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(54) CONTROL METHOD AND CONTROL SYSTEM FOR SUPER-LIFT MAST, AND CONTROLLER

(57) A control method and control system for a super-lift mast, and a controller (610). The control method comprises: acquiring a linear velocity relationship between a main luffing winch wire rope and a super-lift luffing winch wire rope (101); on the basis of the linear velocity relationship, determining an initial main luffing winch control current and an initial super-lift luffing winch control current (102); controlling the movement of a main luffing winch on the basis of the initial main luffing winch control current, and controlling the movement of a super-lift luffing winch on the basis of the initial super-lift luffing winch control current (103); during the movement of the super-lift luffing winch, acquiring the tension of a super-lift mast in real time (104); and on the basis of the tension of the super-lift mast, adjusting a main luffing winch control current and a super-lift luffing winch control current until the super-lift mast moves to a target position (105). Controlling the movement of a main luffing winch and a super-lift luffing winch by means of a main luffing winch control current and a super-lift luffing winch control current reduces operational difficulties during the processes of erecting and lowering a super-lift mast, thus improving the operation precision and efficiency.

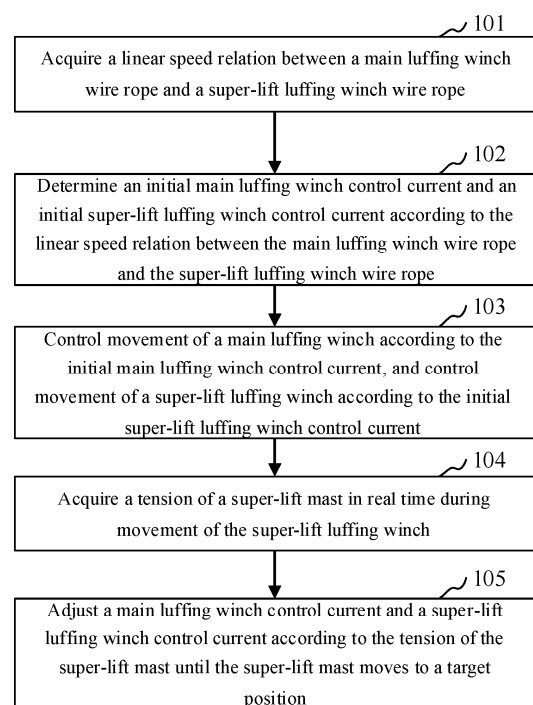


FIG. 1

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Description**Cross Reference to Related Applications**

- 5 [0001] The present disclosure claims priority to Chinese Application No. 202311752680.8, filed on December 19, 2023, which is specific1y and entirely incorporated by reference.

Field of the Invention

- 10 [0002] The present disclosure relates to the technical field of engineering machinery, and in particular to a control method and control system for a super-lift mast, and a controller.

Background of the Invention

- 15 [0003] It is necessary to disassemble and assemble a super-lift mast when a crawler crane with a super-lift device is disassembled and assembled. The super-lift mast is tied to a main luffing winch and its wire rope, and during movement of the super-lift mast, it is necessary to simultaneously control movement of a super-lift luffing winch to maintain a super-lift luffing wire rope at an appropriate length. When the super-lift luffing winch wire rope is unwound excessively, the super-lift luffing wire rope and a stay plate of a main boom fall to ground, resulting in damage. When the
20 super-lift luffing wire rope is unwound insufficiently, the main boom is pulled up, resulting in damage to components caused by an excessive tension. When the super-lift mast of the crawler crane is erected or lowered, an operator needs to manually control speeds of movement of the main luffing winch and the super-lift luffing winch according to stress states of a mast, the super-lift mast, and related stay plates, such that the super-lift mast moves from a lowered state to an erected state, or from an erected state to a lowered state. Operation efficiency is greatly affected by human
25 factors, and a movement state of each mechanism is manually recognized. In consequence, a disorderly wire rope of a luffing mechanism, an excessively-stressed mechanism member, etc. are caused when the movement of each mechanism is not synchronized. During erecting and lowering of the super-lift mast, it is necessary to simultaneously operate multiple handles and focus on a state of each mechanism. Manual work is labor-intensive and prone to misoperations, resulting in an unpredictable result. Thus, the traditional technical solution has high operation difficulty,
30 low precision, and low efficiency during erecting and lowering of the super-lift mast.

Summary of the Invention

- 35 [0004] An objective of embodiments of the present disclosure is to provide a control method and control system for a super-lift mast, and a controller, so as to solve high operation difficulty, low precision, and low efficiency during erecting and lowering of a super-lift mast in the prior art.

[0005] In order to achieve the above objective, a first aspect of the present disclosure provides a control method for a super-lift mast. The control method is applied to a controller, and includes:

- 40 acquiring a linear speed relation between a main luffing winch wire rope and a super-lift luffing winch wire rope; determining an initial main luffing winch control current and an initial super-lift luffing winch control current according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope; controlling movement of a main luffing winch according to the initial main luffing winch control current, and controlling movement of a super-lift luffing winch according to the initial super-lift luffing winch control current;
45 acquiring a tension of the super-lift mast in real time during the movement of the super-lift luffing winch; and adjusting a main luffing winch control current and a super-lift luffing winch control current according to the tension of the super-lift mast until the super-lift mast moves to a target position.

- 50 [0006] In an embodiment of the present disclosure, the determining an initial main luffing winch control current and an initial super-lift luffing winch control current according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope includes:

- determining a corresponding relation between main luffing pump unit displacement and super-lift pump unit displacement according to the linear speed relation between the main luffing winch wire rope and the super-lift
55 luffing winch wire rope; and determining the initial main luffing winch control current and the initial super-lift luffing winch control current according to the corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement.

[0007] In an embodiment of the present disclosure, the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope satisfies Formula (1):

$$\frac{V_w}{V_e} = r_2 \times L_w \times \sin \beta / (r_1 \times L_m \times \cos \gamma) \quad (1),$$

where

V_w is a linear speed of the super-lift luffing winch wire rope, V_e is a linear speed of the main luffing winch wire rope, r_2 is a reeving ratio of a super-lift luffing pulley block, L_w is a length of the super-lift mast, β is an angle between the main luffing winch wire rope and a main luffing mast, r_1 is a reeving ratio of a main luffing pulley block, L_m is a length of the main luffing mast, and γ is an included angle between the super-lift pulley block and a tangent line of a trajectory circle of the super-lift mast.

