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Karashima et al.

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(45) **Date of Patent: Aug. 12, 2025**

(54) **CONTROLLER, BOOM DEVICE, AND TRUCK CRANE**

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B66C 13/46 (2006.01)
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CPC ***B66C 13/48*** (2013.01); ***B66C 13/46*** (2013.01); ***B66C 23/42*** (2013.01); ***B66C 23/88*** (2013.01); *B66C 2700/0371* (2013.01)

(58) **Field of Classification Search**
CPC B66C 13/46; B66C 13/48; B66C 23/42; B66C 23/88; B66C 23/585; B66C 2700/0371
See application file for complete search history.

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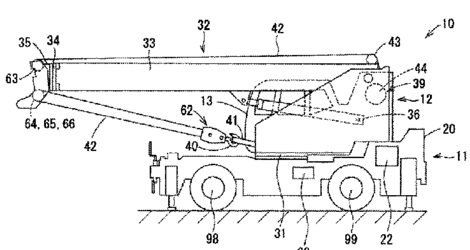
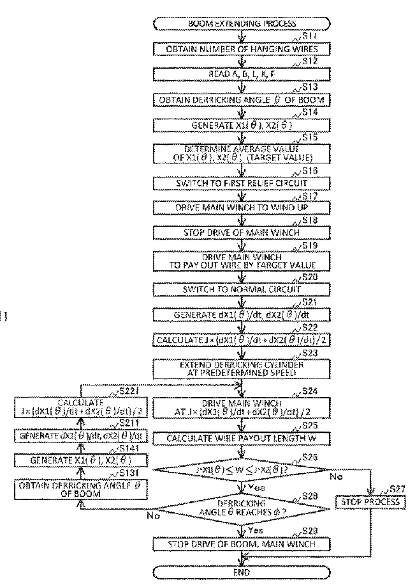
(57) **ABSTRACT**

A controller calculates a theoretical payout length X1(θ) of a wire in a posture in which a hook block is raised, a theoretical payout length X2(θ) of the wire in a posture in which the hook block is lying, dX1(θ)/dt, and dX2(θ)/dt, using a length L of the boom, A and B (first specified values) indicating coordinates of a hook hardware, a length K (second specified value) being a sum of a length of the hook block and a length of a hook hardware, and a derricking angle θ of the boom. The controller makes the boom stand and lie at a constant speed of F=dθ/dt, and makes a winch drive at a wind-up speed of J×{dX1(θ)/dt+dX2(θ)/dt}/2 taking J×{X1(θ)+X2(θ)}/2 as a target value.

9 Claims, 16 Drawing Sheets





(51) **Int. Cl.**

B66C 13/48	(2006.01)
B66C 23/42	(2006.01)
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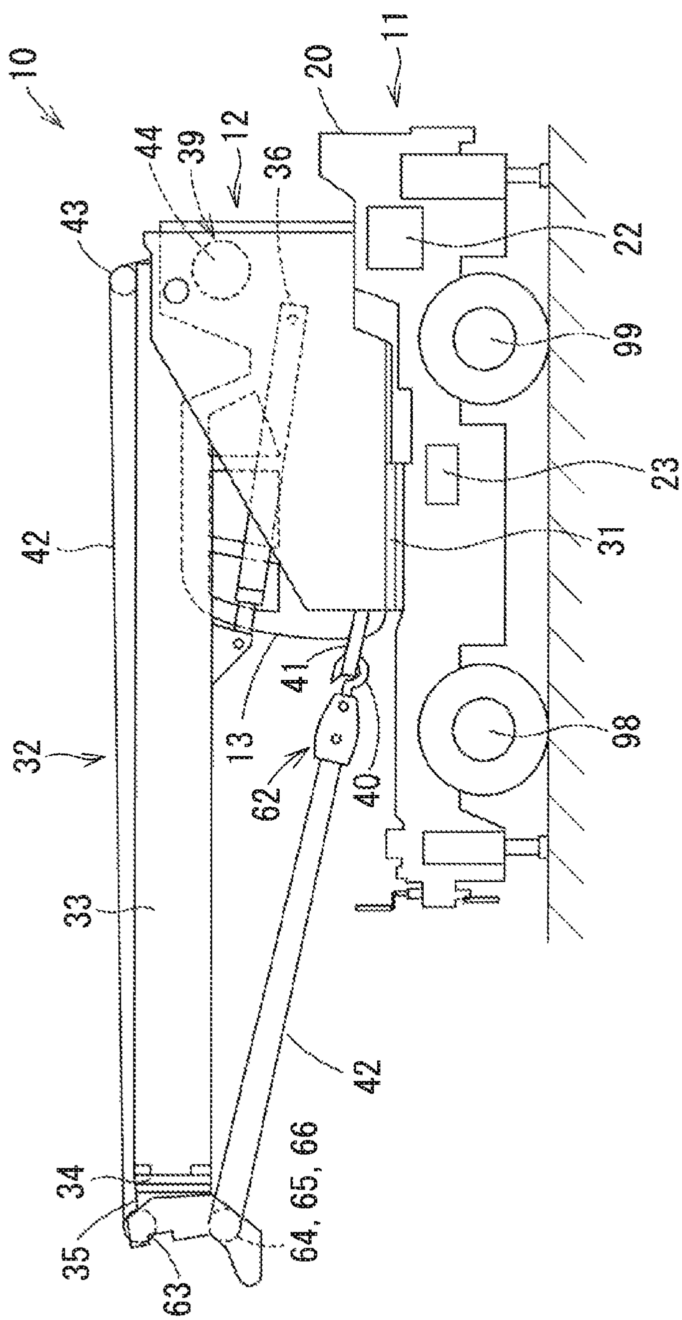
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FIG. 1

FIG. 2

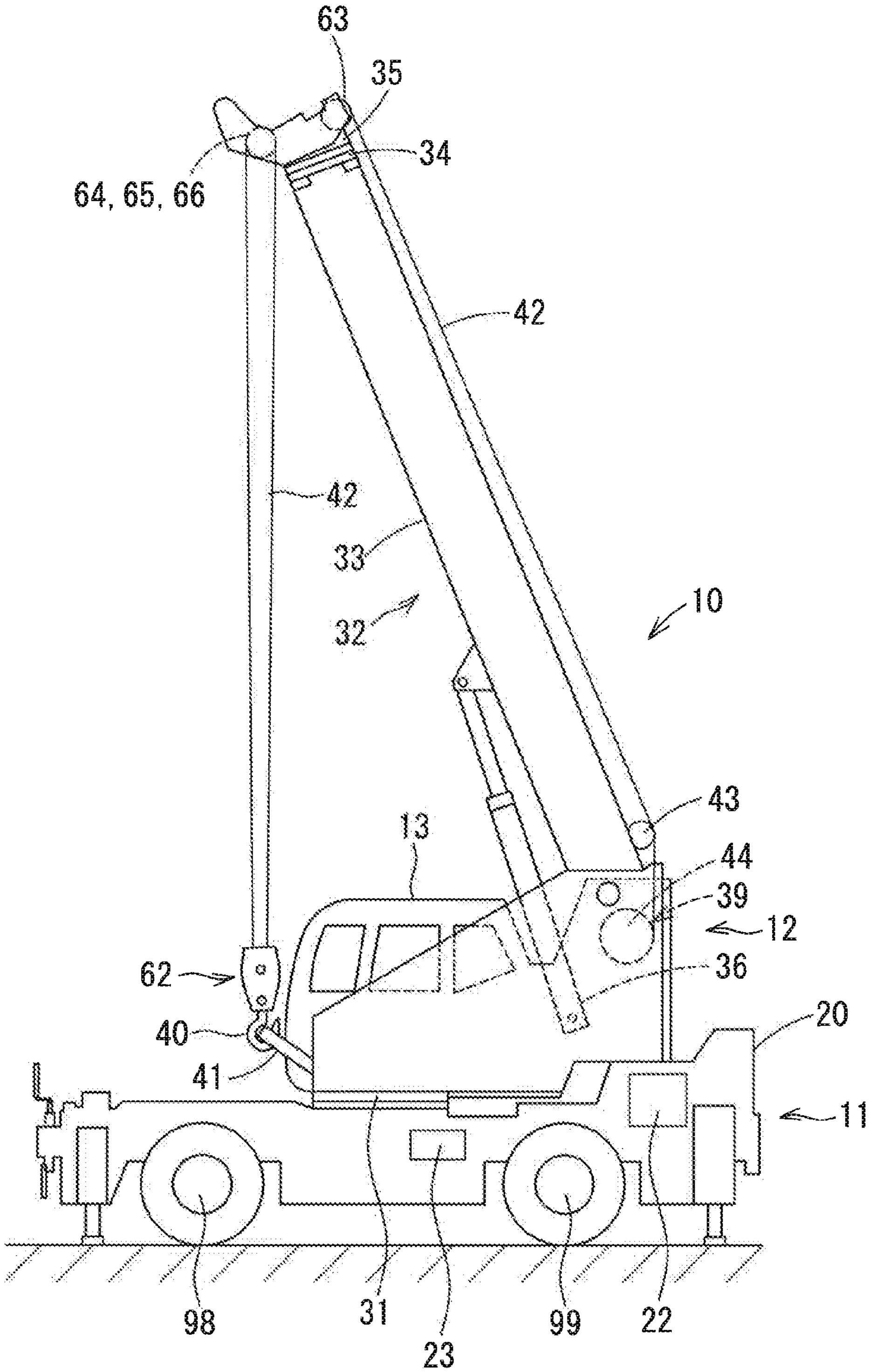
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FIG. 3

