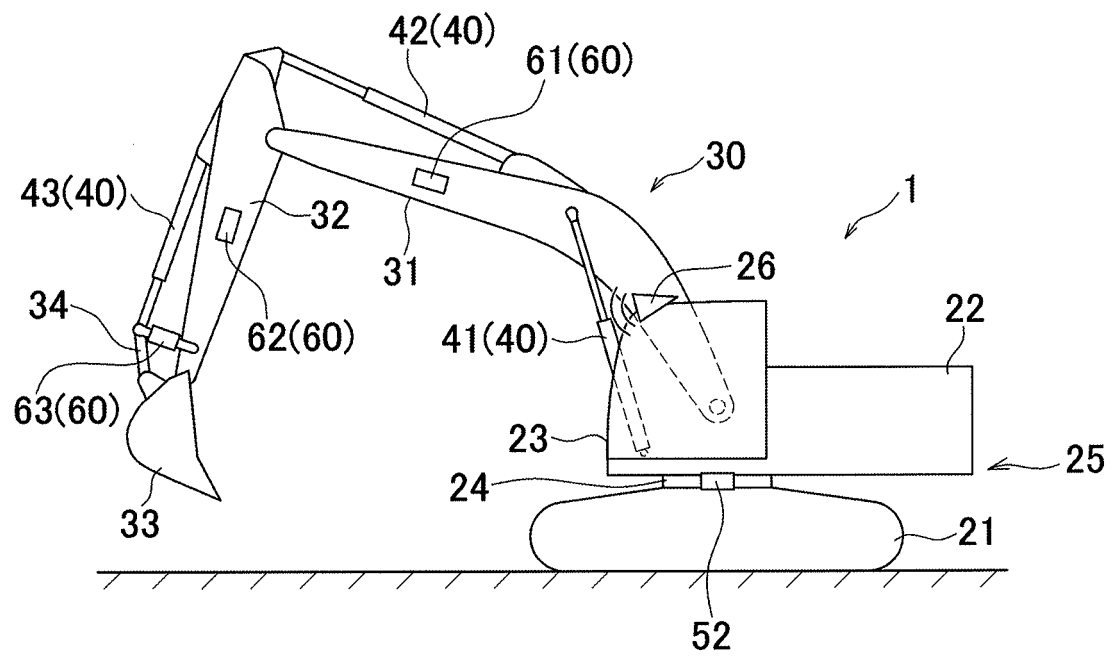


FIG.2

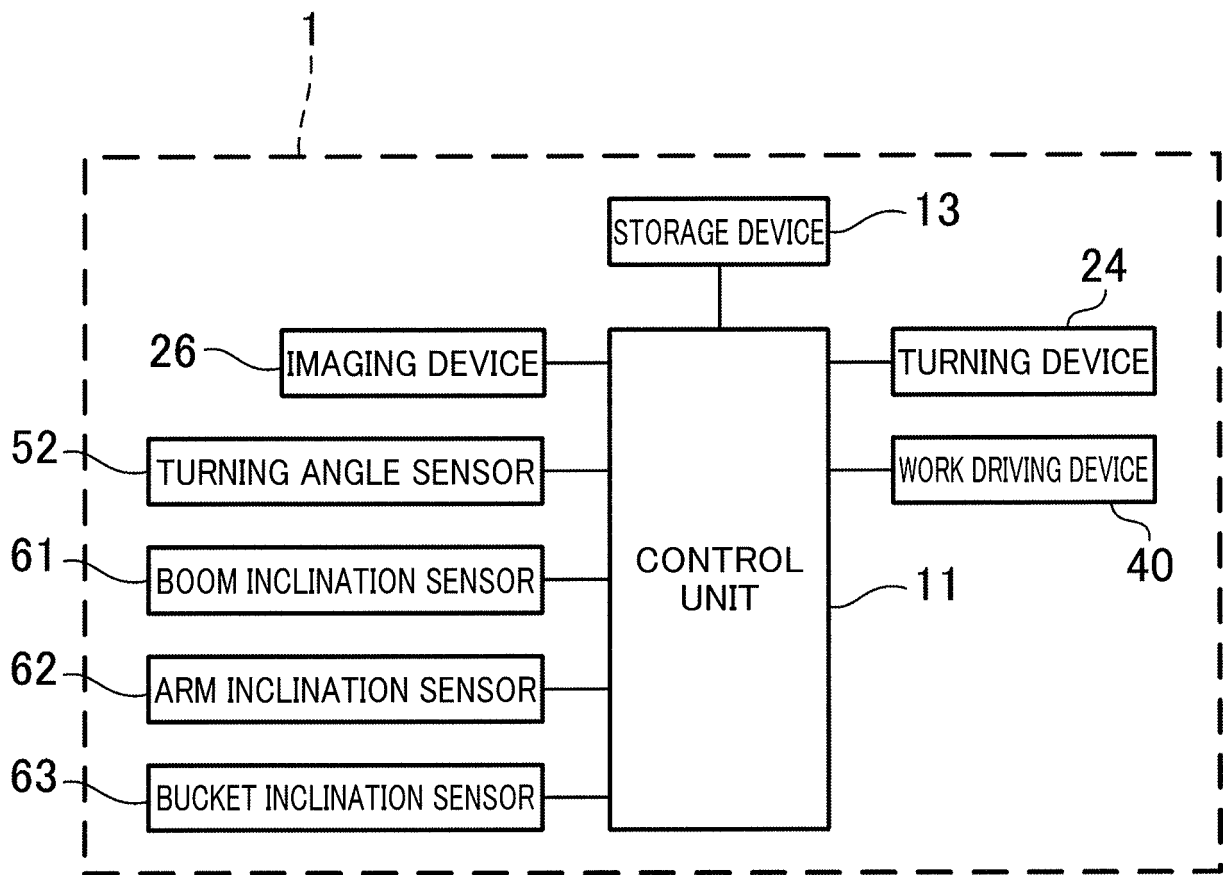


FIG. 3

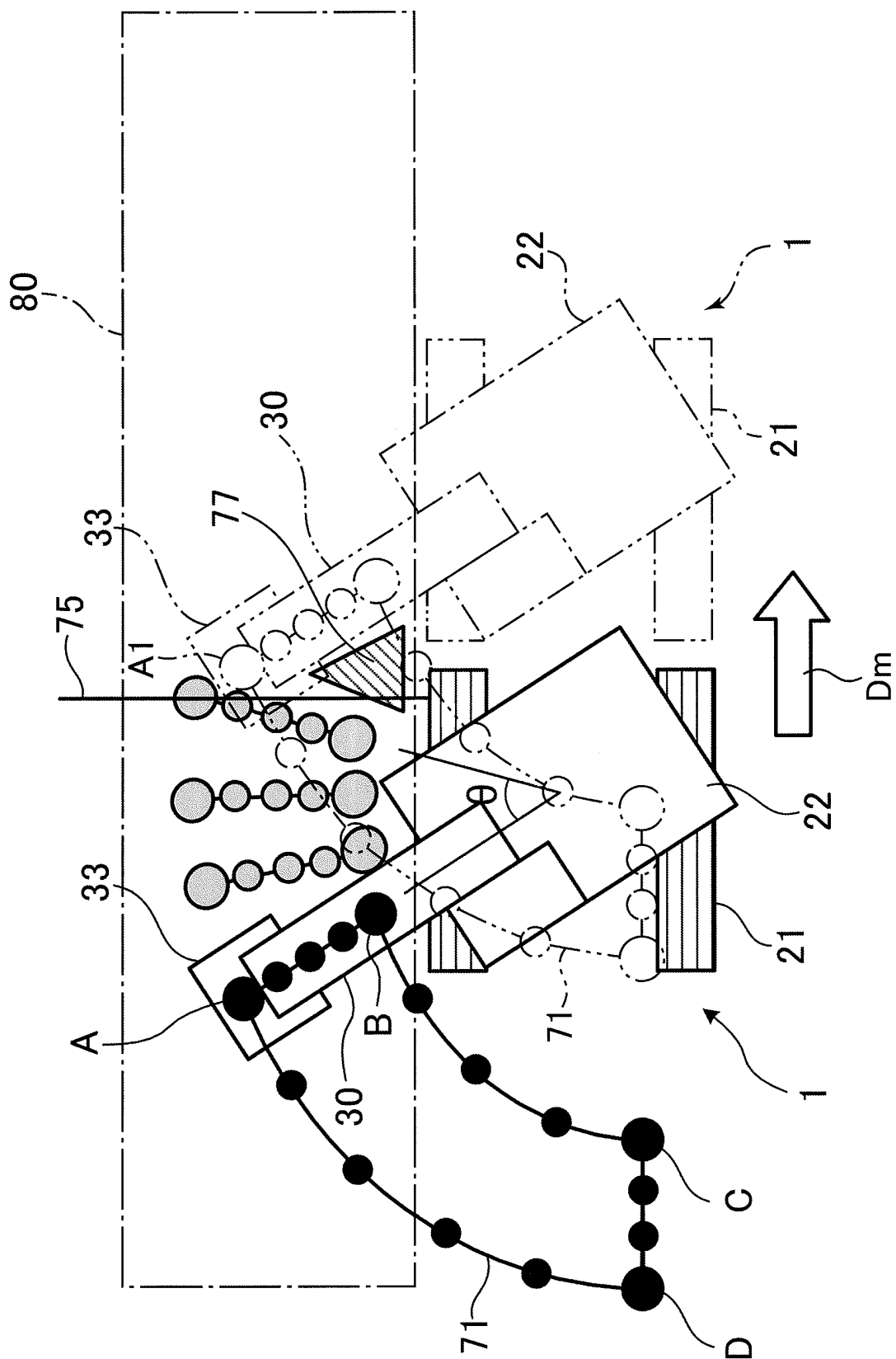


FIG.4

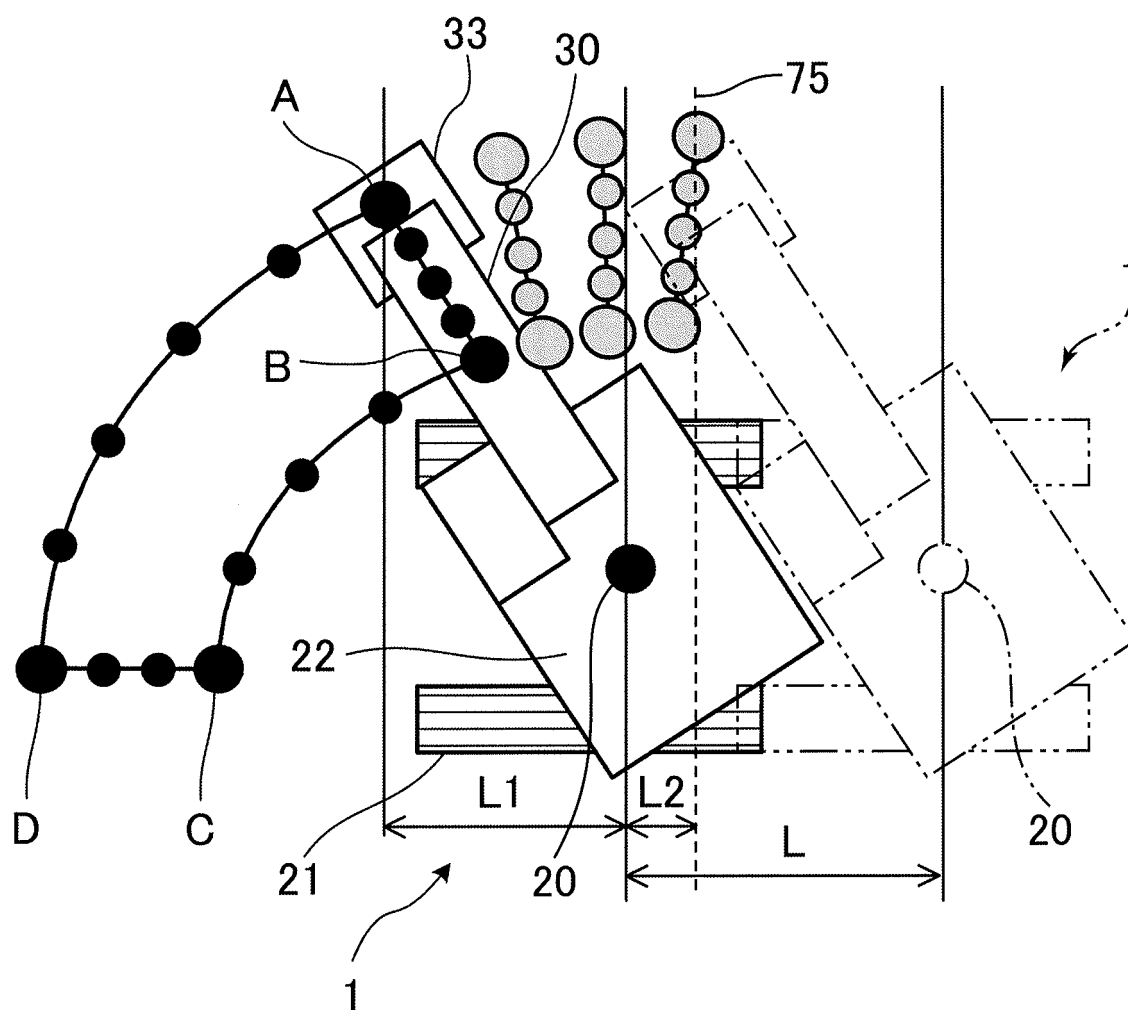


FIG.5

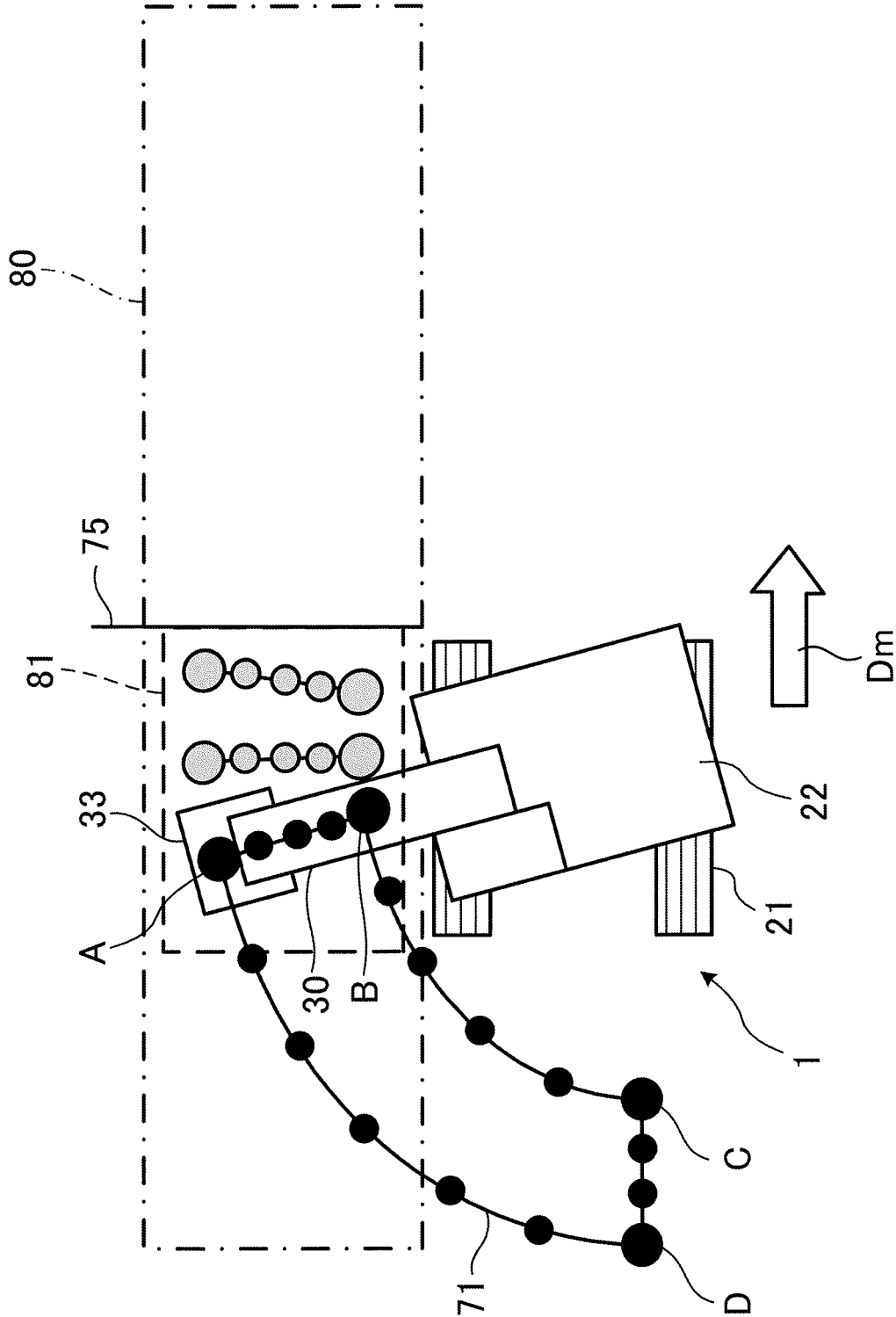


FIG.6

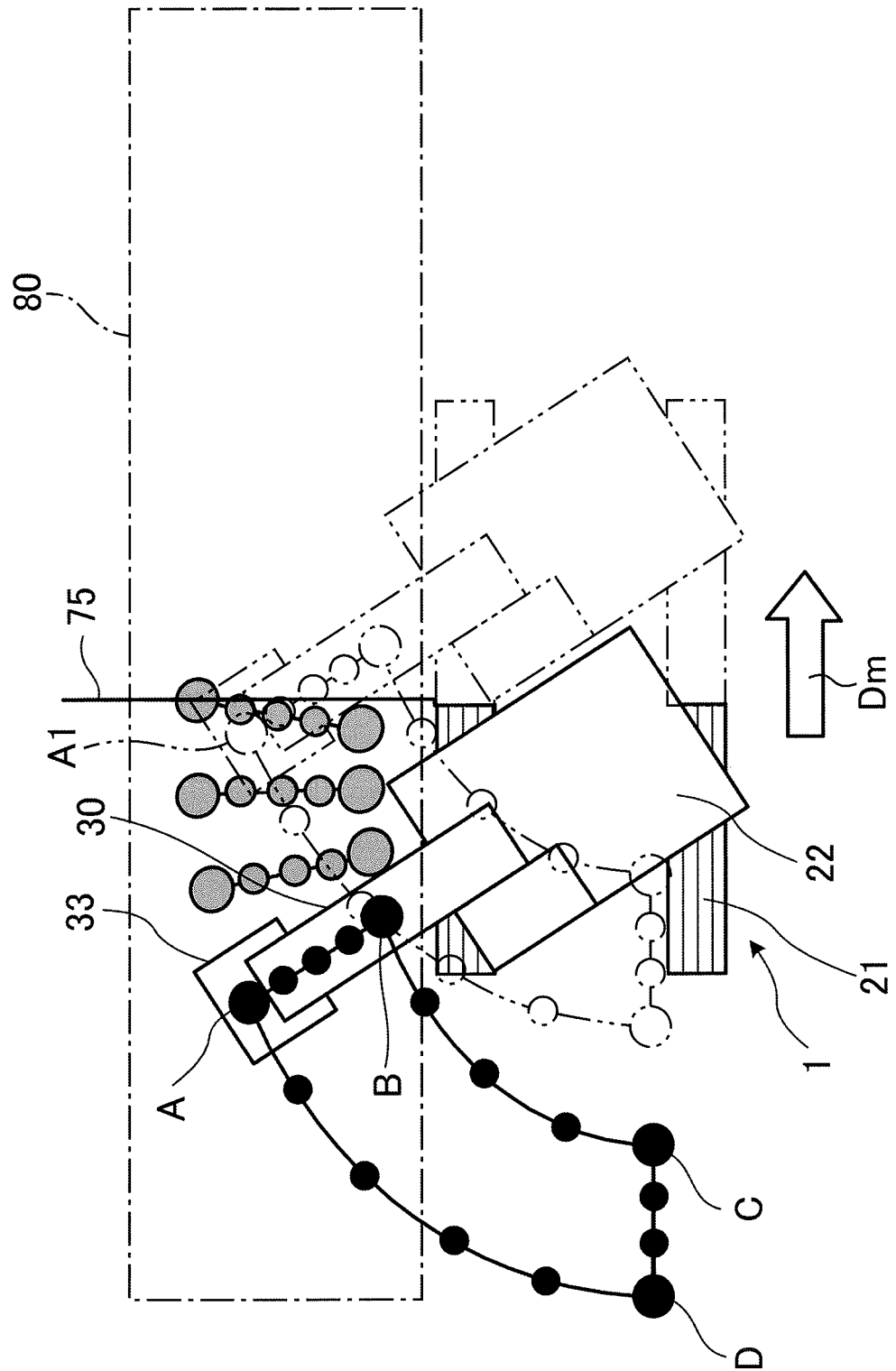