[0008] In an embodiment of the present disclosure, the corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement satisfies Formula (2):

$$\frac{V_{gw}}{V_{ge}} = \frac{r_2 * L_w * \sin \beta * (r_{e0} + (n_e - 1) * d_e * \sin \frac{\pi}{3})}{r_1 * L_m * \cos \gamma * (r_{w0} + (n_w - 1) * d_w * \sin \frac{\pi}{3})} \quad (2),$$

where

[0009] V_{gw} is the super-lift pump unit displacement, V_{ge} is the main luffing pump unit displacement, r_2 is a reeving ratio of a super-lift luffing pulley block, L_w is a length of the super-lift mast, β is an angle between the main luffing winch wire rope and a main luffing mast, r_1 is a reeving ratio of a main luffing pulley block, L_m is a length of the main luffing mast, γ is an included angle between the super-lift pulley block and a tangent line of a trajectory circle of the super-lift mast, d is a diameter of the wire rope, and n is a number of layers of the wire rope.

[0010] In an embodiment of the present disclosure, the adjusting a main luffing winch control current and a super-lift luffing winch control current according to the tension of the super-lift mast until the super-lift mast moves to a target position includes:

- determining whether the tension of the super-lift mast satisfies a preset value;
- updating the initial main luffing winch control current and the initial super-lift luffing winch control current separately according to the tension of the super-lift mast, a target value of the tension of the super-lift mast, and a movement state of the super-lift mast in a case that the tension of the super-lift mast does not satisfy the preset value; and
- controlling the super-lift mast to move to the target position in a case that the tension of the super-lift mast satisfies the preset value.

[0011] In an embodiment of the present disclosure, the updating the main luffing winch control current and the super-lift luffing winch control current separately according to the tension of the super-lift mast, a target value of the tension of the super-lift mast, and a movement state of the super-lift mast in a case that the tension of the super-lift mast does not satisfy the preset value includes:

- determining a difference between the tension of the super-lift mast and the target value of the tension of the super-lift mast;
- determining a difference between the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determining the sum of the initial super-lift luffing winch control current and an adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is an erected state and the difference is greater than zero;
- determining the sum of the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determining a difference between the initial super-lift luffing winch control current and an adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is an erected state and the difference is less than zero;
- determining the sum of the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determining a difference between the initial super-lift luffing winch control current and an adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is a lowered state and the difference is greater than zero; and
- determining a difference between the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determining the sum of the initial super-lift luffing winch control

current and an adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is a lowered state and the difference is less than zero.

[0012] In an embodiment of the present disclosure, the controller communicates with a tension collection device, and the acquiring a tension of the super-lift mast in real time during the movement of the super-lift luffing winch includes:

receiving the tension of the super-lift mast sent by the tension collection device.

[0013] A second aspect of the present disclosure provides a controller. The controller includes: a memory configured to store an instruction; and

a processor configured to invoke the instruction from the memory and implement, when executing the instruction, the control method for a super-lift mast according to the above.

[0014] A third aspect of the present disclosure provides a control system for a super-lift mast. The control system includes:

the controller according to the above; and

a tension collection device communicating with the controller and configured to acquire a tension of the super-lift mast.

[0015] A fourth aspect of the present disclosure provides a machine-readable storage medium. The machine-readable storage medium stores an instruction, where the instruction is configured to cause a machine to perform the control method for a super-lift mast according to the above.

[0016] According to the above technical solution, the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope is acquired to determine the initial main luffing winch control current and the initial super-lift luffing winch control current; the movement of the main luffing winch is controlled according to the initial main luffing winch control current, and the movement of the super-lift luffing winch is controlled according to the initial super-lift luffing winch control current; the tension of the super-lift mast is acquired in real time during the movement of the super-lift luffing winch; and the main luffing winch control current and the super-lift luffing winch control current are adjusted according to the tension of the super-lift mast until the super-lift mast moves to the target position. Thus, a mechanism can be automatically controlled to act, operation difficulty during erecting and lowering of the super-lift mast is reduced, and operation precision and efficiency are improved.

[0017] Other features and advantages of the embodiments of the present disclosure will be described in detail in the following particular implementation.

Brief Description of Drawings

[0018] The accompanying drawings serve to provide further understanding of the embodiments of the present disclosure, constitute part of the description, and serve to explain the embodiments of the present disclosure together with the following particular implementations instead of limiting the embodiments of the present disclosure. In the figures,

FIG. 1 schematically shows a flowchart of a control method for a super-lift mast according to an embodiment of the present disclosure;

FIG. 2 schematically shows a schematic diagram of calculation of a luffing angular speed according to a particular embodiment of the present disclosure;

FIG. 3 schematically shows a schematic diagram of calculation of an angle γ according to a particular embodiment of the present disclosure;

FIG. 4 schematically shows a flowchart of a control method for a super-lift mast according to a particular embodiment of the present disclosure;

FIG. 5 schematically shows a structural block diagram of a controller according to an embodiment of the present disclosure;

FIG. 6 schematically shows a structural diagram of a control system for a super-lift mast according to an embodiment of the present disclosure;

FIG. 7 schematically shows a structural diagram of tension control of a super-lift mast with an angle less than 86° according to a particular embodiment of the present disclosure;

FIG. 8 schematically shows a structural diagram of tension control of a super-lift mast with an angle greater than 86° and less than 94° according to a particular embodiment of the present disclosure; and

FIG. 9 schematically shows a structural diagram of tension control of a super-lift mast with an angle greater than 94° according to a particular embodiment of the present disclosure.

[0019] In the figures, 610, controller; and 620, tension collection device.

Detailed Description of the Embodiments

[0020] In order to make the objectives, the technical solutions and the advantages of the embodiments of the present disclosure clearer, the technical solutions in the embodiments of the present disclosure will be clearly and completely described below in combination with the accompanying drawings in the embodiments of the present disclosure. It should be understood that the particular implementations described herein are merely used for describing and explaining the embodiments of the present disclosure and are not intended to limit the embodiments of the present disclosure. Based on the embodiments in the present disclosure, all other embodiments derived by those of ordinary skill in the art without creative efforts fall within the scope of protection of the present disclosure.

[0021] It should be noted that if involved in the embodiments of the present disclosure, the directional indications (such as upper, lower, left, right, front, rear...) are merely used for explaining the relative position relations and motion situations between components in a specific posture (as shown in the figures). If the specific posture is changed, the directional indications are also changed accordingly.

[0022] In addition, if the descriptions of "first", "second", etc. are involved in the embodiments of the present disclosure, the descriptions of "first", "second", etc. are merely for descriptive purposes and are not to be construed as indicating or implying their relative importance or implicitly specifying the number of indicated technical features. Thus, a feature defined with "first" or "second" can explicitly or implicitly include at least one of the features. In addition, the technical solutions of the embodiments can be combined with one another, but are necessarily based on the achievement of those of ordinary skill in the art. When the combination of the technical solutions is contradictory or impossible to implement, it should be considered that such a combination of the technical solutions does not exist and does not fall within the scope of protection of the present disclosure.