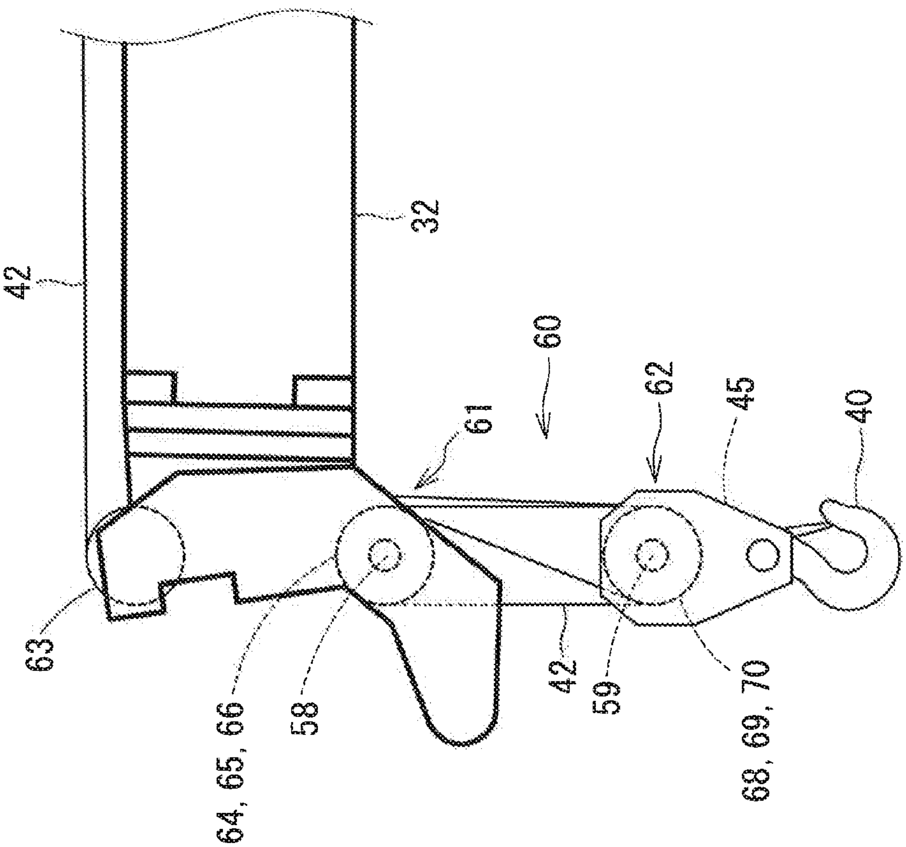


FIG. 4

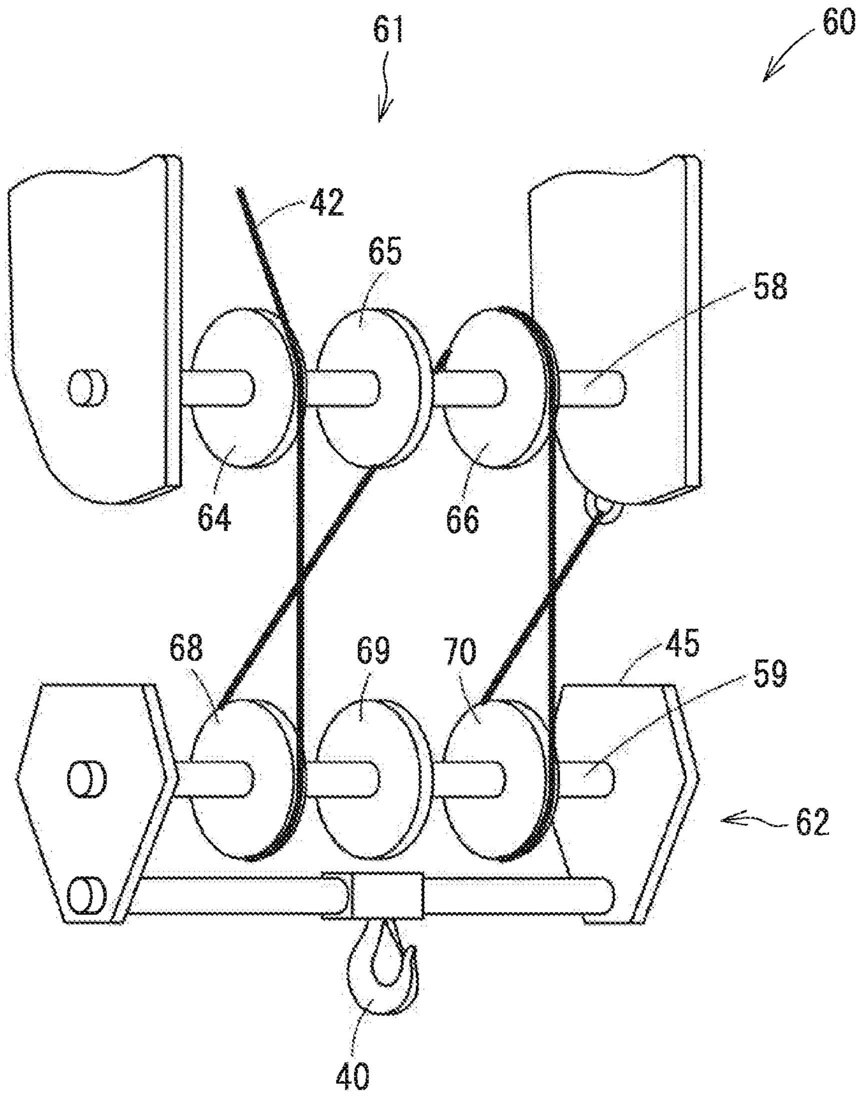


FIG 5

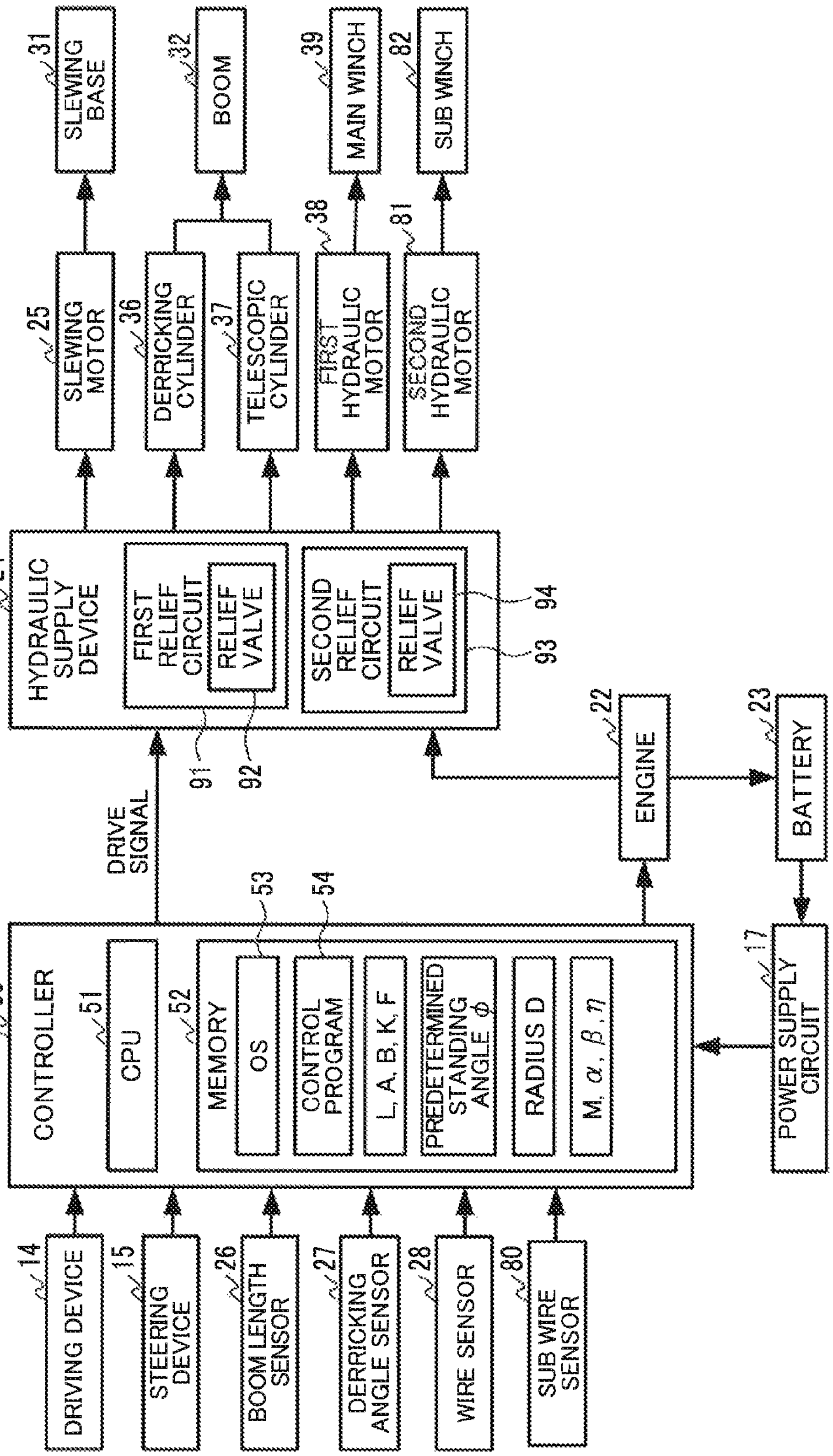

DRIVING DEVICE 14
STEERING DEVICE 15
BOOM LENGTH SENSOR 26
DERRICKING ANGLE SENSOR 27
WIRE SENSOR 28
SUB WIRE SENSOR 80
CONTROLLER 50
CPU 51
MEMORY 52
OS 53
CONTROL PROGRAM 54
L, A, B, K, F
PREDETERMINED STANDING ANGLE ϕ
RADIUS D
M, α, β, η
POWER SUPPLY CIRCUIT 17
DRIVE SIGNAL
ENGINE 22
BATTERY 23
HYDRAULIC SUPPLY DEVICE 24
FIRST RELIEF CIRCUIT
RELIEF VALVE
SECOND RELIEF CIRCUIT
RELIEF VALVE
91
92
93
94
SLEWING MOTOR 25
DERRICKING CYLINDER 36
TELESCOPIC CYLINDER 37
FIRST HYDRAULIC MOTOR 38
SECOND HYDRAULIC MOTOR 81
SLEWING BASE 31
BOOM 32
MAIN WINCH 39
SUB WINCH 82

FIG. 6

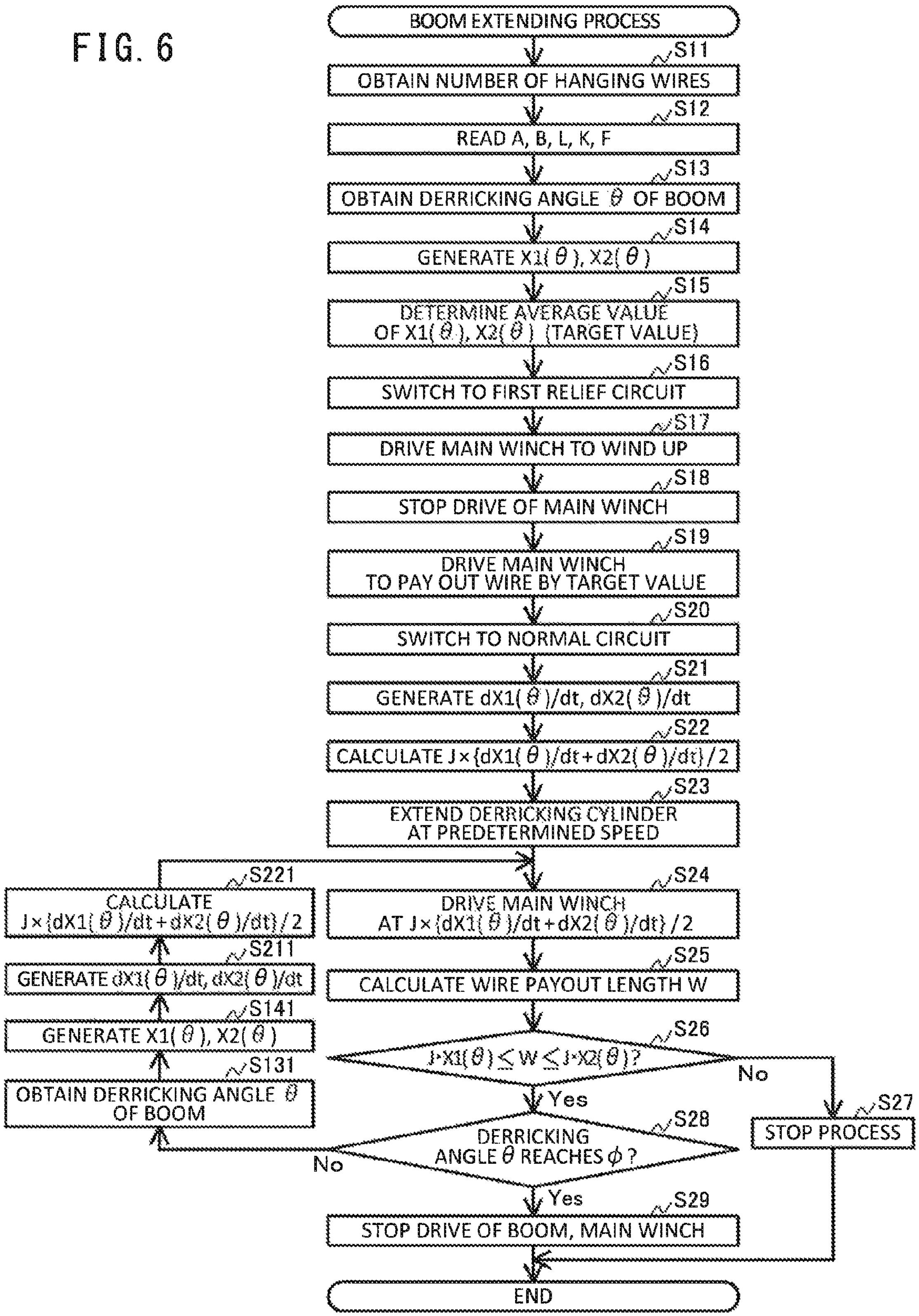

BOOM EXTENDING PROCESS
S11
OBTAIN NUMBER OF HANGING WIRES
S12
READ A, B, L, K, F
S13
OBTAIN DERRICKING ANGLE θ OF BOOM
S14
GENERATE X1(θ), X2(θ)
S15
DETERMINE AVERAGE VALUE OF X1(θ), X2(θ) (TARGET VALUE)
S16
SWITCH TO FIRST RELIEF CIRCUIT
S17
DRIVE MAIN WINCH TO WIND UP
S18
STOP DRIVE OF MAIN WINCH
S19
DRIVE MAIN WINCH TO PAY OUT WIRE BY TARGET VALUE
S20
SWITCH TO NORMAL CIRCUIT
S21
GENERATE dX1(θ)/dt, dX2(θ)/dt
S22
CALCULATE J×{dX1(θ)/dt+dX2(θ)/dt}/2
S23
EXTEND DERRICKING CYLINDER AT PREDETERMINED SPEED
S221
CALCULATE J×{dX1(θ)/dt+dX2(θ)/dt}/2
S24
DRIVE MAIN WINCH AT J×{dX1(θ)/dt+dX2(θ)/dt}/2
S211
GENERATE dX1(θ)/dt, dX2(θ)/dt
S25
CALCULATE WIRE PAYOUT LENGTH W
S141
GENERATE X1(θ), X2(θ)
S26
J·X1(θ) ≤ W ≤ J·X2(θ)?
No
S131
OBTAIN DERRICKING ANGLE θ OF BOOM
Yes
S27
STOP PROCESS
S28
DERRICKING ANGLE θ REACHES φ?
No
Yes
S29
STOP DRIVE OF BOOM, MAIN WINCH
END

FIG. 7

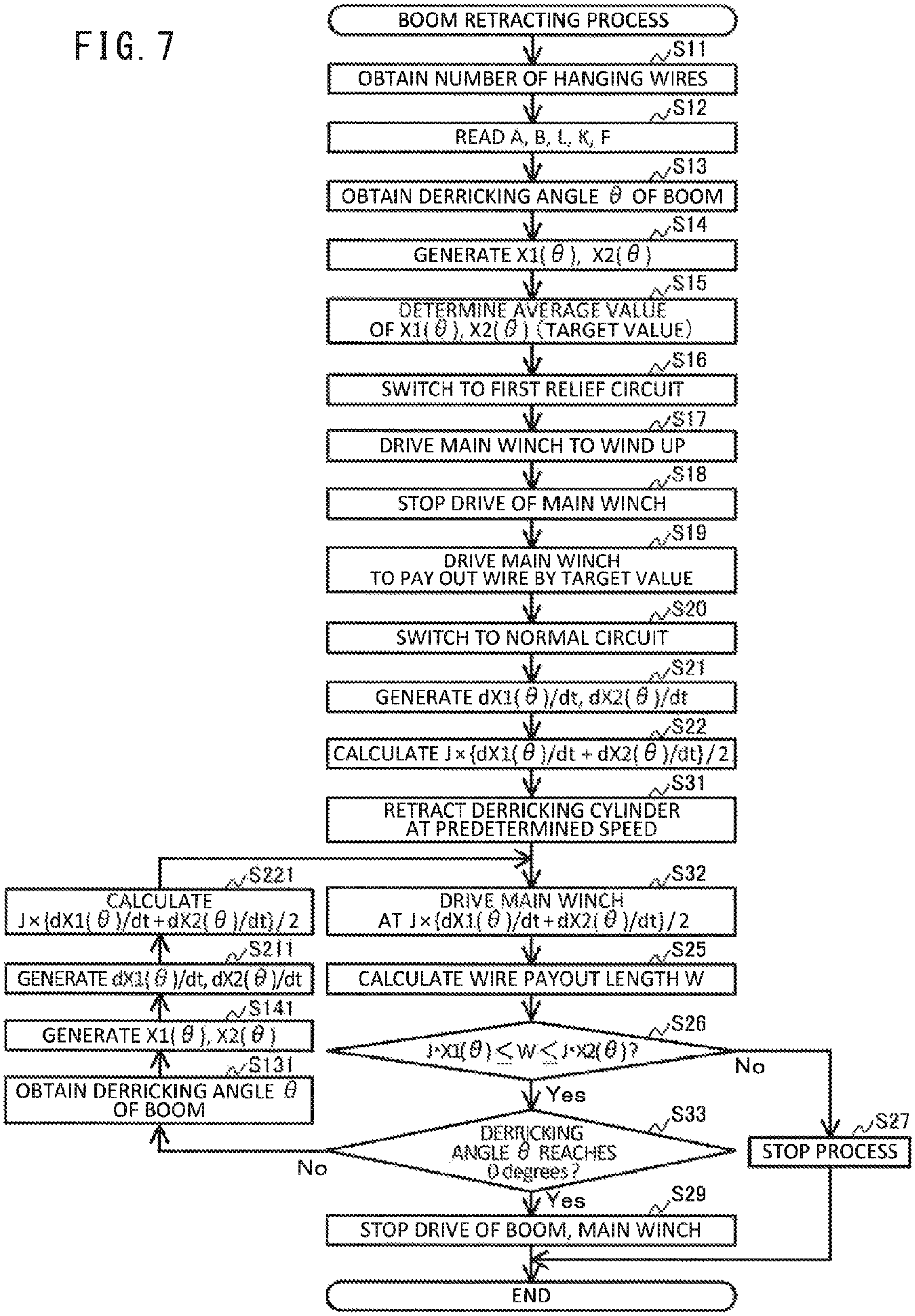
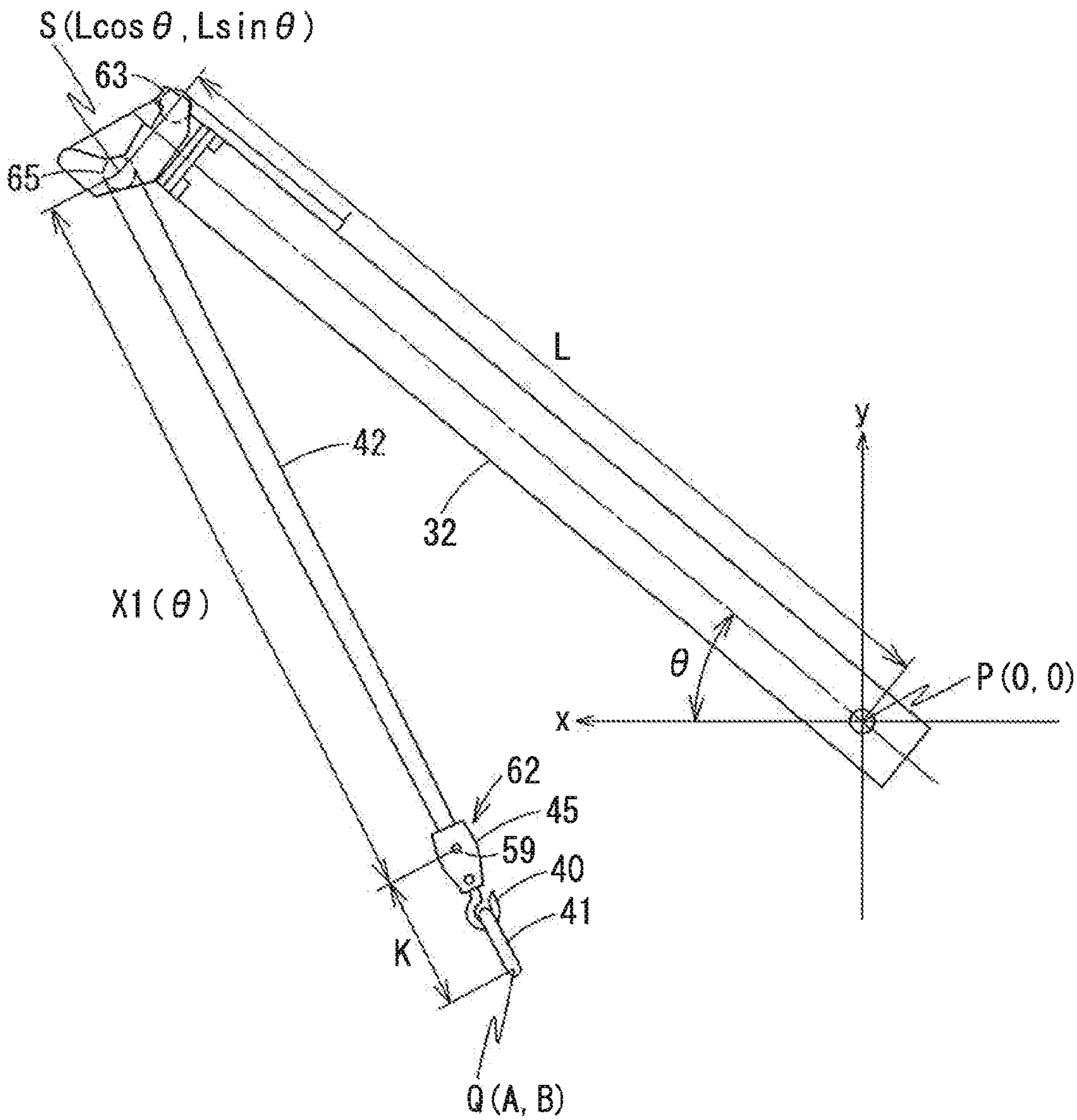