FIG. 7

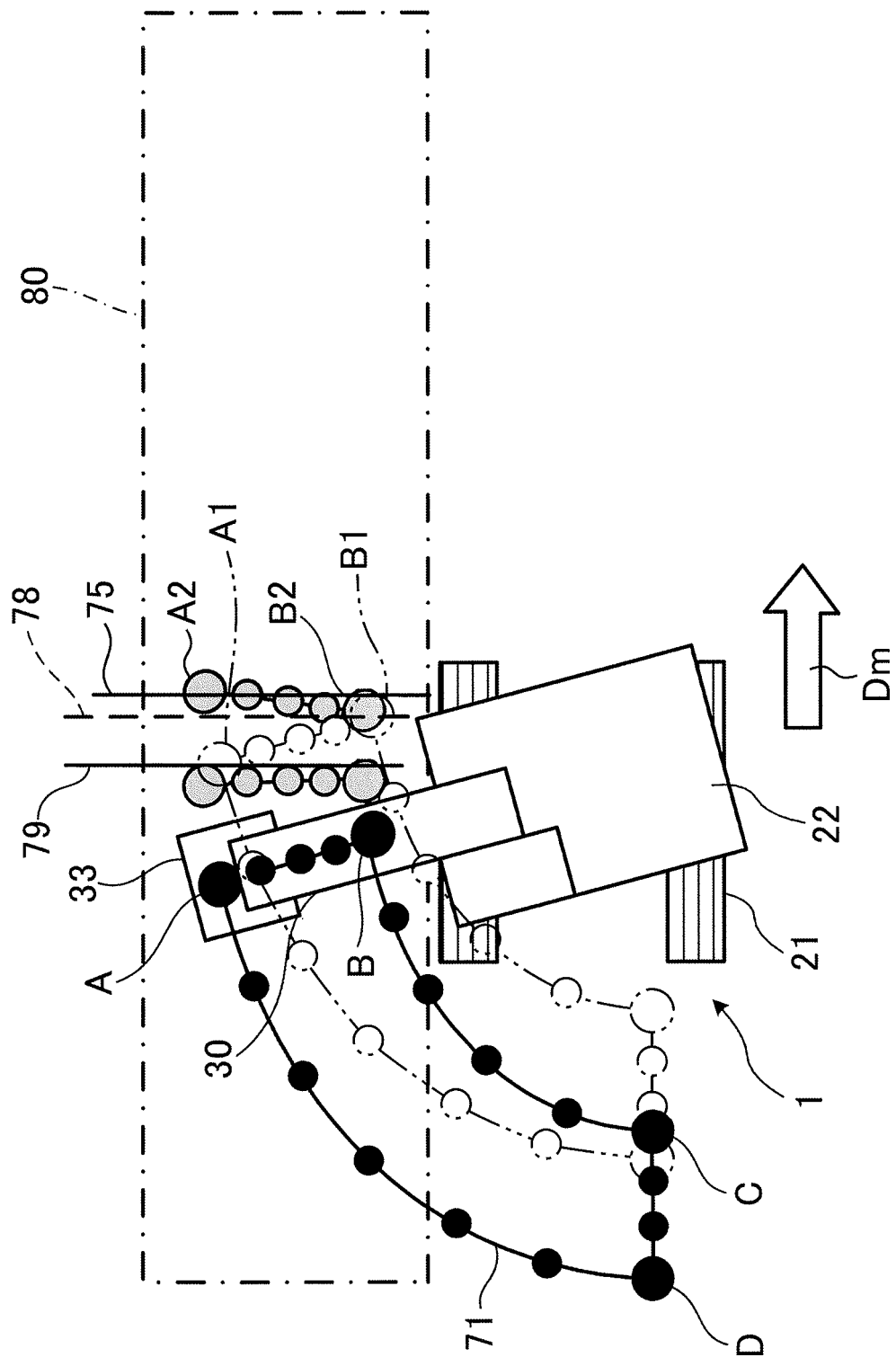


FIG.8

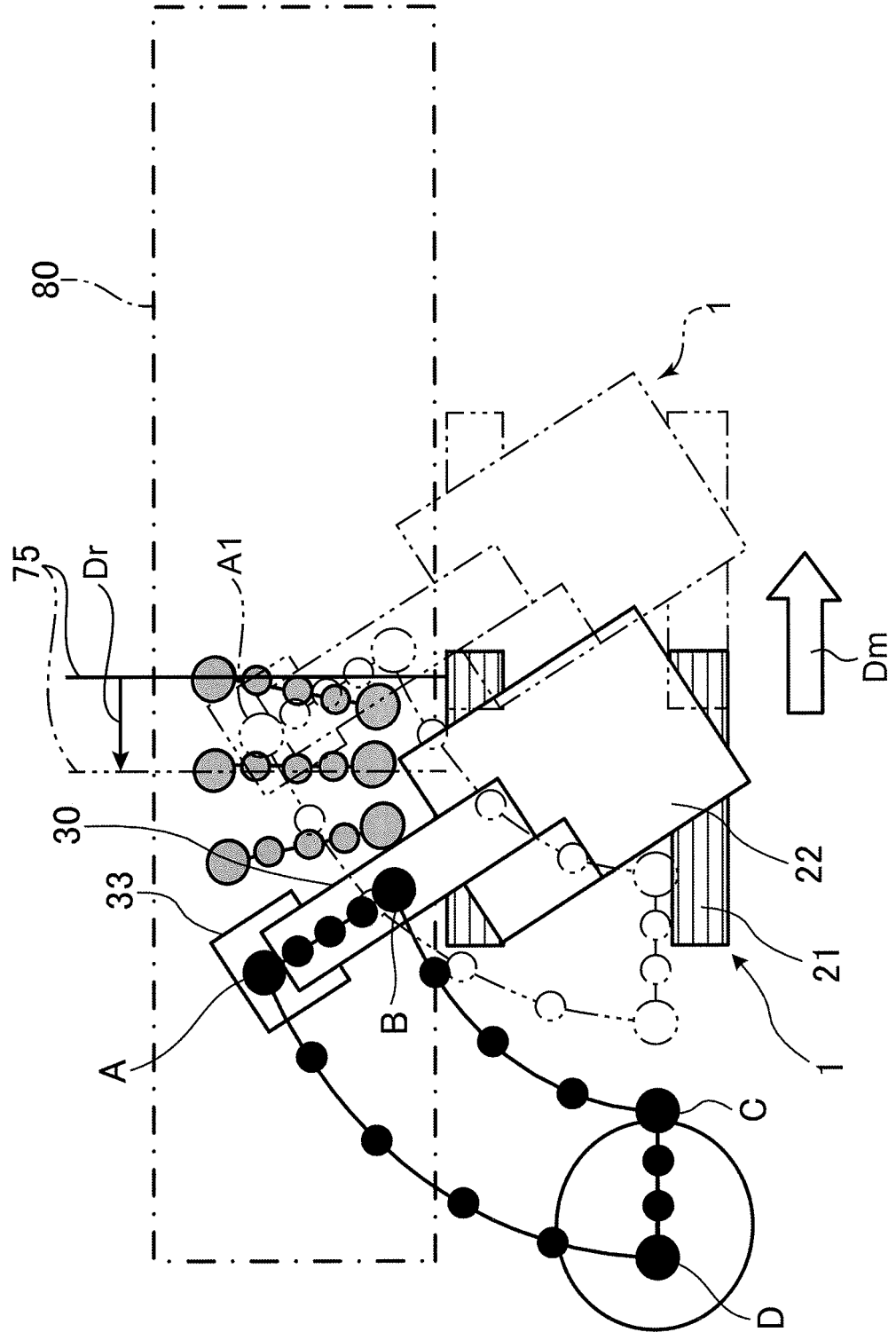


FIG.9

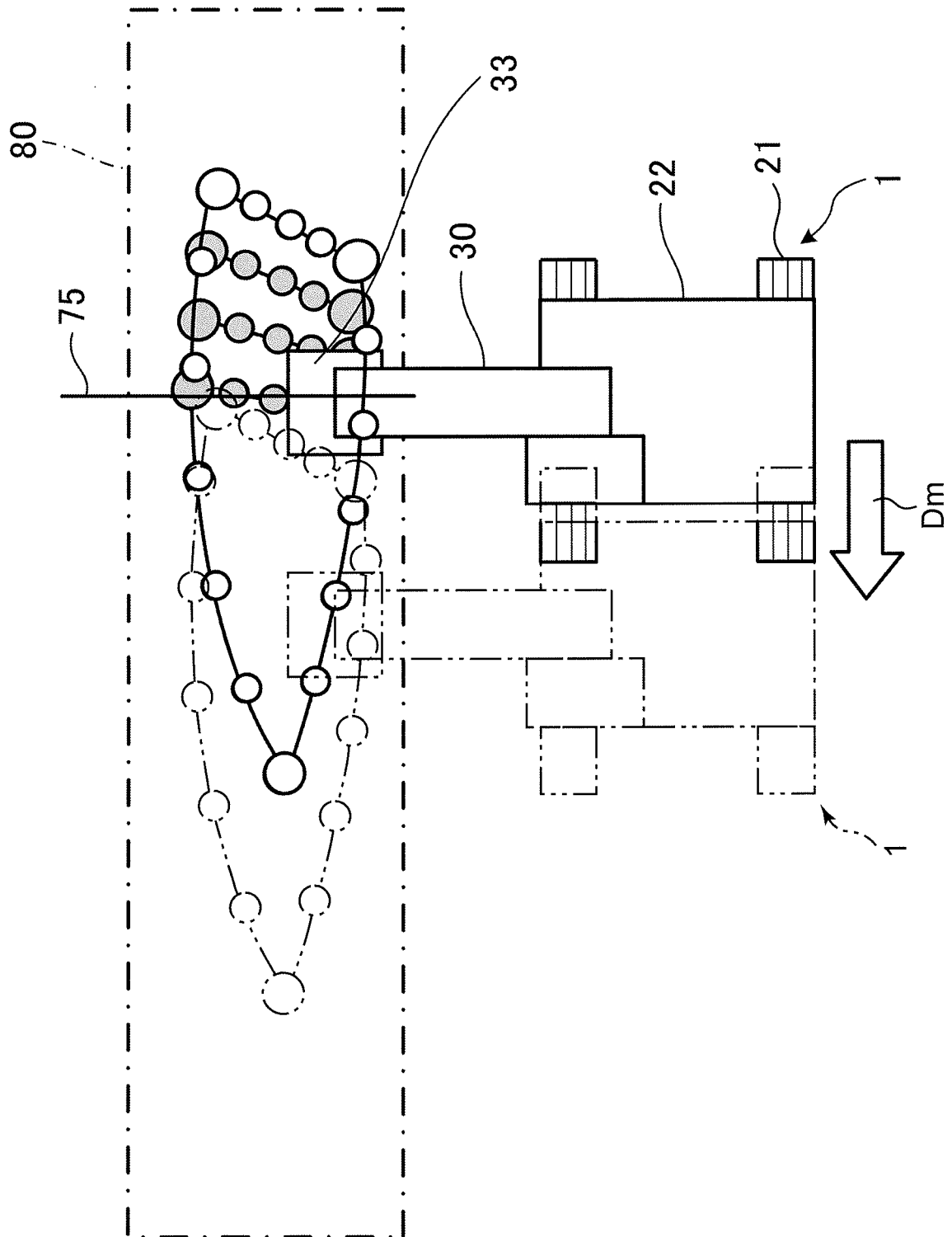


FIG.10

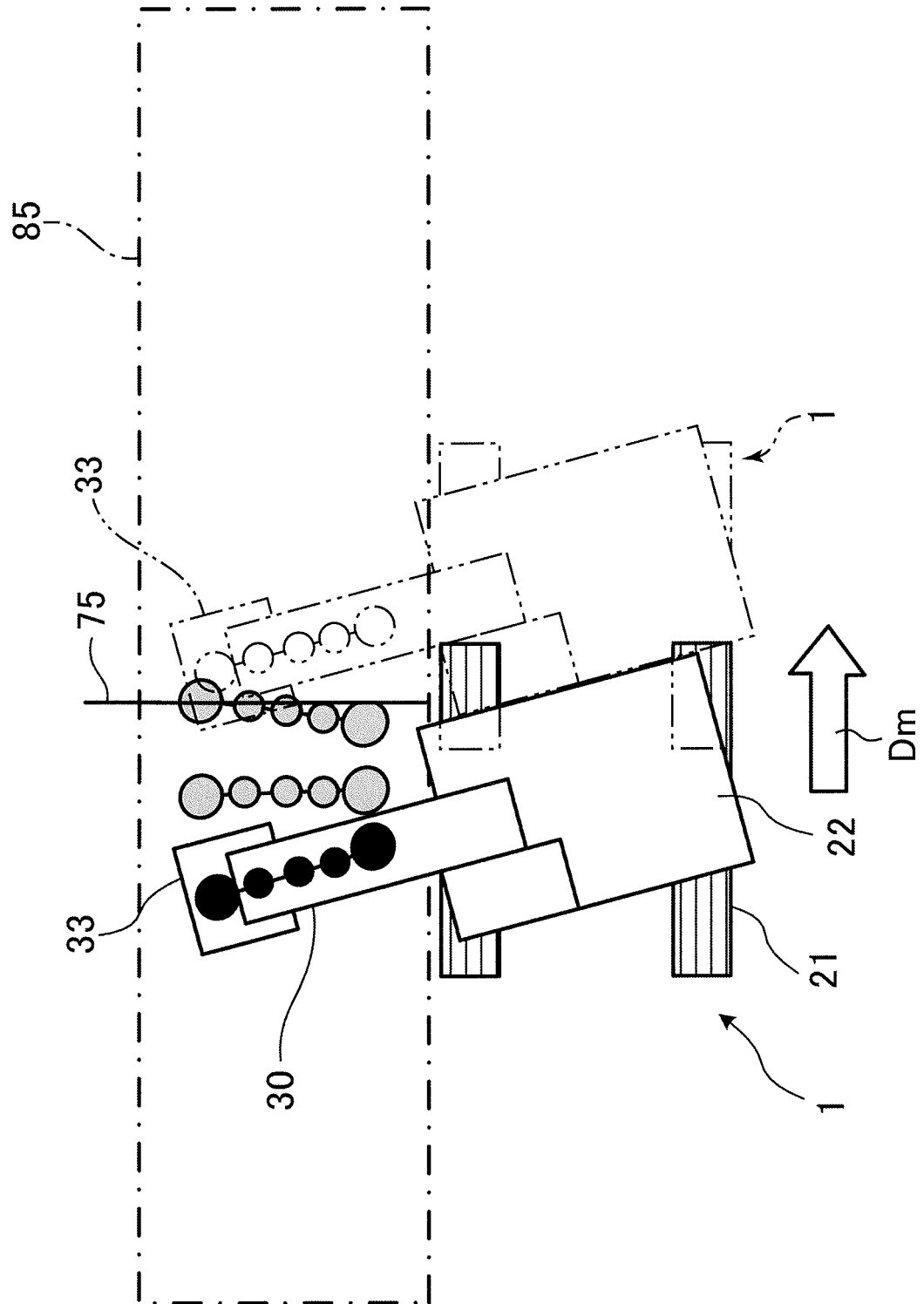


FIG.11

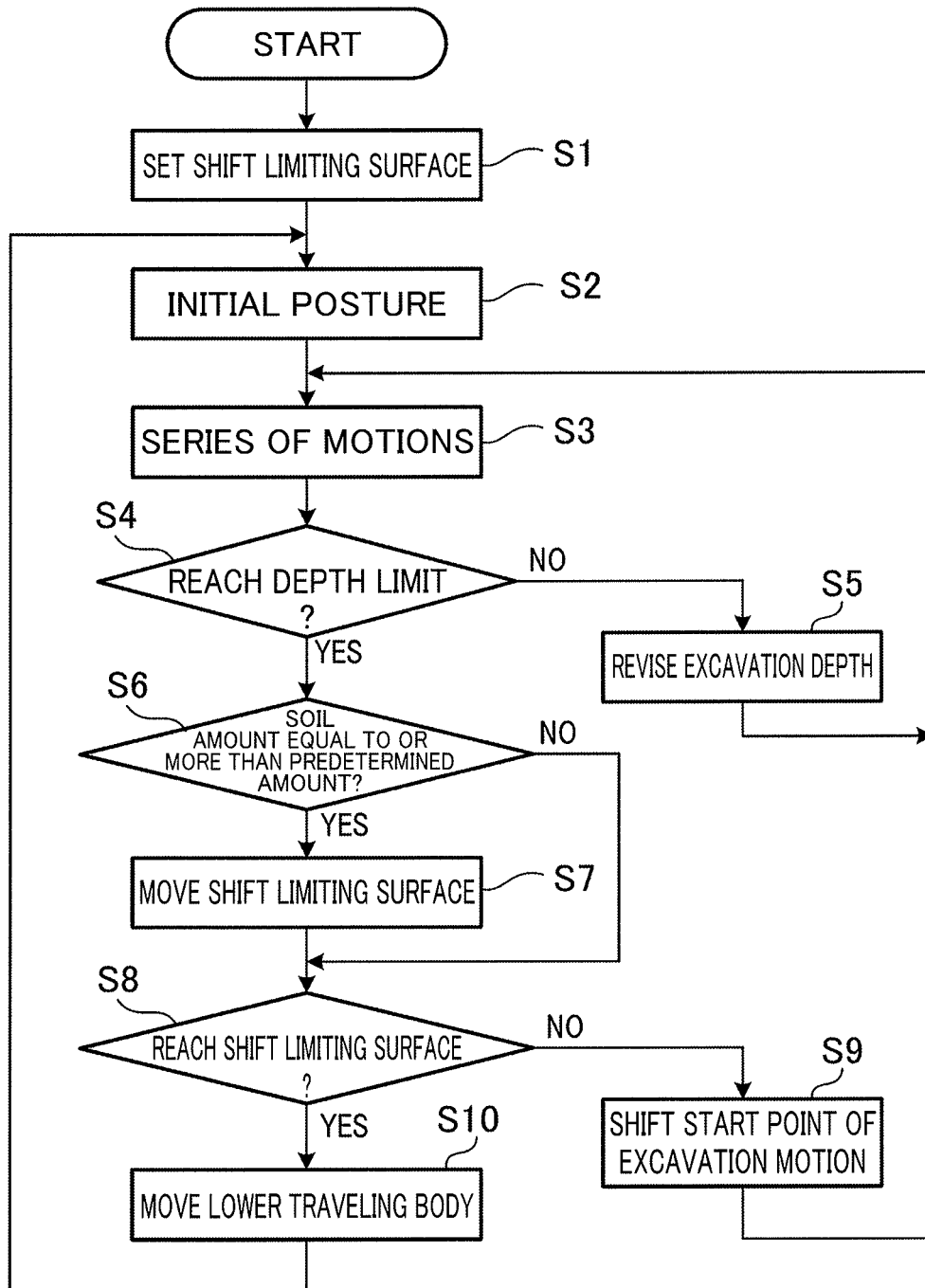


FIG. 12

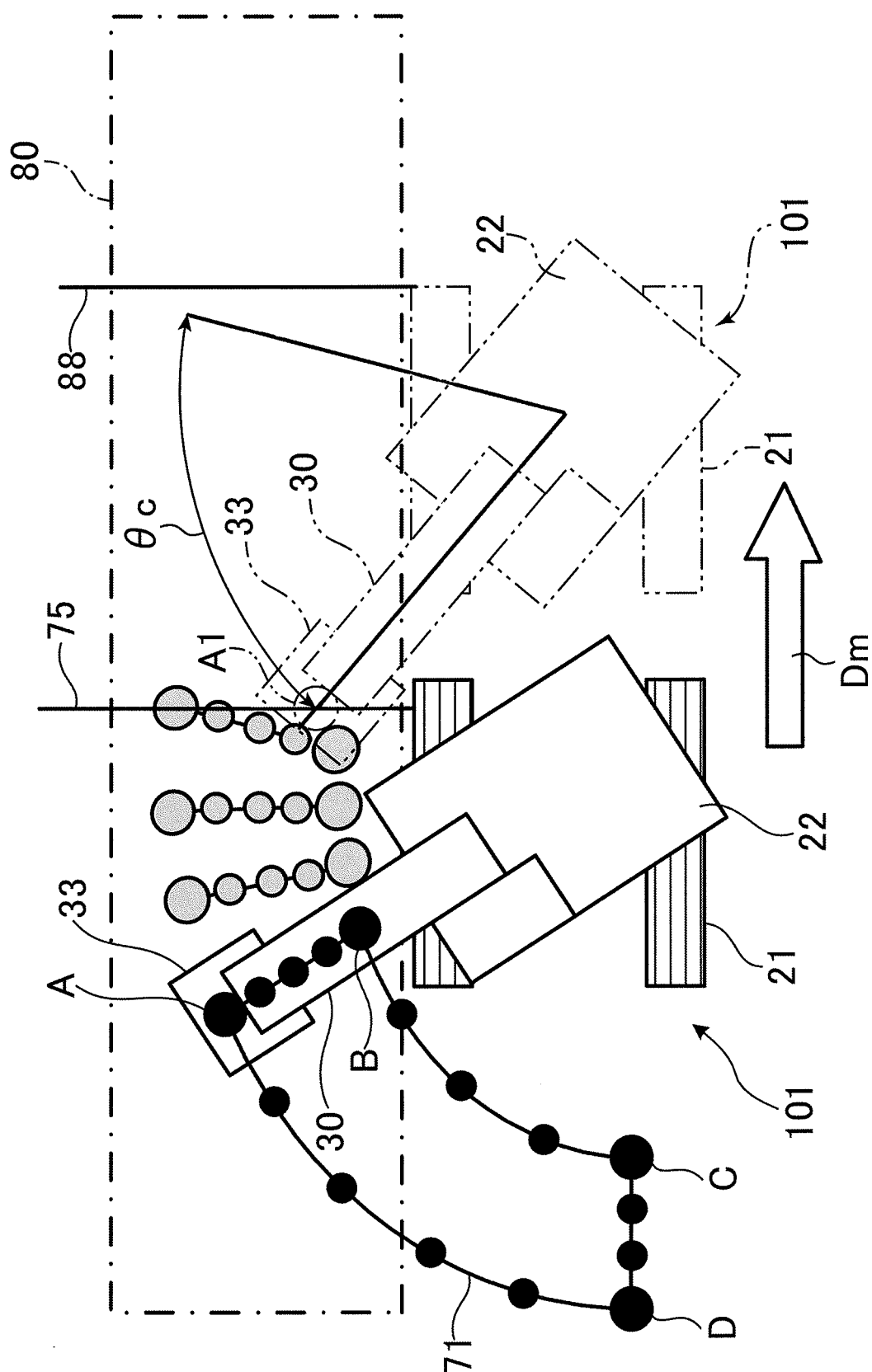