[0023] FIG. 1 schematically shows a flowchart of a control method for a super-lift mast according to an embodiment of the present disclosure. As shown in FIG. 1, a control method for a super-lift mast is provided in an embodiment of the present disclosure. The method may include:

Step 101, a linear speed relation between a main luffing winch wire rope and a super-lift luffing winch wire rope is acquired;

Step 102, an initial main luffing winch control current and an initial super-lift luffing winch control current are determined according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope;

Step 103, movement of a main luffing winch is controlled according to the initial main luffing winch control current, and movement of a super-lift luffing winch is controlled according to the initial super-lift luffing winch control current;

Step 104, a tension of the super-lift mast is acquired in real time during the movement of the super-lift luffing winch; and

Step 105, a main luffing winch control current and a super-lift luffing winch control current are adjusted according to the tension of the super-lift mast until the super-lift mast moves to a target position.

[0024] In an embodiment of the present disclosure, movement of the super-lift mast is controlled by the main luffing winch and the main luffing winch wire rope. During the movement of the super-lift mast, the movement of the super-lift luffing winch needs to be controlled simultaneously, such that the super-lift luffing wire rope is at an appropriate length. When the super-lift luffing winch wire rope is unwound excessively, the super-lift luffing wire rope and a stay plate of a main boom fall to ground, resulting in damage. When the super-lift luffing wire rope is unwound insufficiently, the main boom is pulled up, resulting in damage to components caused by an excessive tension. Thus, an appropriate tension needs to be applied to the super-lift mast to control the movement of the super-lift mast.

[0025] During the movement of the super-lift mast, the main luffing winch wire rope and the super-lift luffing winch wire rope move synchronously. Moreover, the main luffing winch control current and the super-lift luffing winch control current affect a speed of the main luffing winch wire rope and a speed of the super-lift luffing winch wire rope, and the speed of the main luffing winch wire rope and the speed of the super-lift luffing winch wire rope affect the tension of the super-lift mast. Thus, when the super-lift mast is controlled, the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope is acquired first. Then, the initial main luffing winch control current and the initial super-lift luffing winch control current may be determined separately according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope. The initial main luffing winch control current and the initial super-lift luffing winch control current refer to basic currents obtained through calculation. A main luffing mast and the super-lift mast may move according to the initial main luffing winch control current and the initial super-lift luffing winch control current. Moreover, during the movement, the control current is fed

back according to the tension, and the tension of the super-lift mast is obtained.

[0026] After the initial main luffing winch control current and the initial super-lift luffing winch control current are obtained, the initial main luffing winch control current and the initial super-lift luffing winch control current are input into a control system separately, the movement of the main luffing winch is controlled according to the initial main luffing winch control current, and the movement of the super-lift luffing winch is controlled according to the initial super-lift luffing winch control current. The tension of the super-lift mast may be acquired in real time during the movement of the super-lift luffing winch. The main luffing winch control current and the super-lift luffing winch control current are adjusted in real time according to the tension of the super-lift mast acquired in real time until the super-lift mast moves to the target position.

[0027] According to the above technical solution, the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope is acquired to determine the initial main luffing winch control current and the initial super-lift luffing winch control current; the movement of the main luffing winch is controlled according to the initial main luffing winch control current, and the movement of the super-lift luffing winch is controlled according to the initial super-lift luffing winch control current; the tension of the super-lift mast is acquired in real time during the movement of the super-lift luffing winch; and the main luffing winch control current and the super-lift luffing winch control current are adjusted according to the tension of the super-lift mast until the super-lift mast moves to the target position. Thus, a mechanism can be automatically controlled to act, operation difficulty during erecting and lowering of the super-lift mast is reduced, and operation precision and efficiency are improved.

[0028] In an embodiment of the present disclosure, the step that an initial main luffing winch control current and an initial super-lift luffing winch control current are determined according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope may include:

a corresponding relation between main luffing pump unit displacement and super-lift pump unit displacement is determined according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope; and

the initial main luffing winch control current and the initial super-lift luffing winch control current are determined according to the corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement.

[0029] Specifically, the initial main luffing winch control current and the initial super-lift luffing winch control current may be determined according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope. The corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement may be determined according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope. In a case that linear speeds are known, the main luffing pump unit displacement and the super-lift pump unit displacement may be determined separately according to a rotating speed of an engine, a speed reduction ratio of a transfer case, current pump unit displacement of a pump, current motor displacement of a motor, a speed reduction ratio of a speed reducer, volumetric efficiency of the pump, and volumetric efficiency of the motor. Then, the initial main luffing winch control current and the initial super-lift luffing winch control current are determined according to the corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement. A corresponding relation between pump unit displacement and a current is a fixed attribute of a crane. According to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope, the initial main luffing winch control current and the initial super-lift luffing winch control current are determined to control the super-lift mast to move and obtain the tension of the super-lift mast.

[0030] In an embodiment of the present disclosure, the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope may satisfy Formula (1):

$$\frac{V_w}{V_e} = r_2 \times L_w \times \sin \beta / (r_1 \times L_m \times \cos \gamma) \quad (1),$$

where

V_w is a linear speed of the super-lift luffing winch wire rope, V_e is a linear speed of the main luffing winch wire rope, r_2 is a reeving ratio of a super-lift luffing pulley block, L_w is a length of the super-lift mast, β is an angle between the main luffing winch wire rope and a main luffing mast, r_1 is a reeving ratio of a main luffing pulley block, L_m is a length of the main luffing mast, and γ is an included angle between the super-lift pulley block and a tangent line of a trajectory circle of the super-lift mast.