BOOM RETRACTING PROCESS
S11
OBTAIN NUMBER OF HANGING WIRES
S12
READ A, B, L, K, F
S13
OBTAIN DERRICKING ANGLE θ OF BOOM
S14
GENERATE X1(θ), X2(θ)
S15
DETERMINE AVERAGE VALUE OF X1(θ), X2(θ) (TARGET VALUE)
S16
SWITCH TO FIRST RELIEF CIRCUIT
S17
DRIVE MAIN WINCH TO WIND UP
S18
STOP DRIVE OF MAIN WINCH
S19
DRIVE MAIN WINCH TO PAY OUT WIRE BY TARGET VALUE
S20
SWITCH TO NORMAL CIRCUIT
S21
GENERATE dX1(θ)/dt, dX2(θ)/dt
S22
CALCULATE J×{dX1(θ)/dt + dX2(θ)/dt}/2
S31
RETRACT DERRICKING CYLINDER AT PREDETERMINED SPEED
S32
DRIVE MAIN WINCH AT J×{dX1(θ)/dt+dX2(θ)/dt}/2
S25
CALCULATE WIRE PAYOUT LENGTH W
S26
J·X1(θ)≤W≤J·X2(θ)?
No
Yes
S33
DERRICKING ANGLE θ REACHES 0 degrees?
No
Yes
S27
STOP PROCESS
S29
STOP DRIVE OF BOOM, MAIN WINCH
END
S221
CALCULATE J×{dX1(θ)/dt+dX2(θ)/dt}/2
S211
GENERATE dX1(θ)/dt, dX2(θ)/dt
S141
GENERATE X1(θ), X2(θ)
S131
OBTAIN DERRICKING ANGLE θ OF BOOM

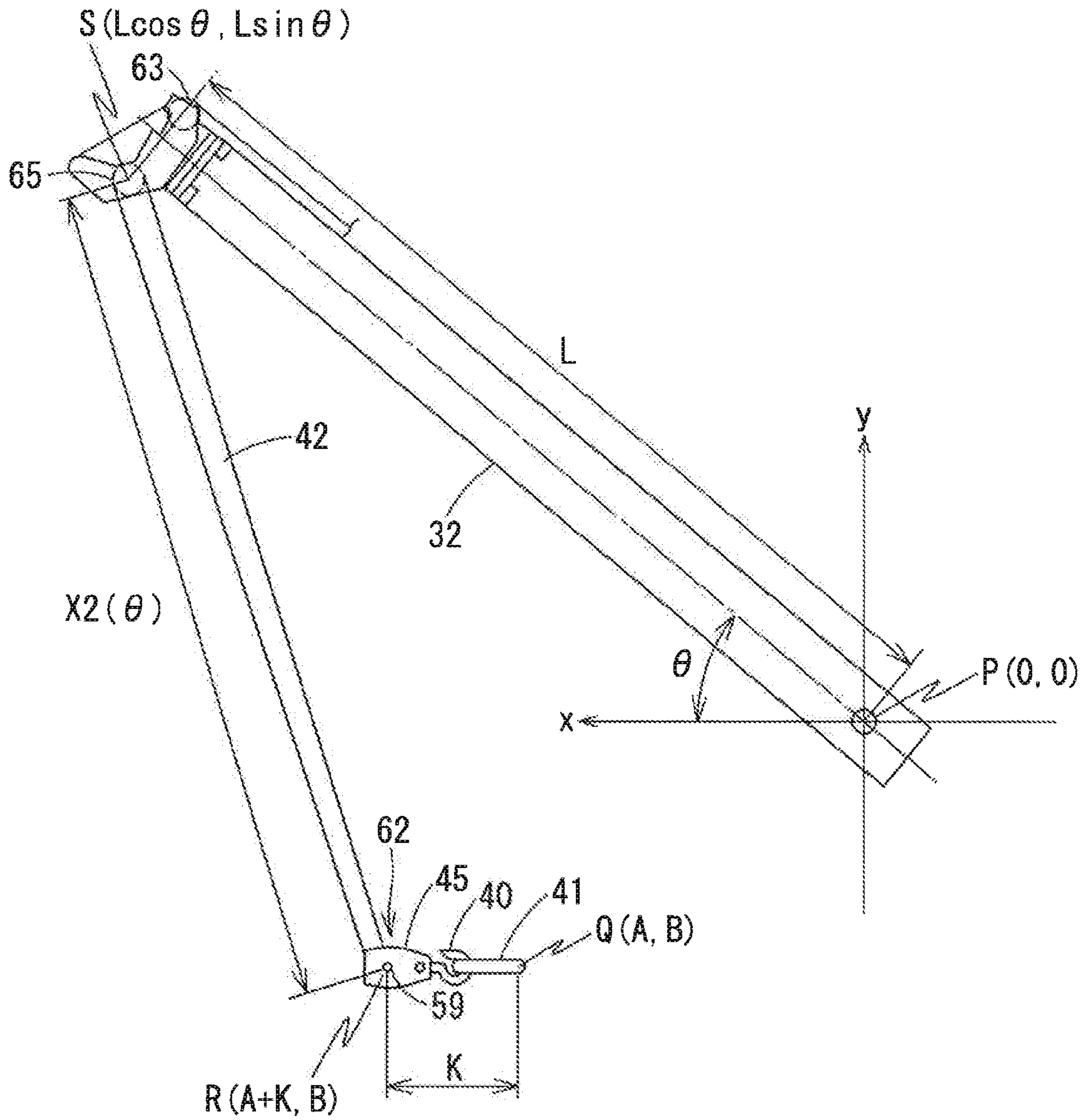
FIG. 8



$$\text{FUNCTION } X1(\theta) = \overline{SQ} - K$$
$$= \sqrt{(L\cos\theta - A)^2 + (L\sin\theta - B)^2} - K$$

$$\frac{d}{dt}X1(\theta) = \frac{d\theta}{dt}\frac{d}{d\theta}X1(\theta) = F\frac{d}{d\theta}X1(\theta)$$

FIG. 9



$$\text{FUNCTION } X2(\theta) = \overline{SR}$$
$$= \sqrt{(L\cos\theta - A - K)^2 + (L\sin\theta - B)^2}$$

$$\frac{d}{dt}X2(\theta) = \frac{d\theta}{dt}\frac{d}{d\theta}X2(\theta) = F\frac{d}{d\theta}X2(\theta)$$

FIG. 10

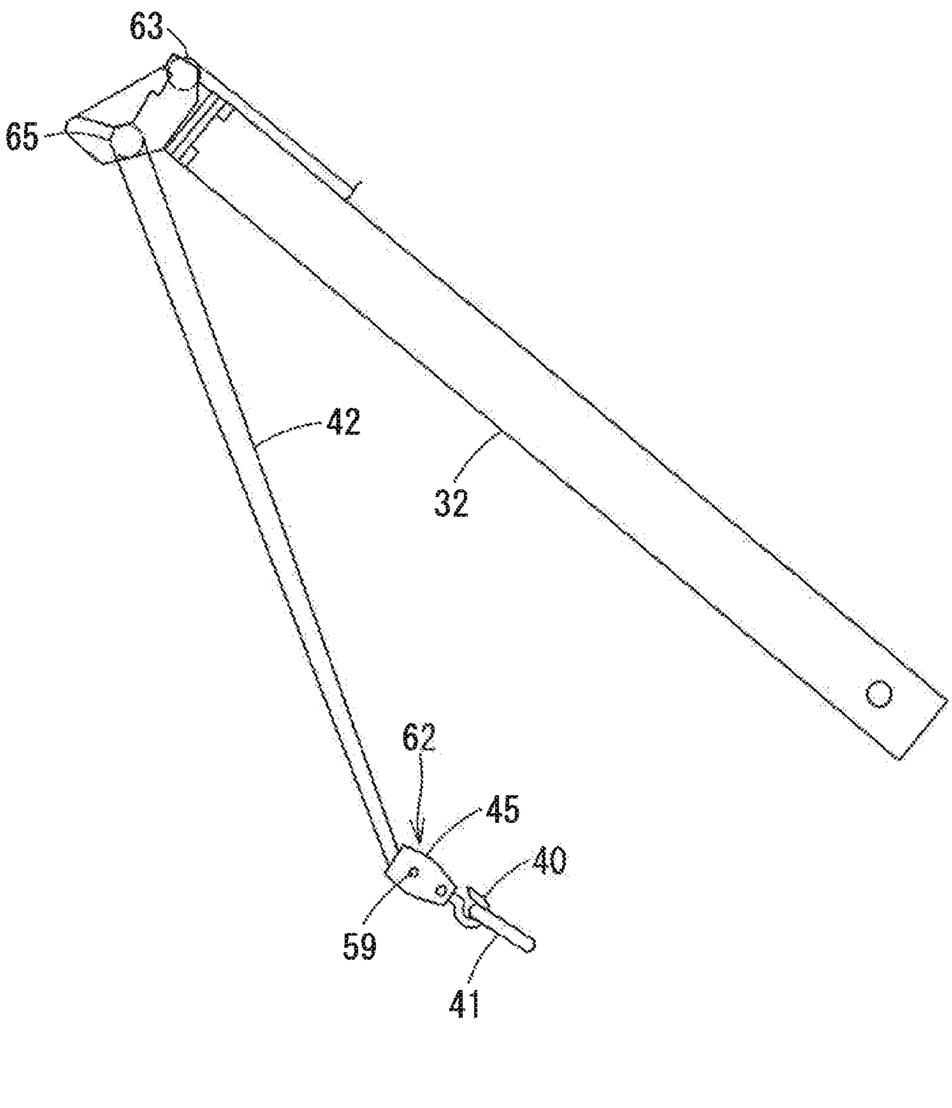
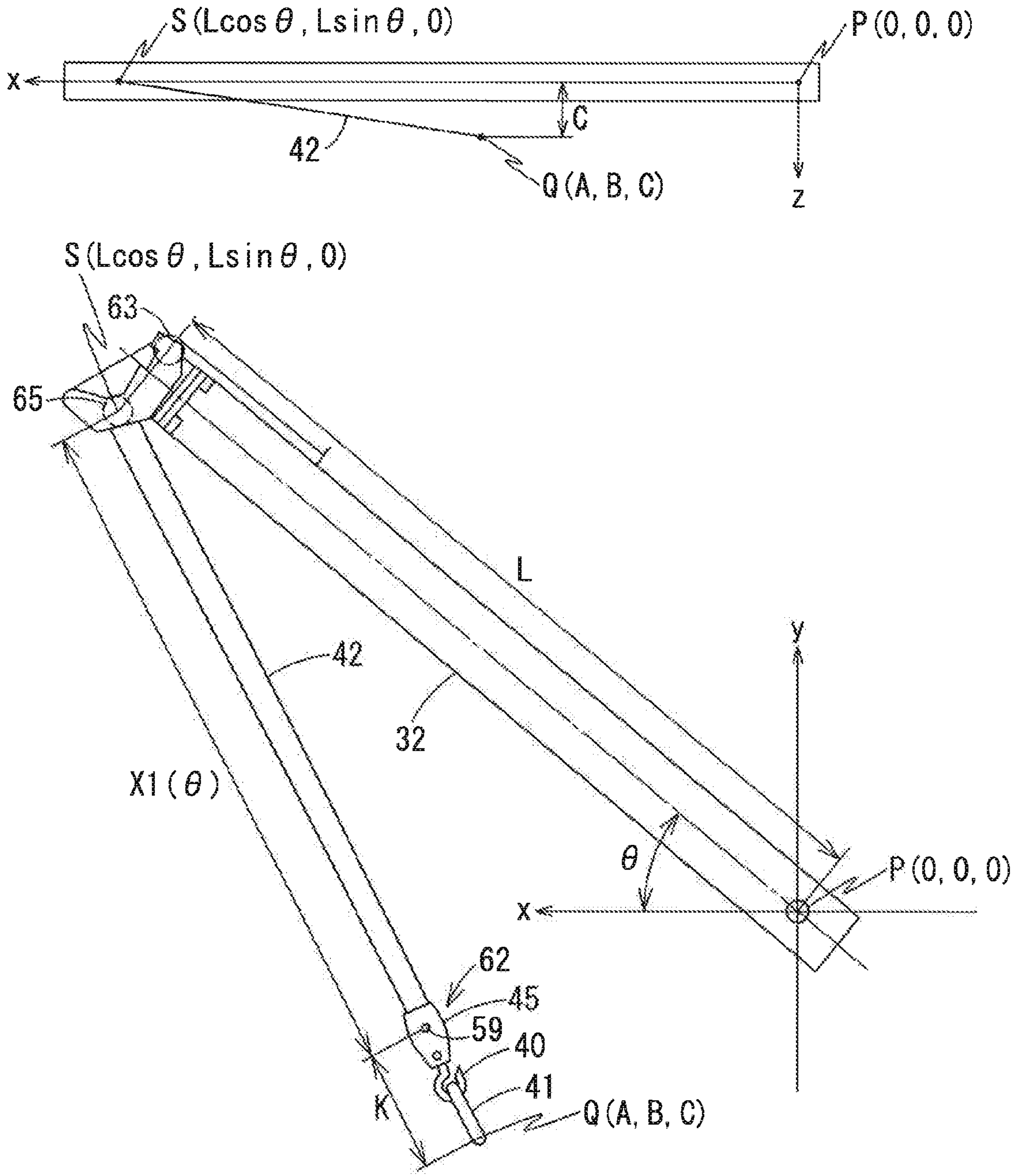