FIG.13

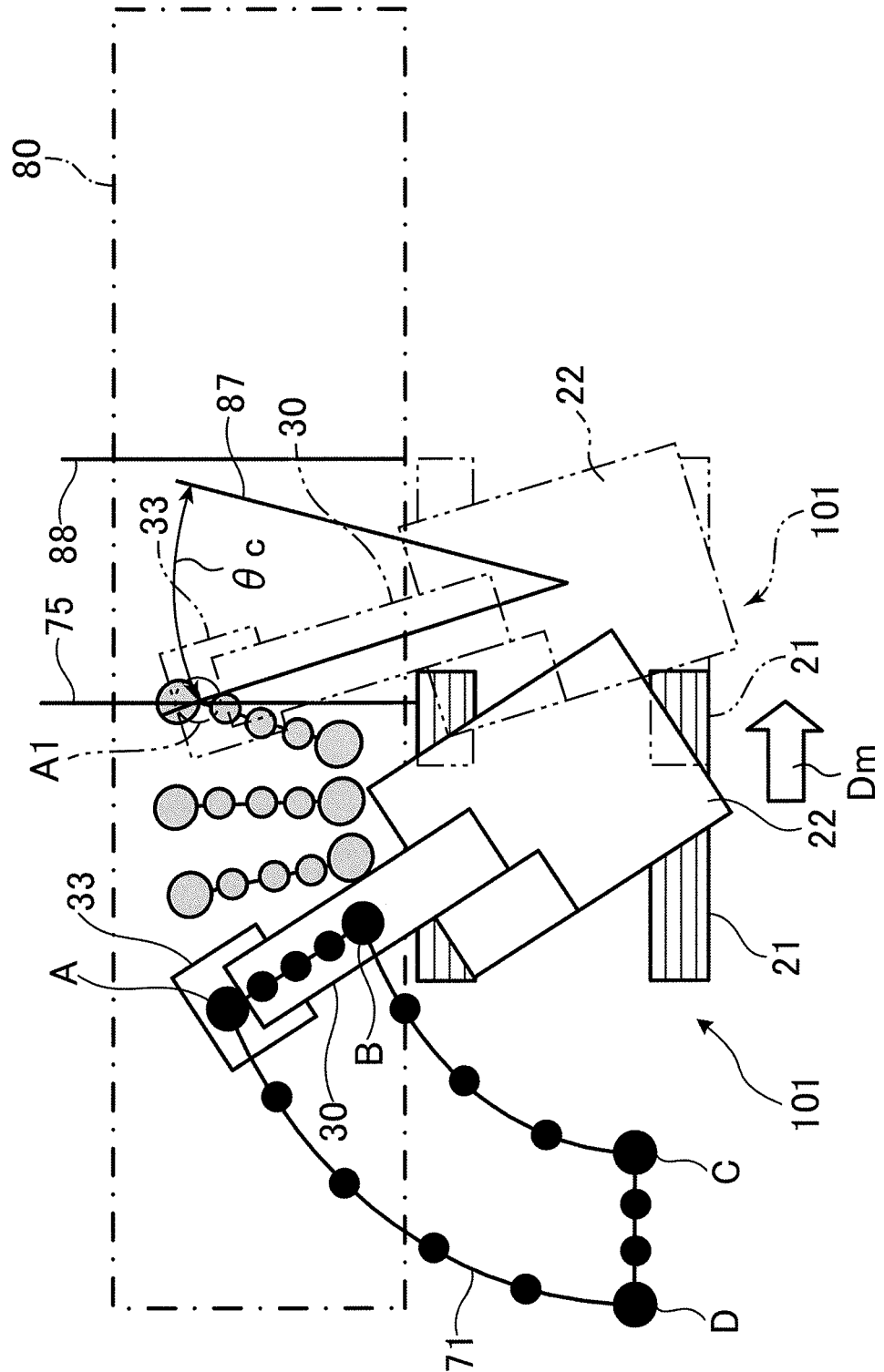
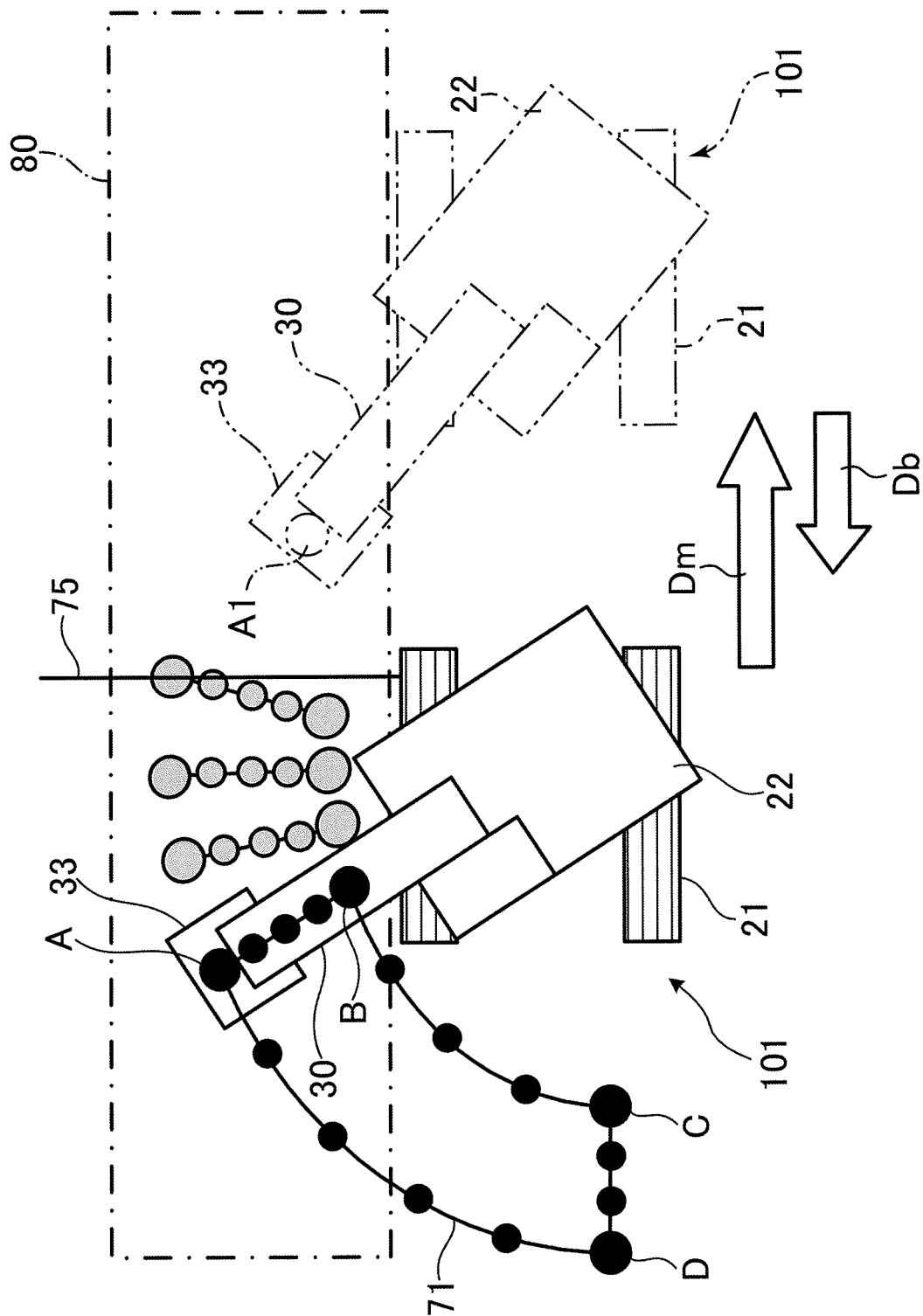


FIG. 14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/034606

A. CLASSIFICATION OF SUBJECT MATTER

E02F 3/43(2006.01)i; **E02F 9/20**(2006.01)i; **E02F 9/22**(2006.01)i; **E02F 9/26**(2006.01)i