[0031] Specifically, the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope satisfies a formula $\frac{V_w}{V_e} = r_2 \times L_w \times \sin \beta / (r_1 \times L_m \times \cos \gamma)$. V_w is a linear speed of the super-

lift luffing winch wire rope, and V_e is a linear speed of the main luffing winch wire rope. FIG. 2 schematically shows a schematic diagram of calculation of a luffing angular speed according to a particular embodiment of the present disclosure. As shown in FIG. 2, a calculation method for a luffing angular speed is provided in an embodiment of the present disclosure. In a calculation process, a coordinate system may be established according to a center of rotation, and hinge point coordinates (A_x, A_y) of a luffing pulley block and hinge point coordinates (C_x, C_y) of a bottom of a mast may be acquired separately. Hinge point coordinates (B_x, B_y) of a top point of the mast may be calculated based on an angle of the mast and a length of the mast. An angle β between a luffing wire rope and the mast may be determined by knowing three-point coordinates of a triangle, and an angular speed ω of the mast may be further determined, i.e. $\omega = (V_e \times \sin \beta) \div L_m \div r_1$. L_m is the length of the mast, r_1 is a reeving ratio of the luffing pulley block, and an angular speed of a super-lift mast is consistent with the angular speed of the mast, and is also ω . A linear speed V_t of a head of the super-lift mast and a speed V_w of a super-lift luffing wire rope are calculated through the angular speed of the mast, i.e. $V_t = \omega \times L_w$ and $V_w = (V_t \div \cos \gamma) \times r_2$. γ is an included angle between the super-lift pulley block and a tangent line of a trajectory circle of the super-lift mast, and r_2 is a reeving ratio of the super-lift luffing pulley block.

[0032] In an embodiment of the present disclosure, data may be collected through a sensor. For example, angle sensors may be mounted on the mast and the super-lift mast to detect angles of the mast and the super-lift mast. A tension sensor may further be mounted between the super-lift mast and a stay plate of a main boom to detect a tension.

[0033] FIG. 3 schematically shows a schematic diagram of calculation of an angle γ according to a particular embodiment of the present disclosure. As shown in FIG. 3, a calculation method for an angle γ is provided in the embodiment of the present disclosure. Vertex coordinates (D_x, D_y) of a super-lift mast may be calculated through a length of the super-lift mast and an angle of the super-lift mast. Vertex coordinates (E_x, E_y) of a stay plate of a main boom are known parameters, and the angle θ_1 of the super-lift mast may be measured by an angle sensor. An included angle θ_2 between a super-lift luffing wire rope and a horizontal direction may be calculated based on (D_x, D_y) and (E_x, E_y), i.e. $\theta_2 = \arctan\left(\frac{D_y - E_y}{E_x - D_x}\right)$. Further, an included angle $\gamma = \pi - \theta_1 - \theta_2 - \frac{\pi}{2}$ between a super-lift pulley block and a tangent line of a trajectory circle of the super-lift mast may be obtained. Finally, a relational expression $\frac{V_w}{V_e} = r_2 \times L_w \times \sin \beta / (r_1 \times L_m \times \cos \gamma)$ between a luffing winch linear speed and a super-lift luffing linear speed based on the angle of the mast may be obtained.

[0034] In an embodiment of the present disclosure, the corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement may satisfy Formula (2):

$$\frac{V_{gw}}{V_{ge}} = \frac{r_2 \times L_w \times \sin \beta \times (r_{e0} + (n_e - 1) \times d_e \times \sin \frac{\pi}{3})}{r_1 \times L_m \times \cos \gamma \times (r_{w0} + (n_w - 1) \times d_w \times \sin \frac{\pi}{3})} \quad (2),$$

where

V_{gw} is the super-lift pump unit displacement, V_{ge} is the main luffing pump unit displacement, r_2 is a reeving ratio of a super-lift luffing pulley block, L_w is a length of the super-lift mast, β is an angle between the main luffing winch wire rope and a main luffing mast, r_1 is a reeving ratio of a main luffing pulley block, L_m is a length of the main luffing mast, γ is an included angle between the super-lift pulley block and a tangent line of a trajectory circle of the super-lift mast, d is a diameter of the wire rope, and n is a number of layers of the wire rope.

[0035] Specifically, the corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement satisfies the formula $\frac{V_{gw}}{V_{ge}} = \frac{r_2 \times L_w \times \sin \beta \times (r_{e0} + (n_e - 1) \times d_e \times \sin \frac{\pi}{3})}{r_1 \times L_m \times \cos \gamma \times (r_{w0} + (n_w - 1) \times d_w \times \sin \frac{\pi}{3})}$. V_{gw} is the super-lift pump unit displacement, and V_{ge} is the main luffing pump unit displacement. A linear speed of a winch is equal to a winding radius of a main luffing winch multiplied by the angular speed. $r = r_0 + (n - 1) \times d \times \sin \frac{\pi}{3}$. r_0 is a bottom diameter of a roller, d is the diameter of the wire rope, and n is a number of layers of the wire rope. Thus, a rotating speed $V = ((s/\eta_1 \times V_{gpump}) / V_{gmotor}) / \eta_2 \times \eta_3 \times \eta_4 \times 2\pi$ of the winch may be determined. s is a rotating speed of an engine, η_1 is a speed reduction ratio of a transfer case, V_{gpump} is current pump unit displacement, V_{gmotor} is current motor displacement, η_2 is a speed reduction ratio of a speed reducer, η_3 is volumetric efficiency of a pump, and η_4 is volumetric efficiency of a motor. Finally, the corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement may be obtained.

[0036] In an embodiment of the present disclosure, the step that a main luffing winch control current and a super-lift luffing winch control current are controlled according to the tension of the super-lift mast until the super-lift mast moves

to a target position may include:

whether the tension of the super-lift mast satisfies a preset value is determined;
 the initial main luffing winch control current and the initial super-lift luffing winch control current are updated
 5 separately according to the tension of the super-lift mast, a target value of the tension of the super-lift mast, and
 a movement state of the super-lift mast in a case that the tension of the super-lift mast does not satisfy the preset
 value; and
 the super-lift mast is controlled to move to the target position in a case that the tension of the super-lift mast
 satisfies the preset value.

10 **[0037]** Specifically, after the initial main luffing winch control current and the initial super-lift luffing winch control
 current are obtained, the movement of the main luffing winch may be controlled according to the initial main luffing
 winch control current, and the movement of the super-lift luffing winch may be controlled according to the initial super-
 lift luffing winch control current. The tension of the super-lift mast may be acquired in real time during the movement of
 15 the super-lift luffing winch. Whether the tension of the super-lift mast satisfies the preset value is determined. The
 preset value is a preset tension value that may make the super-lift mast move normally. The initial main luffing winch
 control current and the initial super-lift luffing winch control current are updated separately according to the tension of
 the super-lift mast, the target value of the tension of the super-lift mast, and the movement state of the super-lift mast
 in a case that the tension of the super-lift mast does not satisfy the preset value. The super-lift mast is controlled to
 20 move to the target position in a case that the tension of the super-lift mast satisfies the preset value.