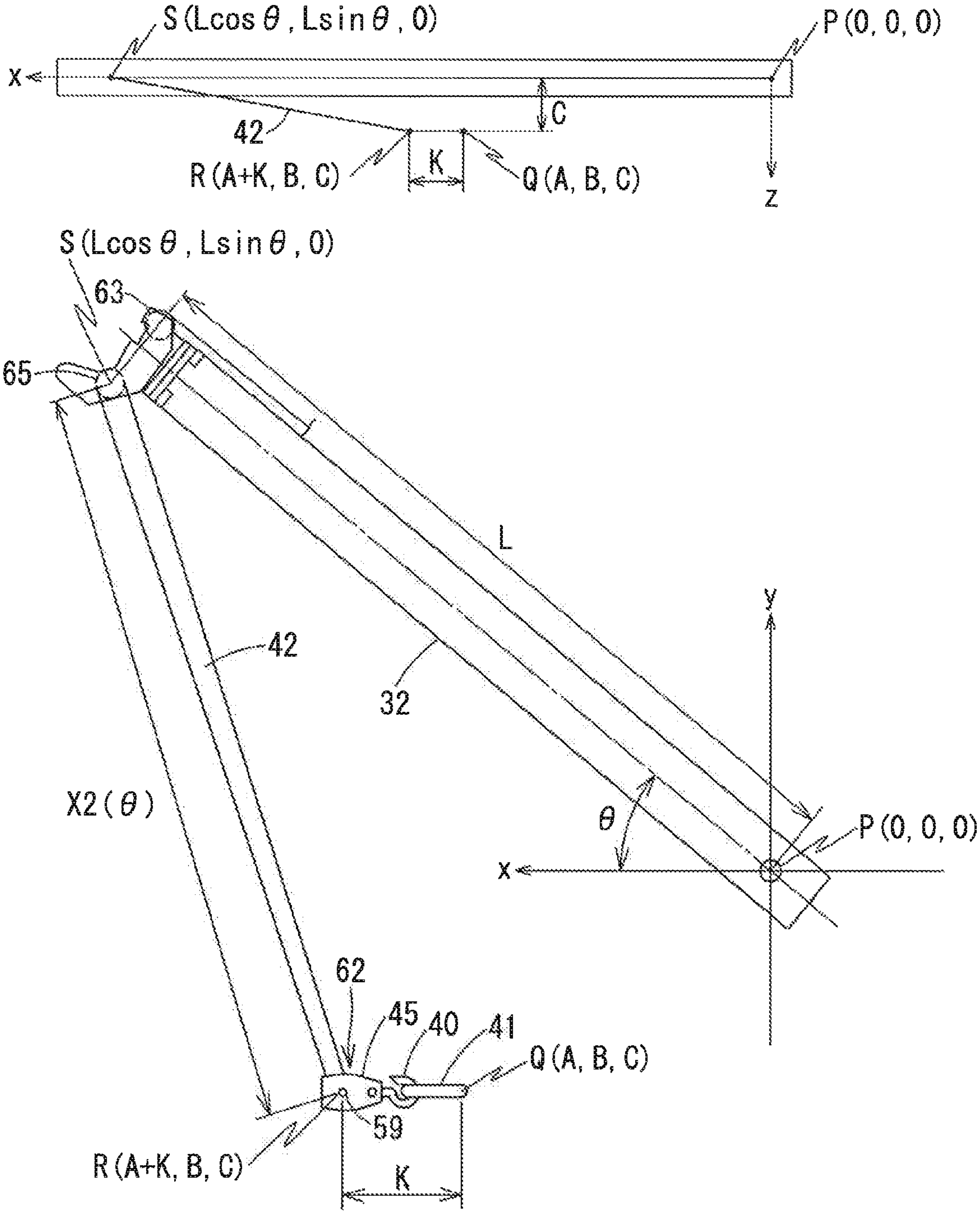
FIG. 11



$$\text{FUNCTION } X1(\theta) = \overline{SQ} - K$$
$$= \sqrt{(L\cos\theta - A)^2 + (L\sin\theta - B)^2 + C^2} - K$$

$$\frac{d}{dt}X1(\theta) = \frac{d\theta}{dt}\frac{d}{d\theta}X1(\theta) = F\frac{d}{d\theta}X1(\theta)$$

FIG. 12

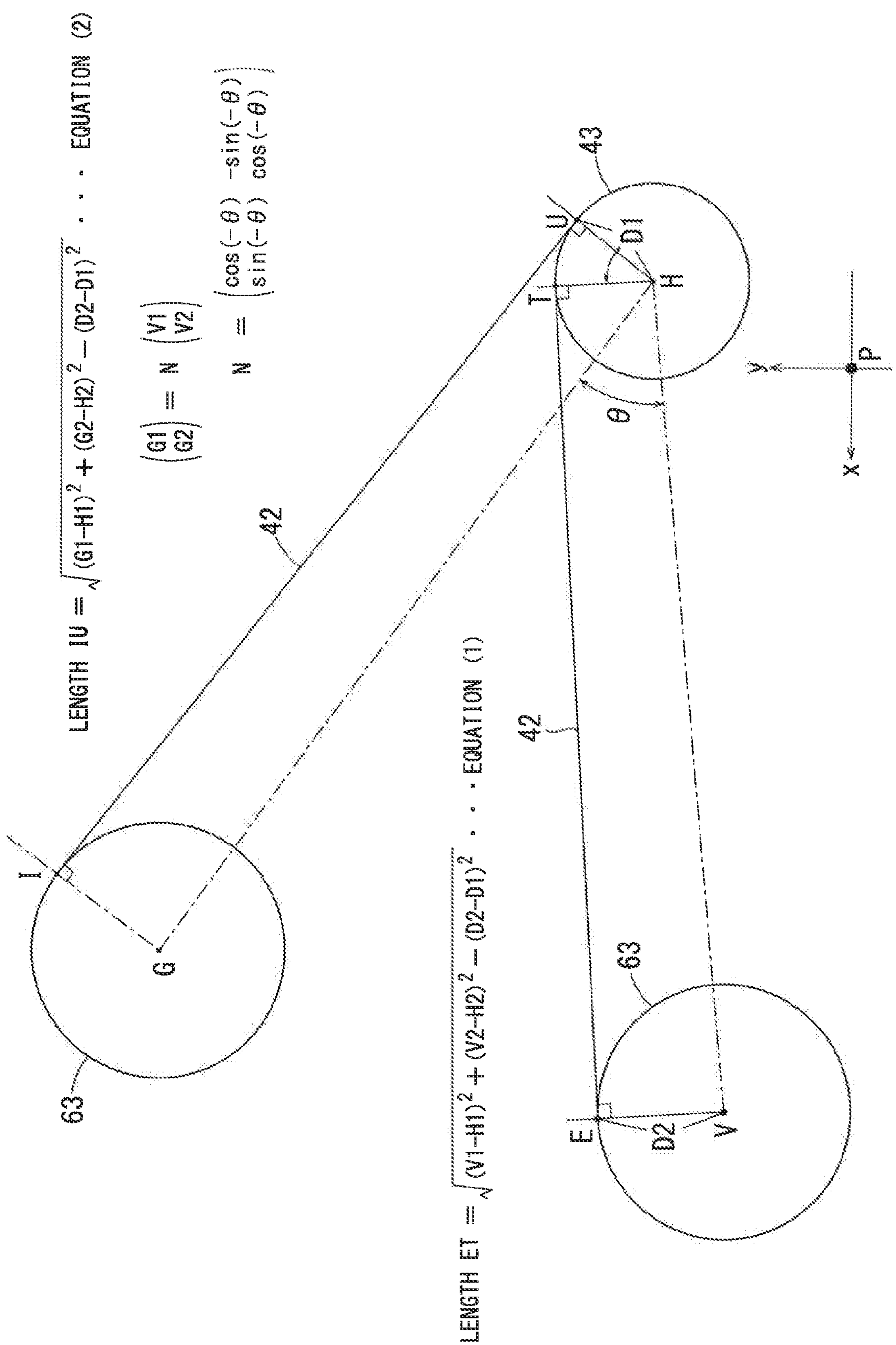


$$\text{FUNCTION } X2(\theta) = \overline{SR}$$

$$= \sqrt{(L\cos\theta - A - K)^2 + (L\sin\theta - B)^2 + C^2}$$

$$\frac{d}{dt} X2(\theta) = \frac{d\theta}{dt} \frac{d}{d\theta} X2(\theta) = F \frac{d}{d\theta} X2(\theta)$$

FIG. 13



LENGTH IU $= \sqrt{(G1-H1)^2 + (G2-H2)^2 - (D2-D1)^2}$ . . . EQUATION (2)
$\begin{pmatrix} G1 \\ G2 \end{pmatrix} = N \begin{pmatrix} V1 \\ V2 \end{pmatrix}$
$N = \begin{pmatrix} \cos(-\theta) & -\sin(-\theta) \\ \sin(-\theta) & \cos(-\theta) \end{pmatrix}$
LENGTH ET $= \sqrt{(V1-H1)^2 + (V2-H2)^2 - (D2-D1)^2}$ . . . EQUATION (1)
43
U
D1
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T
θ
P
Y
X
42
42
I
G
63
63
E
D2
V

FIG. 14

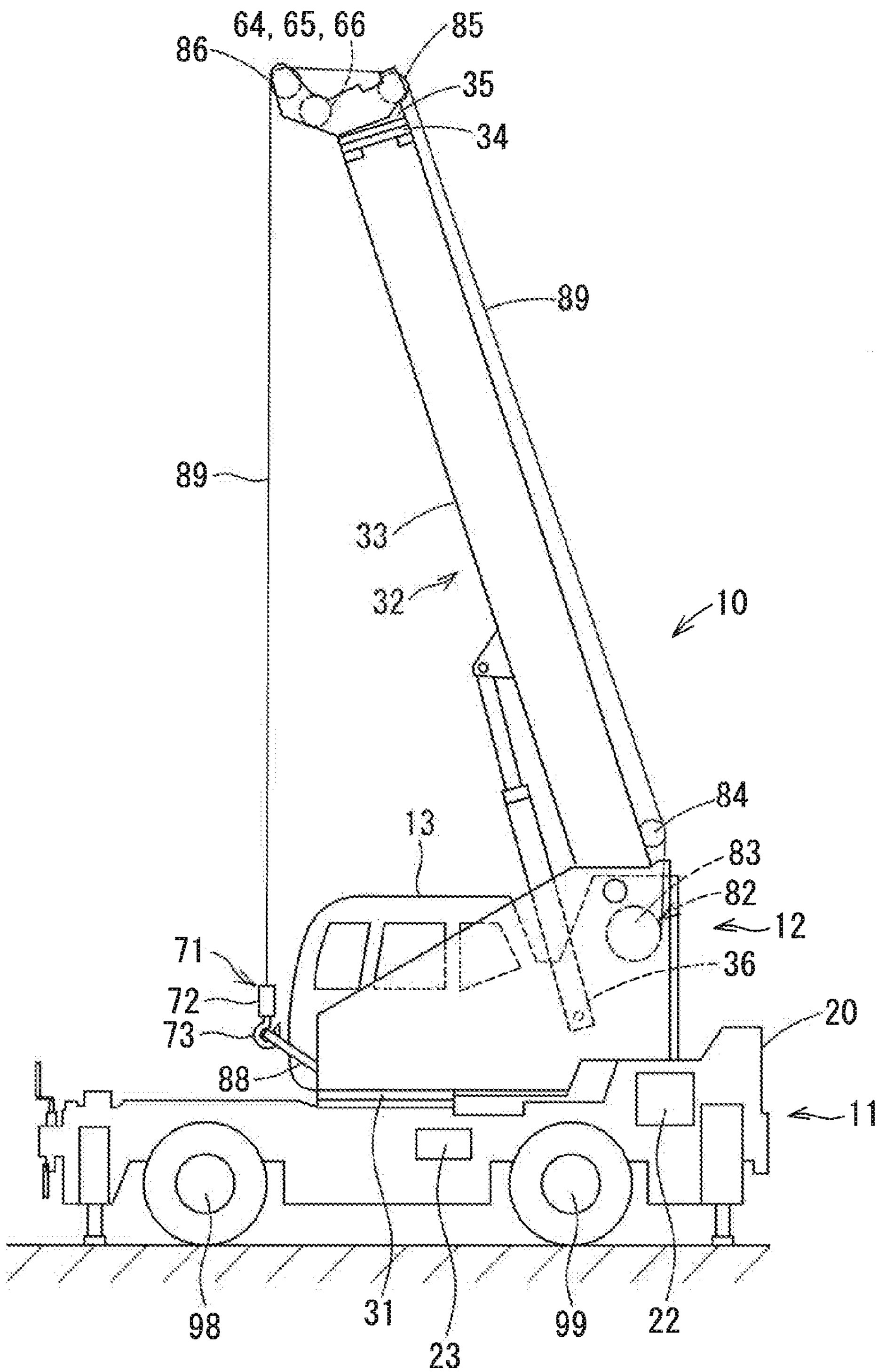
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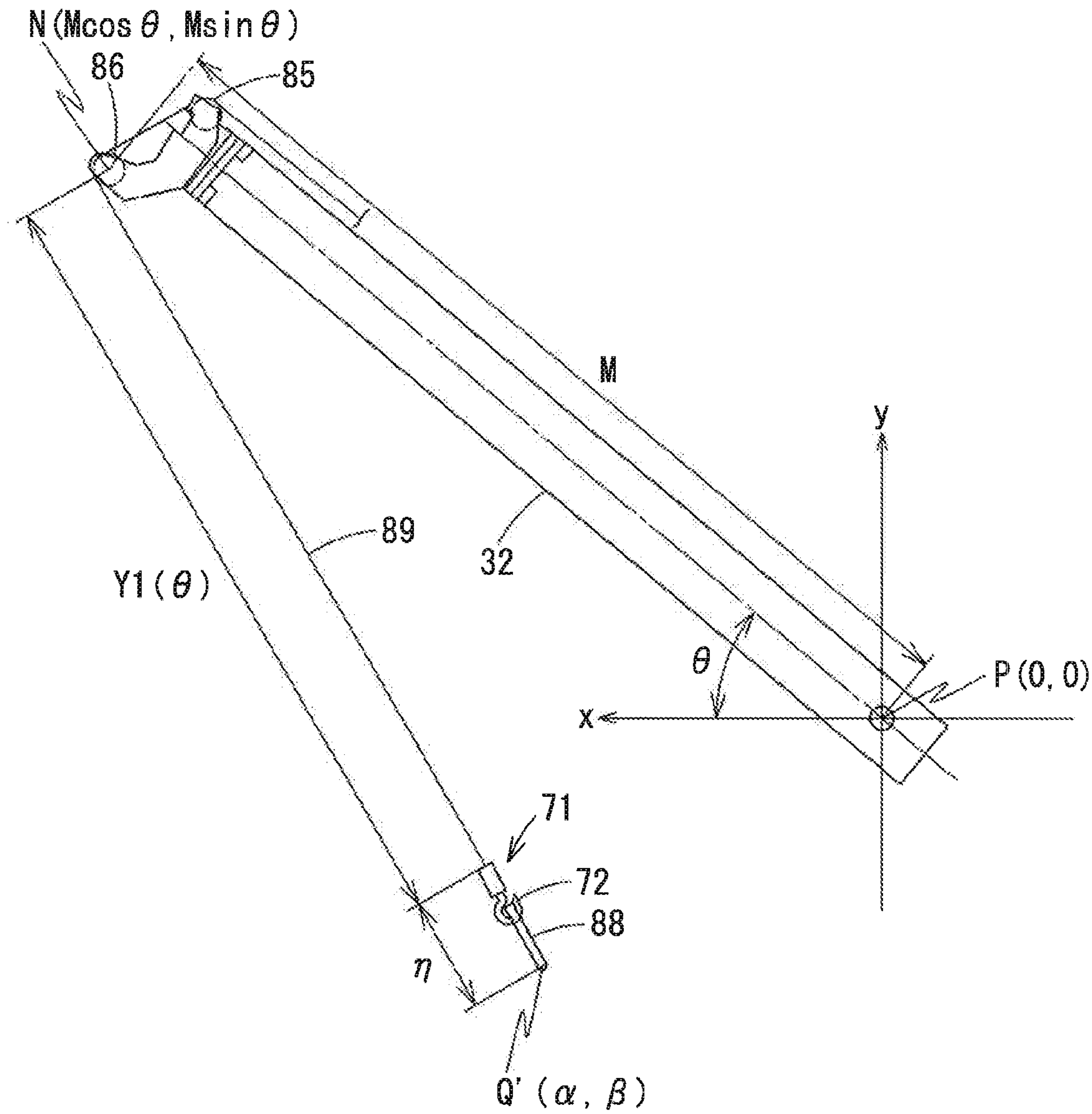
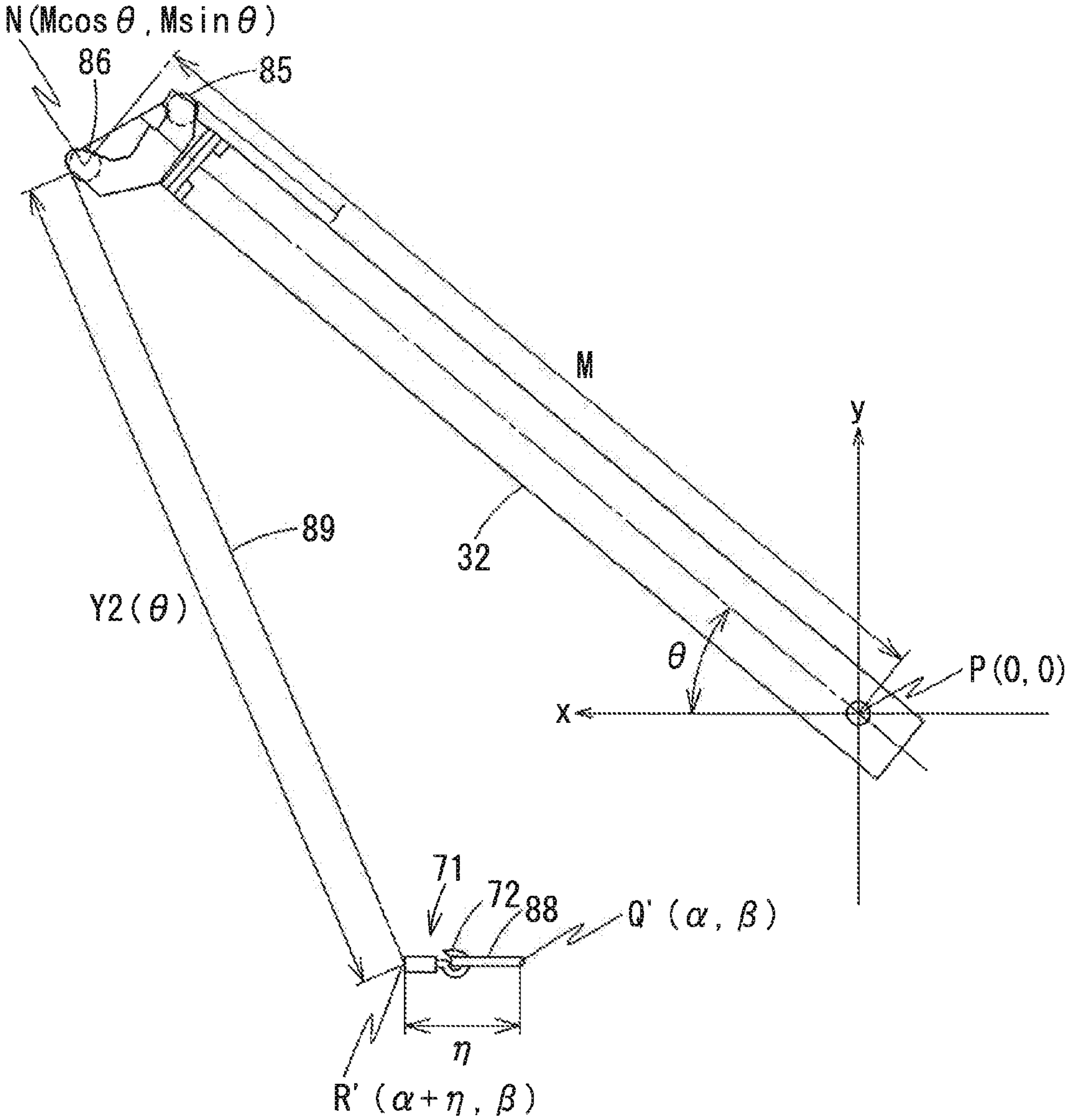
FIG. 15