FI: E02F9/20 C; E02F9/20 M; E02F9/26 B; E02F9/22 A; E02F3/43 C

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; E02F9/22; 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.
Y	JP 2001-123479 A (HITACHI CONSTR. MACH. CO., LTD.) 08 May 2001 (2001-05-08) paragraphs [0010]-[0020], [0024]-[0042], fig. 1, 3	1-10, 12-13
A	paragraphs [0010]-[0020], [0024]-[0042], fig. 1, 3	11
Y	JP 2002-294735 A (KUMANO TAKESHI KENSETSU KK) 09 October 2002 (2002-10-09) paragraphs [0043]-[0044], fig. 5	1-10, 12-13
A	paragraphs [0043]-[0044], fig. 5	11
Y	JP 3364419 B2 (SHIN CATERPILLAR MITSUBISHI LTD.) 08 January 2003 (2003-01-08) paragraphs [0151], [0156]-[0158], fig. 17	13
A	paragraphs [0151], [0156]-[0158], fig. 17	11

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

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

Date of the actual completion of the international search

29 September 2022

Date of mailing of the international search report

11 October 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.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2022/034606

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2001-123479 A	08 May 2001	(Family: none)	
JP 2002-294735 A	09 October 2002	(Family: none)	
JP 3364419 B2	08 January 2003	US 6778097 B1 column 31, line 66 to column 32, line 7, column 32, line 54 to column 33, line 28, fig. 17 WO 99/22079 A1 EP 0976879 A1 CA 2390363 A1	

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 2001123479 A [0004]