[0038] In an embodiment of the present disclosure, the step that the main luffing winch control current and the
 super-lift luffing winch control current are updated separately according to the tension of the super-lift mast, a target
 value of the tension of the super-lift mast, and a movement state of the super-lift mast in a case that the tension of the
 super-lift mast does not satisfy the preset value may include:

25 a difference between the tension of the super-lift mast and the target value of the tension of the super-lift mast is
 determined;

a difference between the initial main luffing winch control current and an adjusting current is determined as an
 updated main luffing winch control current and the sum of the initial super-lift luffing winch control current and an
 30 adjusting current is determined as an updated super-lift luffing winch control current in a case that the movement
 state of the super-lift mast is an erected state and the difference is greater than zero;

the sum of the initial main luffing winch control current and an adjusting current is determined as an updated main
 luffing winch control current and a difference between the initial super-lift luffing winch control current and an
 adjusting current is determined as an updated super-lift luffing winch control current in a case that the movement
 35 state of the super-lift mast is an erected state and the difference is less than zero;

the sum of the initial main luffing winch control current and an adjusting current is determined as an updated main
 luffing winch control current and a difference between the initial super-lift luffing winch control current and an
 adjusting current is determined as an updated super-lift luffing winch control current in a case that the movement
 state of the super-lift mast is a lowered state and the difference is greater than zero; and

40 a difference between the initial main luffing winch control current and an adjusting current is determined as an
 updated main luffing winch control current and the sum of the initial super-lift luffing winch control current and an
 adjusting current is determined as an updated super-lift luffing winch control current in a case that the movement
 state of the super-lift mast is a lowered state and the difference is less than zero.

45 **[0039]** Specifically, the main luffing winch control current and the super-lift luffing winch control current are updated
 separately according to the tension of the super-lift mast, the target value of the tension of the super-lift mast, and the
 movement state of the super-lift mast in a case that the tension of the super-lift mast does not satisfy the preset value.
 The movement of the super-lift mast may include erecting the super-lift mast and lowering the super-lift mast. It is
 defined that a tension of F_2 is F_{2min} at a tensioned state of a stay plate when the super-lift mast is at 90° , and the
 50 tension of F_2 is F_{2max} when a boom is lifted at 0° . F_{2min} and F_{2max} are parameters related to weight of the stay plate of
 the main boom, and may be acquired through a test method. An F_2 tension control target is staged according to the
 angle of the super-lift mast and set according to a range. A maximum tension of F_2 is controlled to be less than F_{2min}
 by erecting or lowering the super-lift mast in a case that an angle between the super-lift mast and the front is less than
 86°. In a case that the super-lift mast is turned over vertically (that is, the angle between the super-lift mast and the
 55 front is between 86° and 94°), when the super-lift mast is erected, it is necessary to maintain the super-lift mast and
 the stay plate of the main boom tensioned to prevent the super-lift mast from falling freely when the super-lift mast is
 turned over 90° . Thus, a minimum tension of F_2 is controlled to be greater than F_{2min} and less than the maximum
 tension F_{2max} when the main boom is pulled up. When the super-lift mast is lowered, the main boom is pulled by the

super-lift mast to control F_2 to be equal to F_{2min} . The maximum tension of F_2 is controlled to be greater than F_{2min} and less than F_{2max} by erecting or lowering the super-lift mast in a case that the angle between the super-lift mast and the front is greater than 94° .

[0040] From the above calculation, $F_{2 \text{ target value}}$ may be obtained, and $F_{2 \text{ actual value}}$ is measured by a tension sensor. ΔF may be obtained by subtraction of $F_{2 \text{ target value}}$ and $F_{2 \text{ actual value}}$. A control strategy for the current under different cases is shown in Table 1:

Table 1

Serial number	Item	ΔF	Main luffing	Super-lift luffing
1	Erecting of super-lift mast	Greater than 0	I-I_PID	I+I_PID
2	Erecting of super-lift mast	Less than 0	I+I_PID	I-I_PID
3	Lowering of super-lift mast	Greater than 0	I+I_PID	I-I_PID
4	Lowering of super-lift mast	Less than 0	I-I_PID	I+I_PID

[0041] Wherein, I is a control current passing through pump unit displacement, and is influenced by parameters of transmission components. I-PID is the adjusting current calculated through a proportional integral derivative (PID) control model based on a difference between $F_{2 \text{ target value}}$ and $F_{2 \text{ actual value}}$. The difference between the initial main luffing winch control current and the adjusting current is determined as the updated main luffing winch control current and the sum of the initial super-lift luffing winch control current and the adjusting current is determined as the updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is the erected state and the difference is greater than zero. The sum of the initial main luffing winch control current and the adjusting current is determined as the updated main luffing winch control current and the difference between the initial super-lift luffing winch control current and the adjusting current is determined as the updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is the erected state and the difference is less than zero. The sum of the initial main luffing winch control current and the adjusting current is determined as the updated main luffing winch control current and the difference between the initial main luffing winch control current and the adjusting current is determined as the updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is the lowered state and the difference is greater than zero. The difference between the initial main luffing winch control current and the adjusting current is determined as the updated main luffing winch control current and the sum of the initial main luffing winch control current and the adjusting current is determined as the updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is the lowered state and the difference is less than zero.

[0042] In an embodiment of the present disclosure, the controller communicates with a tension collection device, and the step that a tension of the super-lift mast is acquired in real time during the movement of the super-lift luffing winch may include:

the tension of the super-lift mast sent by the tension collection device is received.

[0043] Specifically, the controller may communicate with the tension collection device. The tension collection device may include, but not limited to, a tension sensor, etc., and is configured to collect the tension of the super-lift mast and send the tension to the controller.

[0044] According to the above technical solution, the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope is acquired to determine the initial main luffing winch control current and the initial super-lift luffing winch control current; the movement of the main luffing winch is controlled according to the initial main luffing winch control current, and the movement of the super-lift luffing winch is controlled according to the initial super-lift luffing winch control current; the tension of the super-lift mast is acquired in real time during the movement of the super-lift luffing winch; and the main luffing winch control current and the super-lift luffing winch control current are adjusted according to the tension of the super-lift mast until the super-lift mast moves to the target position. Thus, a mechanism can be automatically controlled to act, operation difficulty during erecting and lowering of the super-lift mast is reduced, and operation precision and efficiency are improved.

[0045] FIG. 4 schematically shows a flowchart of a control method for a super-lift mast according to a particular embodiment of the present disclosure. As shown in FIG. 4, a control method for a super-lift mast is provided in an embodiment of the present disclosure. The method may include:

S401, the method is started;

S402, a relation between a luffing winch linear speed and a super-lift luffing winch linear speed is calculated;

S403, a relation between a main luffing winch control current and a super-lift luffing winch control current is

calculated;

S404, a controller executes output;

S405, a main luffing winch acts, and a super-lift luffing winch acts;

S406, a tension is detected, the method returns to S404 in a case that the tension needs to be adjusted, and the method proceeds to S407 in a case that the tension is normal; and S407, the super-lift mast moves to a target position to complete erecting and lowering of the super-lift mast.