$$\text{FUNCTION } Y1(\theta) = \overline{NQ'} - \eta$$
$$= \sqrt{(M\cos\theta - \alpha)^2 + (M\sin\theta - \beta)^2} - \eta$$

$$\frac{d}{dt}Y1(\theta) = \frac{d\theta}{dt}\frac{d}{d\theta}Y1(\theta) = F\frac{d}{d\theta}Y1(\theta)$$

FIG. 16



$$\text{FUNCTION } Y2(\theta) = \overline{NR'}$$

$$= \sqrt{(M\cos\theta - \alpha - \eta)^2 + (M\sin\theta - \beta)^2}$$

$$\frac{d}{dt} Y2(\theta) = \frac{d\theta}{dt}\frac{d}{d\theta} Y2(\theta) = F\frac{d}{d\theta} Y2(\theta)$$

CONTROLLER, BOOM DEVICE, AND TRUCK CRANE

TECHNICAL FIELD

The present invention relates to a truck crane, more specifically to a boom device equipped to the truck crane and a controller that controls the boom device.

BACKGROUND ART

A truck crane is generally equipped with a boom device (see Japanese Patent Application Laid-Open No. Hei 7-172775). A boom device disclosed in Japanese Patent Application Laid-Open No. Hei 7-172775 includes a boom capable of extending and retracting, a boom drive unit, a winch having a wire drum around which a wire is wound, a winch drive unit, a load hanging hook provided to a tip end of the wire, and a hook fixing ring. The boom is supported by a slewing base so as to be capable of standing and lying. The boom drive unit makes the boom extend, retract, stand, and lie. The wire is pulled out from the wire drum and wound around a tip end of the boom, and an end portion of the wire is provided with the load hanging hook. The winch drive unit drives the winch, and the wire is wound up by the wire drum or paid out from the wire drum. The hook fixing ring is provided to the slewing base, and the load hanging hook is hung on and fixed to the hook fixing ring when the crane is traveling (not working).

The boom device disclosed in Japanese Patent Application Laid-Open No. Hei 7-172775 includes a control device. The control device controls the boom drive unit and the winch drive unit in order to safely perform a boom retracting work at the end of a work and a boom extending work at the start of the work. For example, at the boom retracting work, a worker makes the boom retract and stand, and hangs the load hanging hook on the hook fixing ring. Next, the worker operates the boom drive device to make the boom lie. At this time, the control device controls the boom drive unit and the winch drive unit so that the wire is wound up according to lying of the boom in order to prevent slack of the wire.

Specifically, based on a wire length S detected by a sensor that detects the length of the wire and a derricking angle θ of the boom detected by a derricking angle sensor, the control device controls drive of the winch so that the two values have an ideal correspondence D, in other words, so that the wire is not too slack and not too tight. The ideal correspondence relationship D is determined by experiments using actual devices or simulations, and is stored in advance in a storage unit of the control device.

The above-described ideal correspondence D changes depending on a geometry configured by the length of the boom in a retracted state, a position of a tip end position (position of a portion around which the wire is wound) of the boom, a position of a derricking center of the boom, a position of the hook fixing ring, and the like. Thus, the above-described ideal correspondence D is determined for each type of the boom device, and so the control device also has to be designed for each type of the boom device.

SUMMARY OF THE INVENTION

Accordingly, a main object of the present invention is to provide a controller capable of safely and automatically extending/retracting a boom at a start and an end of crane work, irrespective of a type of a boom device.

(1) A controller according to the present invention is mounted on a boom device including a pedestal, a boom supported by the pedestal and capable of performing a derricking motion between a lying position and a predetermined standing position, a winch having a wire wound up by a wire drum and wound around a tip end portion of the boom, a hook member having a load hanging hook provided to the wire, a first actuator configured to make the boom stand and lie, a second actuator configured to drive the winch, a locking member provided to the pedestal, wherein the load hanging hook is locked to the locking member, a derricking angle sensor configured to output a detection value in accordance with a derricking angle of the boom, and a wire sensor configured to output a detection value in accordance with a payout length of the wire. The controller has a memory configured to store in advance a length of the boom, a first specified value in accordance with a position of the locking member taking a derricking center of the boom as a reference, and a second specified value in accordance with at least one of a type of the hook member and a type of the locking member, and the controller is configured to execute a generation process for generating an allowable minimum distance and an allowable maximum distance from a tip end reference position of the boom to the hook member, based on the derricking angle of the boom specified from the detection value of the derricking angle sensor, the length of the boom, the first specified value, and the second specified value, and a drive process for making the first actuator and the second actuator drive so that the payout length of the wire specified from the detection value of the wire sensor becomes a predetermined target value that is not smaller than the allowable minimum distance and not larger than the allowable maximum distance.

The payout length of the wire at which the locking member is not damaged and an irregular winding does not occur when the boom is made to stand and lie is, for example, a length at which the hook member is in a posture between a posture in which the hook member is pulled up by the wire wound up by the wire drum and a lying posture in which the hook member is not pulled up by the wire. The controller calculates the allowable minimum distance (theoretical distance when the hook member is in the pulled-up posture) and the allowable maximum distance (theoretical distance when the hook member is in the lying posture), based on the derricking angle of the boom, the length of the boom, the first specified value, and the second specified value. The controller makes the winch drive while making the boom stand and lie via the first actuator and the second actuator so that a predetermined target value that is not larger than the calculated allowable minimum distance and not smaller than the calculated allowable maximum distance is achieved. In addition, since the length of the boom, the first specified value, and the second specified value stored in the memory are values in accordance with a type of the boom, a type of the load hanging hook, and a type of the locking member, the controller can generate the allowable minimum distance and the allowable maximum distance and can set the target value, irrespective of the type of the boom, the type of the hook member, and the type of the locking member. Therefore, the boom is safely and automatically extended/retracted irrespective of the type of the boom device. Furthermore, the controller according to the present invention can be used in various boom devices.

(2) The allowable minimum distance may be a distance from the tip end portion of the boom to the hook member in a posture in which the wire is wound up and the hook member is pulled up, and the allowable maximum distance

may be a distance from the tip end portion of the boom to the hook member in a posture in which the hook member is lying.

(3) The drive process may include a first process for making the boom stand and lie at a predetermined speed, and a second process for making the second actuator drive so that the payout length of the wire specified from the detection value of the wire sensor becomes the predetermined target value.

Since the boom stands and lies at the predetermined speed, a control target in order for the payout length of the wire to be the predetermined target value can be limited to the second actuator.

(4) The predetermined target value may be an average value of the allowable maximum distance and the allowable minimum distance.

(5) The controller may be configured to further execute a stop process for stopping the drive process, based on determining that the payout length of the wire specified from the detection value of the wire sensor is outside a range from the allowable minimum distance to the allowable maximum distance.

When the payout length of the wire specified from the detection value of the wire sensor is outside the range from the allowable minimum distance to the allowable maximum distance, drive of the first actuator and the second actuator is stopped. For example, when the payout length of the wire is outside the range from the allowable minimum distance to the allowable maximum distance due to a trouble of the second actuator, standing and lying of the boom and drive of the winch are stopped. As a result, safety in an automatic extension and an automatic retraction of the boom is improved.

(6) The controller may be configured to further execute an obtaining process for obtaining a number of hanging wires, and to determine the predetermined target value based on the number of hanging wires.

The controller determines the predetermined target value based on the obtained number of hanging wires. Therefore, the controller according to the present invention can safely perform the automatic extension and the automatic retraction of the boom, even for the boom and the hook member with respect to which the number of hanging wires can be changed.

(7) The controller may be configured to further execute a correction process for correcting the allowable minimum distance and the allowable maximum distance, based on the derricking angle specified from the detection value of the derricking angle sensor and a radius of a winch sheave stored in the memory.

When the derricking angle of the boom changes, a contact position between the winch sheave and the wire changes, and as a result, the payout length of the wire from the wire drum changes. The change amount in the payout length of the wire depends on the derricking angle of the boom and the radius of the winch sheave. The controller corrects the allowable minimum distance and the allowable maximum distance based on the derricking angle specified from the detection value of the derricking angle sensor and the radius of the winch sheave. Therefore, the controller according to the present invention can perform the automatic extension and the automatic retraction of the boom more safely.

(8) A boom device according to the present invention includes the controller, and the pedestal, the boom, the winch, the hook member, the first actuator, the second actuator, the locking member, the derricking angle sensor, and the wire sensor.

The present invention can also be understood as a boom device.

(9) A truck crane according to the present invention includes the boom device.

The present invention can also be understood as a truck crane.

The controller according to the present invention can safely and automatically extend/retract the boom at a start and an end of crane work, irrespective of the type of the boom device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a truck crane **10** according to one embodiment of the present invention.

FIG. **2** is a schematic diagram of the truck crane **10** (a boom **32** is in a predetermined standing posture).

FIG. **3** is a diagram schematically showing a pulley mechanism **60** of the truck crane **10**.

FIG. **4** is a diagram schematically showing a structure of the pulley mechanism **60**.

FIG. **5** is a functional block diagram of the truck crane **10**.

FIG. **6** is a flowchart of a boom extending process of the truck crane **10**.

FIG. **7** is a flowchart of a boom retracting process of the truck crane **10**.

FIG. **8** is a diagram for explaining a function X1(θ) indicating a theoretical payout length of a wire **42**.

FIG. **9** is a diagram for explaining a function X2(θ) indicating a theoretical payout length of the wire **42**.

FIG. **10** is a diagram showing a state in which a hook block **62** is in an intermediate posture.

FIG. **11** is a diagram for explaining the function X1(θ) according to a modification example 1 of the one embodiment of the present invention.

FIG. **12** is a diagram for explaining the function X2(θ) indicating a theoretical payout length of the wire **42** according to the modification example 1.

FIG. **13** is a diagram for explaining change amounts in the function X1(θ) and the function X2(θ) according to a modification example 2 of the one embodiment of the present invention.

FIG. **14** is a schematic diagram of the truck crane **10** according to a modification example 3 of the one embodiment of the present invention.

FIG. **15** is a diagram for explaining a function Y1(θ) indicating a theoretical payout length of a sub wire **89** in the modification example 3.

FIG. **16** is a diagram for explaining a function Y2(θ) indicating a theoretical payout length of the sub wire **89** in the modification example 3.

DETAILED DESCRIPTION

Hereinafter, preferred embodiments of the present invention will be described referring to the drawings appropriately. Note that it is needless to say that the present embodiment is merely one aspect of the present invention, and that aspects may be modified without changing the gist of the present invention. For example, an execution order of each process to be described later can be modified appropriately without changing the gist of the present invention. Alternatively, a part of the processes to be described later can be omitted appropriately without changing the gist of the present invention.

FIG. **1** schematically shows a truck crane **10** according to the present embodiment, showing a state in which a boom **32** is in a lying position.

The truck crane **10** mainly includes a traveling body **11**, a boom device **12** mounted on the traveling body **11**, and a cabin **13**. The traveling body **11** includes a vehicle body **20**, and an engine **22** and a battery **23** mounted on the vehicle body **20**. The engine **22** rotationally drives axles **98**, **99** via a transmission and the like (not shown). The engine **22** drives a hydraulic pump (not shown) included in a hydraulic supply device **24** (see FIG. **5**), and the hydraulic supply device **24** generates hydraulic pressure for driving the boom device **12**, and the like.

The cabin **13** is mounted on a slewing base **31** of the boom device **12**. The cabin **13** has a driving device **14** (see FIG. **5**) for driving the truck crane **10** and a steering device **15** (see FIG. **5**) for steering the boom device **12**. In other words, the truck crane **10** is a so-called rough-terrain crane, and driving of the truck crane **10** and steering of the boom device **12** are performed in the one cabin **13**. However, the truck crane **10** may be a so-called all-terrain crane.

The steering device **15** shown in FIG. **5** has operation levers, operation buttons, and the like for operating the boom device **12**. The steering device **15** outputs operation signals indicating operation directions and operation amounts of the operation levers, and operation signals indicating whether the operation buttons are operated. The operation signals output by the steering device **15** are input to a controller **50**.

The cabin **13** has a control box (not shown). The control box includes a control board. Microcomputers, resistors, capacitors, diodes, and various ICs are mounted on the control board, and constitutes the controller **50** and a power supply circuit **17**.

As shown in FIG. **1**, the boom device **12** includes the slewing base **31**, a boom **32**, and the hydraulic supply device **24** (see FIG. **5**). The slewing base **31** is supported by the vehicle body **20** so as to be capable of slewing. The slewing base **31** corresponds to a "pedestal" recited in the claims. The boom **32** has a base end boom **33**, one or a plurality of intermediate boom(s) **34**, and a tip end boom **35**. The base end boom **33**, the intermediate boom(s) **34**, and the tip end boom **35** are arranged in a nested manner, and form a telescopic structure. The base end boom **33** is supported by the slewing base **31** so as to be capable of standing and lying, and therefore the boom **32** can slew, stand, lie, extend, and retract. The boom **32** extends and retracts between a retracted state shown in FIG. **1** and an extended state (not shown), and stands and lies between the lying position shown in FIG. **1** and a predetermined standing position shown in FIG. **2**. The truck crane **10** travels in a retracted state (see FIG. **1**) in which the boom **32** is in the retracted state and in the lying position.