[0046] In an embodiment of the present disclosure, the relation between the luffing winch linear speed (i.e. a linear speed of a main luffing winch wire rope in the present disclosure) and the super-lift luffing winch linear speed (i.e. a linear speed of a super-lift luffing winch wire rope in the present disclosure) is calculated. The relation between the luffing winch control current (i.e. an initial main luffing winch control current in the present disclosure) and the super-lift winch control current (i.e. an initial super-lift luffing winch control current in the present disclosure) is calculated according to the relation between the luffing winch linear speed and the super-lift luffing winch linear speed. The luffing winch control current and the super-lift winch control current are input into a controller, and the controller controls a luffing winch action and a super-lift luffing winch action. during the luffing winch action and the super-lift luffing winch action, the tension of the super-lift mast is detected in real time. That is, whether the tension of the super-lift mast satisfies a preset value is determined. A super-lift luffing speed and a main luffing speed are adjusted by feedback in a case that the tension of the super-lift mast needs to be adjusted. The super-lift mast is controlled to move to the target position to complete erecting and lowering of the super-lift mast in a case that the tension of the super-lift mast is normal.

[0047] FIG. 5 schematically shows a structural block diagram of a controller according to an embodiment of the present disclosure. As shown in FIG. 5, a controller is provided in an embodiment of the present disclosure. The controller may include:

a memory 510 configured to store an instruction; and

a processor 520 configured to invoke the instruction from the memory 510 and implement, when executing the instruction, the above control method for a super-lift mast.

[0048] Specifically, in an embodiment of the present disclosure, the processor 520 may be configured to:

acquire a linear speed relation between a main luffing winch wire rope and a super-lift luffing winch wire rope; determine an initial main luffing winch control current and an initial super-lift luffing winch control current according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope; control movement of a main luffing winch according to the initial main luffing winch control current, and control movement of a super-lift luffing winch according to the initial super-lift luffing winch control current; acquire a tension of the super-lift mast in real time during the movement of the super-lift luffing winch; and adjust a main luffing winch control current and a super-lift luffing winch control current according to the tension of the super-lift mast until the super-lift mast moves to a target position.

[0049] Further, the processor 520 may further be configured to:

determine the initial main luffing winch control current and the initial super-lift luffing winch control current according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope as follows:

determine a corresponding relation between main luffing pump unit displacement and super-lift pump unit displacement according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope; and

determine the initial main luffing winch control current and the initial super-lift luffing winch control current according to the corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement.

[0050] Further, the processor 520 may further be configured as follows:

the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope satisfies Formula (1):

$$\frac{v_w}{v_e} = r_2 \times L_w \times \sin \beta / (r_1 \times L_m \times \cos \gamma) \quad (1),$$

where

V_w is a linear speed of the super-lift luffing winch wire rope, V_e is a linear speed of the main luffing winch wire rope, r_2 is a reeving ratio of a super-lift luffing pulley block, L_w is a length of the super-lift mast, β is an angle between the main luffing winch wire rope and a main luffing mast, r_1 is a reeving ratio of a main luffing pulley block, L_m is a length of the main luffing mast, and γ is an included angle between the super-lift pulley block and a tangent line of a trajectory circle of the super-lift mast.

[0051] Further, the processor 520 may further be configured as follows:

the corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement satisfies Formula (2):

$$\frac{V_{gw}}{V_{ge}} = \frac{r_2 * L_w * \sin \beta * (re_0 + (ne - 1) * de * \sin \frac{\pi}{3})}{r_1 * L_m * \cos \gamma * (rw_0 + (nw - 1) * dw * \sin \frac{\pi}{3})} \quad (2),$$

where

V_{gw} is the super-lift pump unit displacement, V_{ge} is the main luffing pump unit displacement, r_2 is a reeving ratio of a super-lift luffing pulley block, L_w is a length of the super-lift mast, β is an angle between the main luffing winch wire rope and a main luffing mast, r_1 is a reeving ratio of a main luffing pulley block, L_m is a length of the main luffing mast, γ is an included angle between the super-lift pulley block and a tangent line of a trajectory circle of the super-lift mast, d is a diameter of the wire rope, and n is a number of layers of the wire rope.

[0052] Further, the processor 520 may further be configured to:

adjust the main luffing winch control current and the super-lift luffing winch control current according to the tension of the super-lift mast until the super-lift mast moves to the target position as follows:

determine whether the tension of the super-lift mast satisfies a preset value;

update the initial main luffing winch control current and the initial super-lift luffing winch control current separately according to the tension of the super-lift mast, a target value of the tension of the super-lift mast, and a movement state of the super-lift mast in a case that the tension of the super-lift mast does not satisfy the preset value; and control the super-lift mast to move to the target position in a case that the tension of the super-lift mast satisfies the preset value.

[0053] Further, the processor 520 may further be configured to:

update the main luffing winch control current and the super-lift luffing winch control current separately according to the tension of the super-lift mast, the target value of the tension of the super-lift mast, and the movement state of the super-lift mast in a case that the tension of the super-lift mast does not satisfy the preset value as follows:

determine a difference between the tension of the super-lift mast and the target value of the tension of the super-lift mast;

determine a difference between the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determine the sum of the initial super-lift luffing winch control current and an adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is an erected state and the difference is greater than zero;

determine the sum of the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determine a difference between the initial super-lift luffing winch control current and an adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is an erected state and the difference is less than zero;

determine the sum of the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determine a difference between the initial super-lift luffing winch control current and an adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is a lowered state and the difference is greater than zero; and

determine a difference between the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determine the sum of the initial super-lift luffing winch control current and an adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is a lowered state and the difference is less than zero.

[0054] Further, the processor 520 may further be configured as follows:

the controller communicates with a tension collection device, and the processor may further be configured to acquire the tension of the super-lift mast in real time during the movement of the super-lift luffing winch as follows: receive the tension of the super-lift mast sent by the tension collection device.

[0055] According to the above technical solution, the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope is acquired to determine the initial main luffing winch control current and the initial super-lift luffing winch control current; the movement of the main luffing winch is controlled according to the initial main luffing winch control current, and the movement of the super-lift luffing winch is controlled according to the initial super-lift luffing winch control current; the tension of the super-lift mast is acquired in real time during the movement of the super-lift luffing winch; and the main luffing winch control current and the super-lift luffing winch control current are adjusted according to the tension of the super-lift mast until the super-lift mast moves to the target position. Thus, a mechanism can be automatically controlled to act, operation difficulty during erecting and lowering of the super-lift mast is reduced, and operation precision and efficiency are improved.