As shown in FIG. **5**, the boom device **12** further includes a slewing motor **25**, a derricking cylinder **36** that makes the boom **32** stand and lie, and a telescopic cylinder **37** that makes the boom **32** extend and retract. The slewing motor **25** is provided to the vehicle body **20** (see FIG. **1**). The slewing motor **25** rotates, receiving supply of the hydraulic pressure from the hydraulic supply device **24**, and makes the slewing base **31** slew. The derricking cylinder **36** is provided to the slewing base **31**. The derricking cylinder **36** extends and retracts, receiving supply of the hydraulic pressure from the hydraulic supply device **24**. The derricking cylinder **36** that extends and retracts makes the boom **32** stand and lie. The derricking cylinder **36** corresponds to a "first actuator" recited in the claims. The telescopic cylinder **37** is provided to the boom **32**. The telescopic cylinder **37** extends and retracts, receiving supply of the hydraulic pressure from the hydraulic supply device **24**. The telescopic cylinder **37** that extends and retracts makes the boom **32** extend and retract.

The boom device **12** further includes a first hydraulic motor **38**, a main winch **39**, a pulley mechanism **60** (see FIG. **3**), and a hook hardware **41** (see FIG. **1**). The main winch **39** corresponds to a "winch" recited in the claims.

The main winch **39** is attached to a base end of the boom **32**. The main winch **39** has a wire drum **44**, a winch sheave **43**, and a wire **42**. The wire **42** is wound around the wire drum **44**. The winch sheave **43** is located above the base end of the boom **32** in a state in which the boom **32** is in the lying position along the horizontal direction. The wire **42** pulled out from the wire drum **44** is wound around the winch sheave **43**, and then is pulled out to the pulley mechanism **60** (see FIG. **3**).

The first hydraulic motor **38** rotates, receiving supply of the hydraulic pressure from the hydraulic supply device **24**. The first hydraulic motor **38** that rotates makes the wire drum **44** rotate. The wire drum **44** that rotates winds up the wire **42** (hoist up) or pays out the wire **42** (hoist down). The first hydraulic motor **38** corresponds to a "second actuator" recited in the claims.

As shown in FIG. **3**, the pulley mechanism **60** has a fixed sheave block **61** and a hook block **62**.

The fixed sheave block **61** has one first sheave **63** and three second sheaves **64**, **65**, **66**. The first sheave **63** is rotatably supported by a central shaft (not shown). The second sheaves **64**, **65**, **66** are supported by a central shaft **58** (see FIG. **4**). The second sheaves **64**, **65**, **66** have a disc-shape, and are rotatable around the central shaft **58**.

As shown in FIG. **1**, the first sheave **63** is located above a tip end of the boom **32** in the state in which the boom **32** is in the lying position along the horizontal position. The three second sheaves **64**, **65**, **66** are located below the tip end of the boom **32** in the lying position. As shown in FIG. **4**, the three second sheaves **64**, **65**, **66** are provided side by side in a width direction of the boom **32**. Note that although an example is shown in which the fixed sheave block **61** has the three second sheaves **64**, **65**, **66** in the present embodiment, the fixed sheave block **61** may have two second sheaves, or may have four or more second sheaves.

The hook block **62** has a frame **45**, a load hanging hook **40** attached to the frame **45**, and three third sheaves **68**, **69**, **70**. The third sheaves **68**, **69**, **70** are supported by a central shaft **59** held by the frame **45**, and are provided side by side in the horizontal direction (width direction of the boom **32**). The third sheaves **68**, **69**, **70** have a disc-shape, and are rotatable around the above-described central shaft **59**. Note that the hook block **62** may have two third sheaves, or may have four or more third sheaves. The hook block **62** corresponds to a "hook member" recited in the claims.

The wire **42** pulled out from the winch sheave **43** (see FIG. **1**) is wound around the first sheave **63**, and then is wound around the second sheave of the fixed sheave block **61** and the third sheave of the hook block **62**. In the example shown in FIG. **4**, the wire **42** is wound around the second sheave **64**, the third sheave **68**, the second sheave **66**, and the third sheave **70**. In other words, a number of hanging wires, which is the number of times the wire **42** is wound around the pulley mechanism **60**, is "4". By increasing the number of hanging wires, maximum lifting load of the boom device **12** is increased.

The hook hardware **41** shown in FIG. **1** is engaged with the load hanging hook **40**, and can fix the load hanging hook **40**. One end portion of the hook hardware **41** is rotatably supported by the slewing base **31**. The load hanging hook **40** is hung on the other end portion of the hook hardware **41**. The hook hardware **41** is located directly below the tip end of the boom **32** in a state in which the boom **32** is made to stand to the predetermined standing position and is fully retracted. The hook hardware **41** fixes the load hanging hook **40** so that the load hanging hook **40** does not move while the truck crane **10** is traveling. The hook hardware **41** corresponds to a "locking member" recited in the claims.

The hydraulic supply device **24** shown in FIG. **5** is mounted on the traveling body **11**. The hydraulic supply device **24** supplies hydraulic oil having a predetermined pressure to the slewing motor **25**, the derricking cylinder **36**, the telescopic cylinder **37**, the first hydraulic motor **38**, and other actuators (hereinafter also referred to as the slewing motor **25** and the like).

The hydraulic supply device **24** includes an electromagnetic-type flow path switching valve (not shown). The flow path switching valve operates by a drive signal input from the controller **50** to be described later. The slewing motor **25** and the like are driven by operating the flow path switching valve and changing a hydraulic supply line. In other words, the controller **50** controls drive of the slewing motor **25** and the like by outputting the drive signal.

In addition to a normal circuit (not shown) that supplies the hydraulic oil having the predetermined pressure to the first hydraulic motor **38**, the hydraulic supply device **24** includes a first relief circuit **91** that relieves the hydraulic oil in order to reduce the pressure of the supplied hydraulic oil to be smaller than the predetermined pressure. The first relief circuit **91** has a relief valve **92**. The relief valve **92** switches a flow path between the normal circuit and the first relief circuit **91** by the drive signal input from the controller **50**. In other words, the controller **50** can change the pressure of the hydraulic oil supplied to the first hydraulic motor **38** by inputting the drive signal to the relief valve **92**. The controller **50** changes the pressure of the hydraulic oil supplied to the first hydraulic motor **38** in a boom extending process (see FIG. **6**) and a boom retracting process (see FIG. **7**) to be described later.

As shown in FIG. **5**, the boom device **12** further includes a boom length sensor **26**, a derricking angle sensor **27**, and a wire sensor **28**.

The boom length sensor **26** is a sensor that outputs a detection value in accordance with a length of the boom **32**. The boom length sensor **26** may be a sensor that directly detects the length of the boom **32** or a sensor that detects an extension length of the telescopic cylinder **37**. In other words, the boom length sensor **26** may be any sensor for detecting physical quantity that changes in accordance with the length of the boom **32**.

The derricking angle sensor **27** is a sensor that outputs a detection value in accordance with a derricking angle of the boom **32**. The derricking angle sensor **27** may be a sensor that directly detects the derricking angle of the boom **32** or may be a sensor that detects an extension length of the derricking cylinder **36**. In other words, the derricking angle sensor **27** may be any sensor for detecting physical quantity that changes in accordance with the derricking angle of the boom **32**. The derricking angle sensor **27** is a tilt sensor or a horizontal sensor that is attached to the boom **32** and outputs an angle with respect to the horizontal plane, for example.

The wire sensor **28** is a rotary encoder that detects a rotation amount of the wire drum **44** (see FIGS. **1** and **2**), for example. The wire sensor **28** outputs a pulse signal having a voltage value that changes in accordance with the rotation of the wire drum **44**. The wire sensor **28** is connected to the controller **50** by a signal line such as a cable. The controller **50** calculates the rotation amount of the wire drum **44** from the number of pulses input from the wire sensor **28**, and calculates a payout length of the wire **42** based on the rotation amount of the wire drum **44** and a radius of the wire drum **44**. The radius of the wire drum **44** is stored in advance in a memory **52** to be described later. Note that any type of sensor may be used as the wire sensor **28**, as long as the controller **50** can obtain the payout length of the wire **42**.

The power supply circuit **17** is a circuit that generates power to be supplied to the controller **50** and the like. The power supply circuit **17** is a DC-DC converter, for example. The power supply circuit **17** converts a direct-current voltage supplied from the battery **23** to a stable direct-current voltage having a predetermined voltage value, and outputs the direct-current voltage.

The controller **50** includes a CPU **51**, which is a central processing unit, and the memory **52**. The memory **52** is configured by ROMs, RAMs, EEPROMs, and the like, for example.

The CPU **51**, the memory **52**, the boom length sensor **26**, the derricking angle sensor **27**, and the wire sensor **28** are connected to a communication bus (not shown) included in the controller **50**. Through the communication bus, a control program **54** executed by the CPU **51** reads information and data from the memory **52**, stores information and data in the memory **52**, and obtains detection values output from the boom length sensor **26**, the derricking angle sensor **27**, and the wire sensor **28**.

The memory **52** stores an OS **53**, which is an operating system, the control program **54** that controls drive of the boom device **12**, a length L of the boom **32** (hereinafter referred to as "boom length L"), first specified values A and B, a second specified value K, an angular velocity constant F, and a predetermined standing angle (p. The OS **53** and the control program **54** are executed by the CPU **51** in a pseudo-parallel manner by so-called multitask processing.

The boom length L is, for example, the length of the boom **32** when the boom **32** is fully retracted, and is the length from the base end to the tip end of the boom **32**. The base end of the boom **32** is a position of a derricking center P (see FIG. **8**) of the boom **32**. The tip end of the boom is a position of the central shaft of the second sheaves **64**, **65**, **66** (see FIG. **1**) around which the wire **42** is wound, for example.

The first specified values A and B indicate coordinates of a point Q shown in FIG. **8**. In other words, the coordinates of the point Q are (A, B). The point Q indicates a position of one end of the hook hardware **41** in a two-dimensional coordinate system taking the derricking center P as the origin. Note that the two-dimensional coordinate system is a coordinate system in which a front-back direction of the truck crane **10** is taken as an x-axis direction and an up-down direction is taken as a y-axis direction.

The second specified value K is the sum of the length of the hook block **62** and the length of the hook hardware **41**. The length of the hook block means a distance from a tip end of the load hanging hook **40** to the central shaft **59**. Note that when the length of the hook block **62** is so short to be ignorable, the second specified value K is considered to be the length of the hook hardware **41**, and when the length of the hook hardware **41** is so short to be ignorable, the second specified value K is considered to be the length of the hook block **62**. In other words, the second specified value K is a value in accordance with at least one of the type of the hook block **62** and the type of the hook hardware **41**. Note that the length of the hook hardware **41** and the length of the load hanging hook **40** may be separately stored in the memory **52**. In that case, the control program **54** calculates the second specified value K by adding the length of the load hanging hook **40** to the length of the hook hardware **41**.

The angular velocity constant F is an angular velocity of the boom **32** when the control program **54** makes the boom **32** stand and lie at a constant angular velocity in the boom extending process (see FIG. **6**) and the boom retracting process (see FIG. **7**) to be described later. In other words, $F=d\theta/dt$.

The predetermined standing angle φ is a derricking angle of the boom **32** at the predetermined standing position in which the tip end of the boom **32** is located directly above the hook hardware **41**. The predetermined standing angle φ is used in the boom extending process (see FIG. **6**) to determine whether the boom **32** stands to the predetermined standing position in which the load hanging hook **40** can be safely removed from the hook hardware **41**.

The control program **54** has a class, for example. In other words, the class is stored in the memory **52**. The class generates an instance (object). Specifically, by being provided with the boom length L, the first specified values (A, B), and the second specified value K stored in the memory **52**, the class generates, as an instance, a function X1(θ) shown in FIG. **8**, d/dt{X1(θ)} obtained by differentiating the function X1(θ) with respect to time t, a function X2(θ) shown in FIG. **9**, and d/dt{X2(θ)} obtained by differentiating the function X2(θ) with respect to time t. Note that the control program **54** may generate d/dt{X1(θ)} and d/dt{X2(θ)} by differentiating the generated functions X1(θ) and X2(θ) with respect to time t. Furthermore, the above-described class may be arithmetic expressions that generate X1(θ) and X2(θ) by inputting the boom length L, the first specified values (A, B), and the second specified value K to input fields.

As shown in FIG. **8**, the function X1(θ) indicates a theoretical payout length of the wire **42** in a state in which the hook block **62** and the hook hardware **41** are aligned on a straight line. The function X1(θ) indicates the theoretical payout length of the wire **42** in a case in which the derricking angle of the boom **32** is θ. The function X1(θ) is expressed using A, B, L, K, and **0**, taking **0** as a variable and taking the above-described A, B, L, and K as constants.

Describing in detail, coordinates of a point S indicating a position of the tip end of the boom **32** are expressed as (L cos θ, L sin θ) using the length L of the boom **32** and the derricking angle θ of the boom **32**. Therefore, the distance SQ between the point S and the point Q is expressed using A, B, L, K and θ, as shown in FIG. **8**. Then, the function X1(θ) is the distance SQ−K, and is expressed using A, B, L, K, and θ.

As shown in FIG. **9**, the function X2(θ) indicates a theoretical payout length of the wire **42** in a posture in which the hook block **62** is lying. The posture in which the hook block **62** is lying is a state in which the hook block **62** is supported by the vehicle body **20** and extends along the horizontal direction. Furthermore, the function X2(θ) indicates the theoretical payout length of the wire **42** in the case in which the derricking angle of the boom **32** is θ. The function X2(θ) is expressed using A, B, L, K, and θ, taking 0 as a variable and taking the above-described A, B, L, and K as constants.

Describing in detail, the coordinates of the point S indicating the position of the tip end of the boom **32** are expressed as (L cos θ, L sin θ). Coordinates of a point R indicating a connection position between the wire **42** and the load hanging hook **40**, in other words, coordinates of the central shaft **59** can be expressed as (A+K, B). The function X2(θ) is the distance SR between the point S and the point R, and is expressed using A, B, L, K and θ as shown in FIG. **9**. The function X1(θ) corresponds to an "allowable minimum distance" recited in the claims. The function X2(θ) corresponds to an "allowable maximum distance" recited in the claims.

The control program **54** executes the boom extending process for automatically making the boom **32** in the lying position (see FIG. **1**) stand to the predetermined standing position (see FIG. **2**), and the boom retracting process for automatically making the boom **32** in the predetermined standing position lie to the lying position. Note that a process executed by the control program **54** is also a process executed by the controller **50**.

When the truck crane **10** arrives at a work site, the control program **54** executes the boom extending process. In other words, the boom extending process is executed in order for the truck crane **10** to start working at the work site. Conventionally, this process has been manually performed by a worker using the steering device **15**, however, in the present embodiment, the control program **54** automatically performs the work of extending the boom **32** to the predetermined standing position.

After the crane work is finished, the worker makes the control program **54** execute the boom retracting process. In other words, the boom retracting process is executed in order for the truck crane **10** to perform normal traveling at the work site. Conventionally, this process has been manually performed by the worker using the steering device **15**, however, in the present embodiment, the control program **54** automatically performs the work of retracting the boom **32**.

Hereinafter, the boom extending process and the boom retracting process will be described in detail referring to FIGS. **6** and **7**.

After the truck crane **10** arrives at a work site, the worker performs, using the steering device **15**, an operation to instruct execution of the boom extending process. Note that in a state in which the truck crane **10** arrives at the work site (see FIG. **1**), the boom **32** is in the above-described retracted state and the load hanging hook **40** is fixed to the hook hardware **41**.

The control program **54** starts execution of the boom extending process shown in FIG. **6** in accordance with inputting of the operation signal instructing to execute the boom extending process from the steering device **15**. At first, the control program **54** obtains the number of hanging wires (S**11**). For example, the control program **54** reads the number of hanging wires stored in the memory **52**. Alternatively, the control program **54** executes a process for automatically determining the number of hanging wires and obtains the number of hanging wires. The process of step S**11** corresponds to an "obtaining process" recited in the claims.

Note that although not described in the flowchart, when the length of the boom **32** detected by the boom length sensor **26** is not "L" stored in the memory **52**, the control program **54** may perform an error display and may cancel execution of the boom extending process. With this, the boom extending process can be prevented from being executed in a state in which the boom **32** is not retracted.

Next, the control program **54** reads the above-described A, B, L, K, and F from the memory **52** (S**12**). Furthermore, the control program **54** obtains the derricking angle θ detected by the derricking angle sensor **27** (S**13**). The control program **54** generates X1(θ) and X2(θ) using the obtained θ, A, B, L, K, and F and the above-described class

(**S14**). The process of step **S14** corresponds to a "generation process" recited in the claims.

The control program **54** determines a target value using the generated X1(θ) and X2(θ) (S**15**). Specifically, the control program **54** calculates {X1(θ)+X2(θ)}/2, which is the average value of X1(θ) and X2(θ), as the target value. The control program **54** multiplies the calculated target value by a correction coefficient J to correct the target value. The correction coefficient J is the number of hanging wires obtained in step S**11**. For example, when the number of hanging wires is "4", J=4.

The control program **54** switches the flow path of the hydraulic oil from the above-described normal circuit to the first relief circuit **91** via the relief valve **92** to reduce the hydraulic pressure supplied to the first hydraulic motor **38** to be smaller than the predetermined pressure (S**16**). When the flow path is switched to the first relief circuit **91** and the pressure of the hydraulic oil supplied to the first hydraulic motor **38** becomes smaller than the predetermined pressure, tension generated on the wire **42** to be wound up becomes small, and the hook hardware **41** is prevented from being damaged in a subsequent step **S17**.

The control program **54** drives the main winch **39** via the first hydraulic motor **38**, and winds up the wire **42** (S**17**). By winding up the wire **42**, the hook block **62** becomes a posture in which the hook block **62** is pulled up by the wire **42** (see FIG. **8**).

The control program **54** makes drive of the main winch **39** stop after the hook block **62** becomes the pulled-up posture, in other words, after the payout length of the wire **42** becomes the above-described allowable minimum distance X1(θ) (S**18**). For example, the control program **54** calculates a rotation speed of the wire drum **44** or a payout speed of the wire **42** from the detection value detected by the wire sensor **28**, determines that the hook block **62** is in the pulled-up posture based on the fact that the calculated rotation speed or payout speed becomes zero, and makes drive of the main winch **39** stop. Alternatively, the control program **54** makes drive of the main winch **39** stop based on the fact that elapsed time after driving the main winch **39** reaches a predetermined time stored in advance in the memory **52**.

Alternatively, when a tension sensor that detects a tension applied to the wire **42** is provided, the control program **54** makes drive of the main winch **39** stop based on the fact that the tension detected by the tension sensor reaches a predetermined tension stored in advance in the memory **52**.

The control program **54** drives the main winch **39** via the first hydraulic motor **38**, and pays out the wire **42** by the target value determined in step **S15** (S**19**). Specifically, the control program **54** drives the main winch **39**, counts the pulse signals output by the wire sensor **28**, and makes drive of the main winch **39** stop based on the fact that the payout length of the wire **42** indicated by the count value reaches the above-described target value.

By executing step **S19**, the hook block **62** becomes an intermediate posture (see FIG. **10**) between the above-described pulled-up posture and the above-described lying posture. If the hook block **62** is in the intermediate posture, a wind-up allowance of the wire **42** can be obtained until the hook hardware **41** is damaged due to the tension generated on the wire **42**, and a payout allowance can be obtained until the wire **42** becomes loose and an irregular winding occurs. Note that the irregular winding means a state in which the wire **42** is irregularly wound up by the wire drum **44**, and the like.

The control program **54** switches the flow path of the hydraulic oil from the first relief circuit **91** to the above-described normal circuit via the relief valve **92**, and sets the hydraulic pressure supplied to the first hydraulic motor **38** to the predetermined pressure (S**20**). The control program **54** generates dX1(θ)/dt and dX2(θ)/dt using the derricking angle θ obtained in step **S13** and L, A, B, K, and F read from the memory **52** in step **S12** (S**21**). The control program **54** calculates J×{dX1(θ)/dt+dX2(θ)/dt}/2 obtained by multiplying {dX1(θ)/dt+dX2(θ)/dt}/2, which is the average value of dX1(θ)/dt and dX2(θ)/dt, by the above-described correction coefficient J (S**22**). In other words, the control program **54** calculates the payout speed of the wire **42** at which the hook block **62** maintains the above-described intermediate posture.

The control program **54** makes the derricking cylinder **36** extend at a predetermined speed so that the boom **32** stands at the constant angular velocity F (S**23**). The control program **54** makes the main winch **39** drive via the first hydraulic motor **38** so that the payout speed of the wire **42** becomes J×{dX1(θ)/dt+dX2(θ)/dt}/2 obtained by multiplying {dX1(θ)/dt+dX2(θ)/dt}/2 by the correction coefficient J (S**24**), and pays out the wire **42**. The process of step **S23** corresponds to a "first process" recited in the claims. The process of step **S24** corresponds to a "second process" recited in the claims. The processes of steps **S23** and **S24** correspond to a "drive process" recited in the claims.

Next, the control program **54** calculates a payout length W of the wire **42** from the detection value detected by the wire sensor **28** (S**25**). The control program **54** determines whether the calculated payout length W is not smaller than J×X1(θ) and not larger than J×X2(θ) (S**26**). In other words, the control program **54** determines whether the wire **42** is paid out within a range in which the hook hardware **41** is not damaged and the irregular winding does not occur.

When determining that the payout length W is smaller than J×X1(θ) or larger than J×X2(θ) (S**26**: No), the control program **54** executes a stop process for stopping standing of the boom **32** and drive of the main winch **39** (S**27**), and finishes the boom extending process. Note that although not shown in the flowchart, the control program **54** performs an error notification based on executing of the stop process. The error notification is performed, for example, by displaying on a display (not shown) an error screen indicating that the boom extending process is stopped or outputting an error sound from a speaker (not shown).

When determining that the payout length W is not smaller than J×X1(θ) and not larger than J×X2(θ) (S**26**: Yes), the control program **54** determines whether the derricking angle θ obtained in step **S13** reaches the predetermined standing angle φ stored in the memory **52** (S**28**). When determining that the derricking angle θ does not reach the predetermined standing angle φ (S**28**: No), the control program **54** executes processes of steps **S131**, **S141**, **S211**, and **S221**. The processes of steps **S131**, **S141**, **S211** and **S221** are the same process as the processes of steps **S13**, **S14**, **S21** and **S22**. In other words, when the boom **32** does not reach the predetermined standing position (S**28**: No), the control program **54** obtains the derricking angle θ again, and generates or calculates the function dX1(θ), the function dX2(θ), dX1(θ)/dt, dX2(θ)/dt, and J×{dX1(θ)/dt+dX2(θ)/dt}/2. The control program **54** repeatedly executes a series of processes of steps **S131**, **S141**, **S211**, and **S221** at a fixed time interval of, for example, several milliseconds to several tens of milliseconds until the boom **32** reaches the predetermined standing position. The process of step **S141** corresponds to a "generation process" recited in the claims.

When determining that the derricking angle θ reaches the predetermined standing angle φ (S**28**: Yes), the control program **54** makes drive of the boom **32** and the main winch **39** stop via the derricking cylinder **36** and the first hydraulic motor **38** (S**29**), and finishes the boom extending process.

Next, the boom retracting process shown in FIG. **7** will be described. Note that as for the same processes as those described in the boom extending process (see FIG. **6**), same reference numerals are assigned and descriptions thereof are omitted.

The control program **54** executes the processes from steps S**11** to S**22** described in the boom extending process. Next, the control program **54** makes the derricking cylinder **36** retract at a predetermined speed, and makes the boom **32** lie at the constant angular velocity F (S**31**).

The control program **54** makes the main winch **39** drive via the first hydraulic motor **38** so that the wind-up speed of the wire **42** becomes $J\times\{dX1(\theta)/dt+dX2(\theta)/dt\}/2$ (S**32**). In other words, the control program **54** makes the main winch **39** wind up the wire **42** at a speed so that the hook block **62** maintains the intermediate posture (see FIG. **10**).

The control program **54** executes the processes of the above-described steps S**25**, S**26**, and S**27**. When determining in step S**26** that the payout length W is not smaller than $J\times X1(\theta)$ and not larger than $J\times X2(\theta)$ (S**26**: Yes), the control program **54** determines whether the derricking angle θ obtained in step S**13** reaches zero (S**33**). In other words, the control program **54** determines whether the boom **32** is laid to a retracted position. When determining that the derricking angle θ does not reach zero (S**33**: No), the control program **54** executes the processes of steps S**131**, S**141**, S**211**, and S**221**. The processes of steps S**131**, S**141**, S**211** and S**221** are the same process as the processes of steps S**13**, S**14**, S**21** and S**22**. In other words, when the boom **32** does not reach the retracted position (S**33**: No), the control program **54** obtains the derricking angle θ again, and generates or calculates the function $dX1(\theta)$, the function $dX2(\theta)$, $dX1(\theta)/dt$, $dX2(\theta)/dt$, and $J\times\{dX1(\theta)/dt+dX2(\theta)/dt\}/2$. The control program **54** repeatedly executes a series of the processes of steps S**131**, S**141**, S**211**, and S**221** at time intervals of, for example, several milliseconds to several tens of milliseconds until the boom **32** reaches the retracted position. The process of step S**141** corresponds to a "generation process" recited in the claims.

When determining that the derricking angle θ reaches zero (S**33**: Yes), the control program **54** makes drive of the boom **32** and the main winch **39** stop through the derricking cylinder **36** and the first hydraulic motor **38** (S**29**), and finishes the boom retracting process.

Actions and Effects of Embodiment

In the present embodiment, the boom **32** is made to stand and lie while the hook block **62** is maintained in the intermediate posture between the pulled-up posture and the lying posture. Therefore, the boom **32** can be made to stand and lie while preventing the damage of the hook hardware **41** and occurrence of the irregular winding of the wire **42**.

The controller **50** generates $X1(\theta)$ which is the allowable minimum distance and $X2(\theta)$ which is the allowable maximum distance, based on the boom length L, the first specified values (A, B), and the second specified value K in accordance with the type of the boom **32**, the type of the hook block **62**, and the type of the hook hardware **41**. Therefore, irrespective of the type of the boom **32**, the type of the hook block **62**, and the type of the hook hardware **41**, the allowable minimum distance $X1(\theta)$ and the allowable maximum distance $X2(\theta)$ can be calculated, and the target value can be set. As a result, the controller **50** can safely and automatically extend/retract the boom **32** irrespective of the type of the boom device **12**. In other words, the controller **50** can be used with various boom devices.

In the boom extending process and the boom retracting process, the controller **50** makes the boom stand and lie so that the angular velocity $d\theta/dt$ of the boom **32** is constant (=F) (S**23**, S**31**). Therefore, a target for controlling drive in order for the payout length of the wire **42** to be the above-described target value can be limited to the first hydraulic motor **38**. As a result, processing load on the CPU **51** is reduced.

The above-described target value is a value in accordance with the average value of $X1(\theta)$ and $X2(\theta)$. In other words, the wind-up allowance of the wire **42** until the damage of the hook hardware **41** is substantially the same as the payout allowance of the wire **42** until the irregular winding occurs. Therefore, occurrence of the damage of the hook hardware **41** and the occurrence of the irregular winding can be prevented to the same degree.

When the payout length W of the wire **42** is smaller than $J\times X1(\theta)$ or larger than $J\times X2(\theta)$ (S**26**: No), the controller **50** makes drive of the derricking cylinder **36** and the first hydraulic motor **38** stop (S**27**). Therefore, for example, even if a trouble occurs in the derricking cylinder **36**, the first hydraulic motor **38**, or the like, standing and lying of the boom **32** and drive of the main winch **39** are stopped safely. As a result, safety of an automatic extension and an automatic retraction of the boom **32** is improved.

The controller **50** determines the above-described target value based on the obtained number of hanging wires. Therefore, even if the hook block **62** has a specification that the number of hanging wires can be changed, the controller **50** can safely perform the automatic extension/retraction of the boom **32**.

Modification Example 1

In the above-described embodiment, an example is described in which the first specified values A and B (coordinates of the position Q of one end of the hook hardware **41** in the two-dimensional coordinate system taking the derricking center P as the origin) are stored in the memory **52**. In the present modification example, as shown in FIG. **11**, first specified values A, B, and C (coordinates of the position Q of one end of the hook hardware **41** in a three-dimensional coordinate system taking the derricking center P as the origin) are stored in the memory **52**. The first specified value C indicates a coordinate related to a z-axis in the above-described three-dimensional coordinate system. The z-axis is an axis along a width direction of the truck crane **10**.

In the present modification example, the coordinates of the above-described point S (tip end position of the boom **32**) are expressed as ($L\cos\theta$, $L\sin\theta$, 0). The function $X1(\theta)$ is a value obtained by subtracting the second specified value K from the distance SQ between the point Q and the point S, and is calculated using L, A, B, C, θ, and K. Similarly, as shown in FIG. **12**, the function $X2(\theta)$ is the distance SR between the point R (connection position between the wire **42** and the load hanging hook **40**) and the point S, and is calculated using L, A, B, C, K, and θ. The control program **54** has a class that generates the function $X1(\theta)$ and the function $X2(\theta)$ by inputting L, A, B, C, K, and θ. The control program **54** has a class that generates $dX1(\theta)/dt$ and $dX2(\theta)/dt$ by inputting L, A, B, C, K, θ, and F. In steps S**14** and

S21, the control program **54** generates X1(θ), X2(θ), dX1(θ)/dt, and dX2(θ)/dt using L, A, B, C, K, F, θ and the above-described classes.

In the present modification example, even if the tip end position of the boom **32** and the position of the hook hardware **41** are deviated in the width direction of the truck crane **10**, accurate X1(θ), X2(θ), dX1(θ)/dt, and dX2(θ)/dt can be generated. As a result, even if the positions of the tip end of the boom **32** and the hook hardware **41** are deviated in the width direction of the truck crane **10**, the damage of the hook hardware **41** and the occurrence of the irregular winding can be prevented.

Modification Example 2

In the present modification example, X1(θ), X2(θ), dX1(θ)/dt, and dX2(θ)/dt are corrected based on the derricking angle θ (see FIG. **13**) of the boom **32**.

As shown in FIG. **13**, when the derricking angle of the boom **32** changes from 0 degrees to θ, a contact point between the wire **42** and the wire drum **44** changes from a contact point T to a contact point U. When the contact point moves in this manner, the function X1(θ) and the function X2(θ), which are the theoretical payout lengths of the wire **42**, change. Change amounts in the function X1(θ) and the function X2(θ) due to the movement of the contact point correspond to a value obtained by subtracting the length of a straight line IU from the sum of the length of a straight line ET and the length of an arc TU. A point E is a point at which the wire **42** contacts the first sheave **63** when the boom **32** is in the lying position (derricking angle θ=0). A point I is a point at which the wire **42** contacts the first sheave **63** when the derricking angle of the boom **32** is θ.

The length of the straight line ET (hereinafter referred to as "length ET") can be calculated according to equation (1) shown in FIG. **13**, from coordinates (H1, H2) of a center H of the winch sheave **43**, a radius D1 of the winch sheave **43**, coordinates (V1, V2) of a center V of the first sheave **63**, and a radius D2 of the first sheave **63**. Here, H1, H2, D1, V1, V2, and D2 are fixed values determined by the type of the boom device **12**.