[0056] FIG. 6 schematically shows a structural diagram of a control system for a super-lift mast according to an embodiment of the present disclosure. As shown in FIG. 6, a control system for a super-lift mast is provided in an embodiment of the present disclosure. The control system may include:

the controller 610 according to the above; and

a tension collection device 620 communicating with the controller 610 and configured to acquire a tension of the super-lift mast.

[0057] In an embodiment of the present disclosure, the control system for a super-lift mast may include the controller 610 and the tension collection device 620. The tension collection device 620 communicates with the controller 610 and is configured to acquire the tension of the super-lift mast. When movement of the super-lift mast is controlled, the controller 610 acquires a linear speed relation between a main luffing winch wire rope and a super-lift luffing winch wire rope, and then determines an initial main luffing winch control current and an initial super-lift luffing winch control current according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope. Then, the controller controls movement of a main luffing winch according to the initial main luffing winch control current, and controls movement of a super-lift luffing winch according to the initial super-lift luffing winch control current. The controller 610 receives the tension of the super-lift mast sent by the tension collection device 620 in real time during the movement of the super-lift luffing winch, and adjusts a main luffing winch control current and a super-lift luffing winch control current according to the tension of the super-lift mast until the super-lift mast moves to a target position.

[0058] FIG. 7 schematically shows a structural diagram of tension control of a super-lift mast with an angle less than 86° according to a particular embodiment of the present disclosure. FIG. 8 schematically shows a structural diagram of tension control of a super-lift mast with an angle greater than 86° and less than 94° according to a particular embodiment of the present disclosure. FIG. 9 schematically shows a structural diagram of tension control of a super-lift mast with an angle greater than 94° according to a particular embodiment of the present disclosure. As shown in FIGs. 7, 8, and 9, a control structure for a tension in different angles is provided in a particular embodiment of the present disclosure. Movement of the super-lift mast may include erecting the super-lift mast and lowering the super-lift mast. It is defined that a tension of F_2 is F_{2min} at a tensioned state of a stay plate when the super-lift mast is at 90° , and the tension of F_2 is F_{2max} when a boom is lifted at 0° . F_{2min} and F_{2max} are parameters related to weight of the stay plate of the main boom, and may be acquired through a test method. An F_2 tension control target is staged according to the angle of the super-lift mast and set according to a range. A maximum tension of F_2 is controlled to be less than F_{2min} by erecting or lowering the super-lift mast in a case that an angle between the super-lift mast and the front is less than 86° . In a case that the super-lift mast is turned over vertically (that is, the angle between the super-lift mast and the front is between 86° and 94°), when the super-lift mast is erected, it is necessary to maintain the super-lift mast and the stay plate of the main boom tensioned to prevent the super-lift mast from falling freely when the super-lift mast is turned over 90° . Thus, a minimum tension of F_2 is controlled to be greater than F_{2min} and less than the maximum tension F_{2max} when the main boom is pulled up. When the super-lift mast is lowered, the main boom is pulled by the super-lift mast to control F_2 to be equal to F_{2min} . The maximum tension of F_2 is controlled to be greater than F_{2min} and less than F_{2max} by erecting or lowering the super-lift mast in a case that the angle between the super-lift mast and the front is greater than 94° .

[0059] According to the above technical solution, the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope is acquired to determine the initial main luffing winch control current and the initial super-lift luffing winch control current; the movement of the main luffing winch is controlled according to the initial main luffing winch control current, and the movement of the super-lift luffing winch is controlled according to the initial super-lift luffing winch control current; the tension of the super-lift mast is acquired in real time during the movement of

the super-lift luffing winch; and the main luffing winch control current and the super-lift luffing winch control current are adjusted according to the tension of the super-lift mast until the super-lift mast moves to the target position. Thus, a mechanism can be automatically controlled to act, operation difficulty during erecting and lowering of the super-lift mast is reduced, and operation precision and efficiency are improved.

[0060] A machine-readable storage medium is further provided in an embodiment of the present disclosure. The machine-readable storage medium stores an instruction, and the instruction is configured to cause a machine to perform the control method for a super-lift mast according to the above.

[0061] Those skilled in the art should understand that the embodiments of the present disclosure can be provided as methods, systems, or computer program products. Thus, the forms of full hardware embodiments, full software embodiments, or software and hardware combined embodiments can be used in the present disclosure. Moreover, the form of a computer program product implemented on one or more computer usable storage media (including, but not limited to, disk memories, compact disc read-only memories (CD-ROMs), optical memories, etc.) including computer usable program codes can be used in the present disclosure.

[0062] The present disclosure is described with reference to flowcharts and/or block diagrams of methods, devices (systems), and computer program products according to the embodiments of the present disclosure. It should be understood that each flow and/or block in the flowcharts and/or block diagrams and combinations of the flows and/or blocks in the flowcharts and/or block diagrams can be implemented by computer program instructions. These computer program instructions can be provided for a general-purpose computer, a special-purpose computer, an embedded processor, or a controller of another programmable data processing device to generate a machine, such that an apparatus for implementing a specific function in one or more flows in the flowcharts and/or in one or more blocks in the block diagrams is generated by the instructions executed by the computer or the controller of another programmable data processing device.

[0063] These computer program instructions may be stored in a computer-readable memory that can instruct the computer or another programmable data processing device to work in a specific manner, such that an artifact that includes an instruction apparatus is generated by the instructions stored in the computer-readable memory. A specific function in one or more flows in the flowcharts and/or in one or more blocks in the block diagrams is implemented by the instruction apparatus.

[0064] These computer program instructions may be loaded onto a computer or another programmable data processing device, such that a series of operation steps are performed on the computer or the another programmable device to generate computer-implemented processing. Thus, steps for implementing a specific function in one or more flows in the flowcharts and/or in one or more blocks in the block diagrams are provided by the instructions executed on the computer or the another programmable device.

[0065] In a typical configuration, a computing device includes one or more central processing units (CPUs), an input/output interface, a network interface, and a memory.

[0066] The memory probably includes a non-permanent memory, a random access memory (RAM) and/or a non-volatile memory (such as a read-only memory (ROM) or a flash memory (flash RAM)) and so on of a computer-readable medium. The memory is an example of a computer-readable medium.