Furthermore, the length of the straight line IU (hereinafter referred to as "length IU") can be calculated according to equation (2) shown in FIG. **13**, from the coordinates (H1, H2) of the center H of the winch sheave **43**, the radius D1 of the winch sheave **43**, coordinates (G1, G2) of a center G of the first sheave **63**, and the radius D2 of the first sheave **63**. Here, G1 and G2 can be calculated using a rotation matrix N, V1, and V2. In other words, the length IU can be calculated using H1, H2, D1, V1, V2, D2 and the derricking angle θ.

Furthermore, the length of the arc TU is D1×θ. Therefore, the change amounts (correction amounts) of the function X1(θ) and the function X2(θ) when the derricking angle of the boom **32** changes from 0 degrees to θ can be calculated using H1, H2, D1, V1, V2, D2, and the derricking angle θ.

The control program **54** has a class that generates the correction amounts as an instance, by inputting H1, H2, D1, V1, V2, and D2, which are values in accordance with the type of the boom device **12** and are stored in advance in the memory **52**, and the derricking angle θ detected by the derricking angle sensor **27**. The control program **54** corrects the function X1(θ) and the function X2(θ) by adding the correction amounts generated using the above-described class to the function X1(θ) and the function X2(θ). For example, dX1(θ)/dt and dX2(θ)/dt are generated by differentiating X1(θ) after the correction and X2(θ) after the correction with respect to time t, or by using the above-described class. The process in which the control program **54** corrects the function X1(θ) and the function X2(θ) using the correction amounts corresponds to a "correction process" recited in the claims.

In the present modification example, since the function X1(θ), the function X2(θ), dX1(θ)/dt, and dX2(θ)/dt are corrected using H1, H2, D1, V1, V2, and D2 in accordance with the type of the boom device **12** and the derricking angle θ of the boom **32**, the damage of the hook hardware **41** and the occurrence of the irregular winding can be prevented more reliably.

Modification Example 3

In the present modification example, the boom device **12** further includes a second hydraulic motor **81**, a sub winch **82**, and a sub wire sensor **80** shown in FIG. **5**, and sheaves **85**, **86**, a sub hook member **71**, and a hook hardware **88** shown in FIG. **14**. Note that illustration of the main winch **39**, the winch sheave **43**, the wire **42**, the hook block **62**, and the hook hardware **41** is omitted in FIG. **14**.

The second hydraulic motor **81** rotates, receiving supply of the hydraulic pressure from the hydraulic supply device **24**. The second hydraulic motor **81** corresponds to a "second actuator" recited in the claims.

As shown in FIG. **5**, the sub winch **82** has a sub wire drum **83** rotated by the second hydraulic motor **81**, a sub wire **89** wound up by the sub wire drum **83**, and a sub winch sheave **84**. The sub wire **89** pulled out from the sub wire drum **83** is wound around the sub winch sheave **84** and then is wound around the sheave **85**. The sub winch **82** corresponds to a "winch" recited in the claims. The sub wire drum **83** corresponds to a "wire drum" recited in the claims.

The sheave **85** is provided to the tip end portion of the boom **32** to align side by side with the first sheave **63** in the horizontal direction (see FIG. **1**). The sheave **86** is provided to the tip end portion of the boom **32** apart from the sheave **85**. The sub wire **89** wound around the sheave **85** is wound around the sheave **86**, and then is connected to the sub hook member **71**.

The sub hook member **71** has a sub hook main body **72** and a sub hook **73**. The sub hook **73** is coupled to the sub hook main body **72**, and is hung on the hook hardware **88**.

The sub hook member **71** does not have a wire sheave. In other words, the number of hanging wires of the sub wire **89** is always "1". The sub hook member **71** corresponds to a "hook member" recited in the claims. The sub hook **73** corresponds to a "load hanging hook" recited in the claims.

The hook hardware **88** is arranged side by side with the hook hardware **41** (see FIG. **1**) in the horizontal direction. One end of the hook hardware **88** is rotatably supported by the slewing base **31**. The sub hook **73** is hooked on the other end of the hook hardware **88**. The hook hardware **88** corresponds to a "locking member" recited in the claims.

The sub wire sensor **80** (see FIG. **5**) is a rotary encoder that detects a rotation amount of the sub wire drum **83**, for example. The sub wire sensor **80** outputs a pulse signal having a voltage value that changes in accordance with the rotation of the sub wire drum **83**. The sub wire sensor **80** is connected to the controller **50** by a signal line such as a cable. The controller **50** calculates the rotation amount of the sub wire drum **83** from the number of pulses input from the sub wire sensor **80**, and calculates a payout length of the sub wire **89** based on the rotation amount of the sub wire drum **83** and a radius of the sub wire drum **83**. The radius of the sub wire drum **83** is stored in advance in the memory **52**.

Note that any type of sensor may be used for the sub wire sensor **80**, as long as the controller **50** can obtain the payout length of the sub wire **89**. The sub wire sensor **80** corresponds to a "wire sensor" recited in the claims.

In the present modification example, as shown in FIG. **5**, in addition to a normal circuit (not shown) that supplies hydraulic oil having a predetermined pressure to the second hydraulic motor **81**, the hydraulic supply device **24** includes a second relief circuit **93** that relieves the hydraulic oil in order to reduce the pressure of the supplied hydraulic oil to be smaller than the predetermined pressure. The second relief circuit **93** has a relief valve **94**. The relief valve **94** switches a flow path between the normal circuit and the second relief circuit **93** by a drive signal input from the controller **50**. In other words, the controller **50** can change the pressure of the hydraulic oil supplied to the second hydraulic motor **81** by inputting the drive signal to the relief valve **94**. Note that when the first relief circuit **91** reduces the pressure of the hydraulic oil supplied to the second hydraulic motor **81** in addition to the first hydraulic motor **38** to be smaller than the predetermined pressure, the second relief circuit **93** may not be provided.

The memory **52** further stores α and β indicating coordinates of a point Q' at one end of the hook hardware **88** as the first specified values. The memory **52** further stores, as the second specified value, a length η in accordance with the length of the hook hardware **88** and the length of the sub hook member **71**.

As shown in FIG. **15**, assuming that the length from the base end of the boom **32** to the sheave **86** is a boom length M, coordinates of a point N indicating a position of the sheave **86** when the derricking angle of the boom is θ are expressed by (M cos θ, M sin θ). On the other hand, a function Y1(θ), which is a theoretical payout length of the sub wire **89** in the posture in which the sub wire **89** is pulled up, is a value obtained by subtracting η from the distance between the point N and the point Q'. Therefore, the function Y1(θ) can be expressed using the length M of the boom **32**, the first specified values α and β, and the second specified value η.

As shown in FIG. **16**, a function Y2(θ), which is a theoretical payout length of the sub wire **89** in a posture in which the sub wire **89** is lying, is the distance between the point N and the point R'. Therefore, the function Y2(θ) can be expressed using the length M of the boom **32**, the first specified values α and β, and the second specified value η. Note that when the boom length M is substantially the same as the boom length L, the boom length L may be used in place of the boom length M.

The control program **54** has a class that generates the functions Y1(θ), the function Y2(θ), dY1(θ)/dt, and dY2(θ)/dt. Note that the control program **54** may have a class that generates the function Y1(θ) and the function Y2(θ), and may generate dY1(θ)/dt and dY2(θ)/dt by differentiating the function Y1(θ) and the function Y2(θ) with respect to time t.

In step S**12** (see FIG. **6**), the control program **54** further reads the boom length M, the first specified values α and β, and the second specified value η from the memory **52**. The control program **54** further generates Y1(θ) and Y2(θ) using M, α, β, η, and F read in step S**12**, the derricking angle θ obtained in step S**13**, and the above-described class. Then, in step S**15**, the control program **54** calculates the average value of Y1(θ) and Y2(θ) as the target value.

In step S**16**, the control program **54** switches the flow path of the hydraulic oil from the above-described normal circuit to the second relief circuit **93**, and the pressure of the hydraulic oil supplied to the second hydraulic motor **81** is set to be smaller than the predetermined pressure. In steps S**17** and S**18**, the control program **54** makes the sub winch **82** drive via the second hydraulic motor **81** so that the sub wire **89** is paid out by the target value. In other words, the control program **54** sets the sub hook member **71** in the intermediate posture in the same manner as the hook block **62**. In step S**20**, the control program **54** switches the flow path of the hydraulic oil from the first relief circuit **91** and the second relief circuit **93** to the normal circuit.

In step S**21**, the control program **54** further generates dY1(θ)/dt and dY2(θ)/dt. The control program **54** further calculates {dY1(θ)/dt+dY2(θ)/dt}/2 in step S**22**, and in step S**24**, makes the sub wire drum **83** rotate at a rotation speed at which the sub wire **89** is paid out at {dY1(θ)/dt+dY2(θ)/dt}/2. In other words, the control program **54** makes the sub winch **82** drive so that the sub hook member **71** maintains the intermediate posture.

In step S**25**, the control program **54** further obtains a payout length l of the sub wire **89** detected by the sub wire sensor **80**. In step S**26**, the control program **54** further determines whether the obtained payout length l is not smaller than Y1(θ) and not larger than Y2(θ). When determining that Y1(θ)≤l≤Y2(θ) is not true (S**26**: No), the control program **54** executes the stop process (S**27**), and when determining that Y1(θ)≤l≤Y2(θ) is true (S**26**: Yes), the control program **54** executes processes after step S**28**.

In the present modification example, even in the truck crane **10** including the hook block **62**, which is a so-called main hook, and the sub hook member **71**, the occurrence of the irregular winding can be prevented in both winches, which are the main winch **39** and the sub winch **82**, and the damage of the hook hardware **41**, **88** can be prevented.

Note that the truck crane **10** may have the sub hook member **71** together with the hook block **62**, or may have the sub hook member **71** in place of the hook block **62**.

Other Modification Examples

In the above-described embodiment, the coordinates of the above-described point S are expressed by (L cos θ, L sin θ) using the length L and the derricking angle θ of the boom **32**. However, the function X1(θ) and the function X2(θ) may be generated, taking the center of the first sheave **63** as (L cos θ, L sin θ) and taking the coordinates of the point S as (L cos θ+G1, L sin θ+G2). Here, "G1" and "G2" are differences between the center of the first sheave **63** and the center of the second sheave **65**, and are stored in advance in the memory **52** as constants.

In the above-described embodiment, in steps S**23** and S**31**, the derricking cylinder **36** is extended and retracted at a predetermined speed so that the boom **32** stands and lies at the constant angular velocity F. However, the derricking cylinder **36** may be extended and retracted at a constant speed. In that case, an angular velocity (de/dt) of the boom **32** is calculated from an extension/retraction speed of the derricking cylinder **36**, the calculated angular velocity is used in place of the above-described angular velocity F (constant), and dX1(θ)/dt and dX2(θ)/dt are generated or calculated.

Furthermore, in steps S**23** and S**31**, the boom **32** may be made to stand and lie by the steering device **15** operated by an operator. In that case, the control program **54** makes the derricking cylinder **36** stand and lie at a derricking speed (angular velocity) based on a signal input from the steering device **15** and in accordance with the operation amounts of the operator. The angular velocity (de/dt) is used in place of the above-described angular velocity F, and $dX1(\theta)/dt$ and $dX2(\theta)/dt$ are generated or calculated.

In the above-described embodiment, a value in accordance with the average value of the allowable minimum distance $X1(\theta)$ and the allowable maximum distance $X2(\theta)$ is calculated as the target value. However, a value closer to the allowable minimum distance $X1(\theta)$ may be taken as the target value, or a value closer to the allowable maximum distance $X2(\theta)$ may be taken as the target value. For example, $J\times\{X1(\theta)+X2(\theta)\}\times 2/3$ or $J\times\{X1(\theta)+X2(\theta)\}\times 1/3$ may be taken as the target value.

In the above-described embodiment, the first specified values A and B indicating the coordinates of the above-described point Q are stored in the memory **52**. However, if the function $X1(\theta)$ and the function $X2(\theta)$ can be generated, other values may be stored in the memory **52** as the first specified values in place of the first specified values A and B. For example, the distance from the point P, which is the origin, to the point Q, and a predetermined angle may be stored in the memory **52**. Here, the predetermined angle is an angle (angle of depression) formed by the straight line PQ and the horizontal plane, for example.

In the above-described embodiment, the hook hardware **41** is rotatably provided to the slewing base **31**. However, the hook hardware **41** may be fixed to the slewing base **31**. In this case, the position of the other end of the hook hardware **41** is taken as the point Q, and the second specified value K is taken as the length of the hook block **62**. Therefore, even when the hook hardware **41** is fixed to the slewing base **31**, the controller **50** can prevent the damage of the hook hardware **41** and the occurrence of the irregular winding of the wire **42** in the boom extending process and the boom retracting process.

Furthermore, the hook hardware **41** may be provided to a member other than the slewing base **31**, such as the vehicle body **20**, or the cabin **13**.

Furthermore, the hook block **62** may be directly hooked to be locked to a bar or the like provided to the slewing base **31**, the vehicle body **20**, the cabin **13**, or the like without using the hook hardware **41**. In that case, the function $X1(\theta)$, the function $X2(\theta)$, and the like are calculated, taking the position of the bar as the point Q and setting the second specified value K=0.

The invention claimed is:

1. A controller mounted on a boom device comprising:
   a pedestal;
   a boom supported by the pedestal and capable of performing a derricking motion between a lying position and a predetermined standing position;
   a winch having a wire wound up by a wire drum and wound around a tip end portion of the boom;
   a hook member having a load hanging hook provided to the wire;
   a first actuator configured to make the boom stand and lie;
   a second actuator configured to drive the winch;
   a locking member provided to the pedestal, wherein the load hanging hook is locked to the locking member;
   a derricking angle sensor configured to output a detection value in accordance with a derricking angle of the boom; and
   a wire sensor configured to output a detection value in accordance with a payout length of the wire, wherein
   the controller has a memory configured to store in advance a length of the boom, a first specified value in accordance with a position of the locking member taking a derricking center of the boom as a reference, and a second specified value in accordance with at least one of a type of the hook member and a type of the locking member, and
   the controller is configured to execute:
   a generation process for generating an allowable minimum distance and an allowable maximum distance from a tip end reference position of the boom to the hook member, based on the derricking angle of the boom specified from the detection value of the derricking angle sensor, the length of the boom, the first specified value, and the second specified value, and
   a drive process for making the first actuator and the second actuator drive so that the payout length of the wire specified from the detection value of the wire sensor becomes a predetermined target value that is not smaller than the allowable minimum distance and not larger than the allowable maximum distance.

2. The controller according to claim **1**, wherein:
   the allowable minimum distance is a distance from the tip end portion of the boom to the hook member in a posture in which the wire is wound up and the hook member is pulled up, and
   the allowable maximum distance is a distance from the tip end portion of the boom to the hook member in a posture in which the hook member is lying.

3. The controller according to claim **1**, wherein the drive process includes:
   a first process for making the boom stand and lie at a predetermined speed, and
   a second process for making the second actuator drive so that the payout length of the wire specified from the detection value of the wire sensor becomes the predetermined target value.

4. The controller according to claim **1**, wherein the predetermined target value is an average value of the allowable maximum distance and the allowable minimum distance.

5. The controller according to claim **1**, wherein the controller is configured to further execute a stop process for stopping the drive process, based on determining that the payout length of the wire specified from the detection value of the wire sensor is outside a range from the allowable minimum distance to the allowable maximum distance.

6. The controller according to claim **1**, wherein the controller is configured to further execute an obtaining process for obtaining a number of hanging wires, and to determine the predetermined target value based on the number of hanging wires.

7. The controller according to claim **1**, wherein the controller is configured to further execute a correction process for correcting the allowable minimum distance and the allowable maximum distance, based on the derricking angle specified from the detection value of the derricking angle sensor and a radius of a winch sheave stored in the memory.

8. A boom device comprising:
   the controller according to claim **1**; and
   the pedestal; the boom; the winch; the hook member; the first actuator; the second actuator; the locking member; the derricking angle sensor; and the wire sensor.

9. A truck crane comprising the boom device according to claim **8**.

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