[0067] The computer-readable medium includes permanent and non-permanent, movable and non-movable media and may store information through any method or technology. The information can be modules of computer-readable instructions, data structures and programs, or other data. Examples of a computer storage medium include, but are not limited to, a phase-change random access memory (PRAM), a static random access memory (SRAM), a dynamic random access memory (DRAM), other types of random access memories (RAMs), a read-only memory (ROM), an electrically erasable programmable read-only memory (EEPROM), a flash memory or other memory technologies, a compact disc read-only memory (CD-ROM), a digital versatile disc (DVD) or other optical storage, a cassette tape, tape or disk storage or other magnetic storage devices, or any other non-transmission media that may be configured to store information capable of being accessed by a computing device. As defined herein, the computer-readable medium does not include transitory media, such as modulated data signals and carrier waves.

[0068] It should be noted that the terms "comprise", "include", "contain", or any other variations thereof are intended to cover non-exclusive inclusions, such that a process, a method, a commodity, or a device that includes a series of elements not only includes those elements, but also includes other elements that are not explicitly listed, or further includes inherent elements of the process, the method, the commodity, or the device. Without more restrictions, the elements defined by the sentence "include a..." or "comprise a..." do not exclude the existence of other identical elements during the process, the method, the commodity, or the device that includes the elements.

[0069] What are described above are merely embodiments of the present disclosure and are not configured to limit the present disclosure. Those skilled in the art can make various modifications and variations to the present disclosure. Any modifications, equivalent substitutions, improvements, etc. made within the spirit and principle of the present disclosure should fall within the scope of the claims of the present disclosure.

Claims

1. A control method for a super-lift mast, **characterized by** being applied to a controller, and comprising:

acquiring a linear speed relation between a main luffing winch wire rope and a super-lift luffing winch wire rope;
determining an initial main luffing winch control current and an initial super-lift luffing winch control current according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope;
controlling movement of a main luffing winch according to the initial main luffing winch control current, and controlling movement of a super-lift luffing winch according to the initial super-lift luffing winch control current; acquiring a tension of the super-lift mast in real time during the movement of the super-lift luffing winch; and adjusting a main luffing winch control current and a super-lift luffing winch control current according to the tension of the super-lift mast until the super-lift mast moves to a target position.

2. The control method according to claim 1, **characterized in that** the determining an initial main luffing winch control current and an initial super-lift luffing winch control current according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope comprises:

determining a corresponding relation between main luffing pump unit displacement and super-lift pump unit displacement according to the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope; and
determining the initial main luffing winch control current and the initial super-lift luffing winch control current according to the corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement.

3. The control method according to claim 2, **characterized in that** the linear speed relation between the main luffing winch wire rope and the super-lift luffing winch wire rope satisfies Formula (1):

$$\frac{V_w}{V_e} = r_2 \times L_w \times \sin \beta / (r_1 \times L_m \times \cos \gamma) \quad (1),$$

wherein

V_w is a linear speed of the super-lift luffing winch wire rope, V_e is a linear speed of the main luffing winch wire rope, r_2 is a reeving ratio of a super-lift luffing pulley block, L_w is a length of the super-lift mast, β is an angle between the main luffing winch wire rope and a main luffing mast, r_1 is a reeving ratio of a main luffing pulley block, L_m is a length of the main luffing mast, and γ is an included angle between the super-lift pulley block and a tangent line of a trajectory circle of the super-lift mast.

4. The control method according to claim 2, **characterized in that** the corresponding relation between the main luffing pump unit displacement and the super-lift pump unit displacement satisfies Formula (2):

$$\frac{V_{gw}}{V_{ge}} = \frac{r_2 \times L_w \times \sin \beta \times (r_{e0} + (n_e - 1) \times d \times \sin \frac{\pi}{3})}{r_1 \times L_m \times \cos \gamma \times (r_{w0} + (n_w - 1) \times d \times \sin \frac{\pi}{3})} \quad (2),$$

wherein

V_{gw} is the super-lift pump unit displacement, V_{ge} is the main luffing pump unit displacement, r_2 is a reeving ratio of a super-lift luffing pulley block, L_w is a length of the super-lift mast, β is an angle between the main luffing winch wire rope and a main luffing mast, r_1 is a reeving ratio of a main luffing pulley block, L_m is a length of the main luffing mast, γ is an included angle between the super-lift pulley block and a tangent line of a trajectory circle of the super-lift mast, d is a diameter of the wire rope, and n is a number of layers of the wire rope.

5. The control method according to claim 1, **characterized in that** the adjusting a main luffing winch control current and a super-lift luffing winch control current according to the tension of the super-lift mast until the super-lift mast moves to a target position comprises:

determining whether the tension of the super-lift mast satisfies a preset value;

updating the initial main luffing winch control current and the initial super-lift luffing winch control current separately according to the tension of the super-lift mast, a target value of the tension of the super-lift mast, and a movement state of the super-lift mast in a case that the tension of the super-lift mast does not satisfy the preset value; and

controlling the super-lift mast to move to the target position in a case that the tension of the super-lift mast satisfies the preset value.

6. The control method according to claim 5, **characterized in that** the updating the main luffing winch control current and the super-lift luffing winch control current separately according to the tension of the super-lift mast, a target value of the tension of the super-lift mast, and a movement state of the super-lift mast in a case that the tension of the super-lift mast does not satisfy the preset value comprises:

determining a difference between the tension of the super-lift mast and the target value of the tension of the super-lift mast;

determining a difference between the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determining the sum of the initial super-lift luffing winch control current and the adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is an erected state and the difference is greater than zero;

determining the sum of the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determining a difference between the initial super-lift luffing winch control current and the adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is an erected state and the difference is less than zero;

determining the sum of the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determining a difference between the initial super-lift luffing winch control current and the adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is a lowered state and the difference is greater than zero; and

determining a difference between the initial main luffing winch control current and an adjusting current as an updated main luffing winch control current and determining the sum of the initial super-lift luffing winch control current and the adjusting current as an updated super-lift luffing winch control current in a case that the movement state of the super-lift mast is a lowered state and the difference is less than zero.

7. The control method according to claim 1, **characterized in that** the controller communicates with a tension collection device, and the acquiring a tension of the super-lift mast in real time during the movement of the super-lift luffing winch comprises:

receiving the tension of the super-lift mast sent by the tension collection device.

8. A controller, **characterized by** comprising:

a memory configured to store an instruction; and

a processor configured to invoke the instruction from the memory and implement, when executing the instruction, the control method for a super-lift mast according to any one of claims 1-7.

9. A control system for a super-lift mast, **characterized by** comprising:

the controller according to claim 8; and

a tension collection device communicating with the controller and configured to acquire a tension of the super-lift mast.

10. A machine-readable storage medium, **characterized by** storing an instruction, wherein the instruction is configured to cause a machine to perform the control method for a super-lift mast according to any one of claims 1-7.

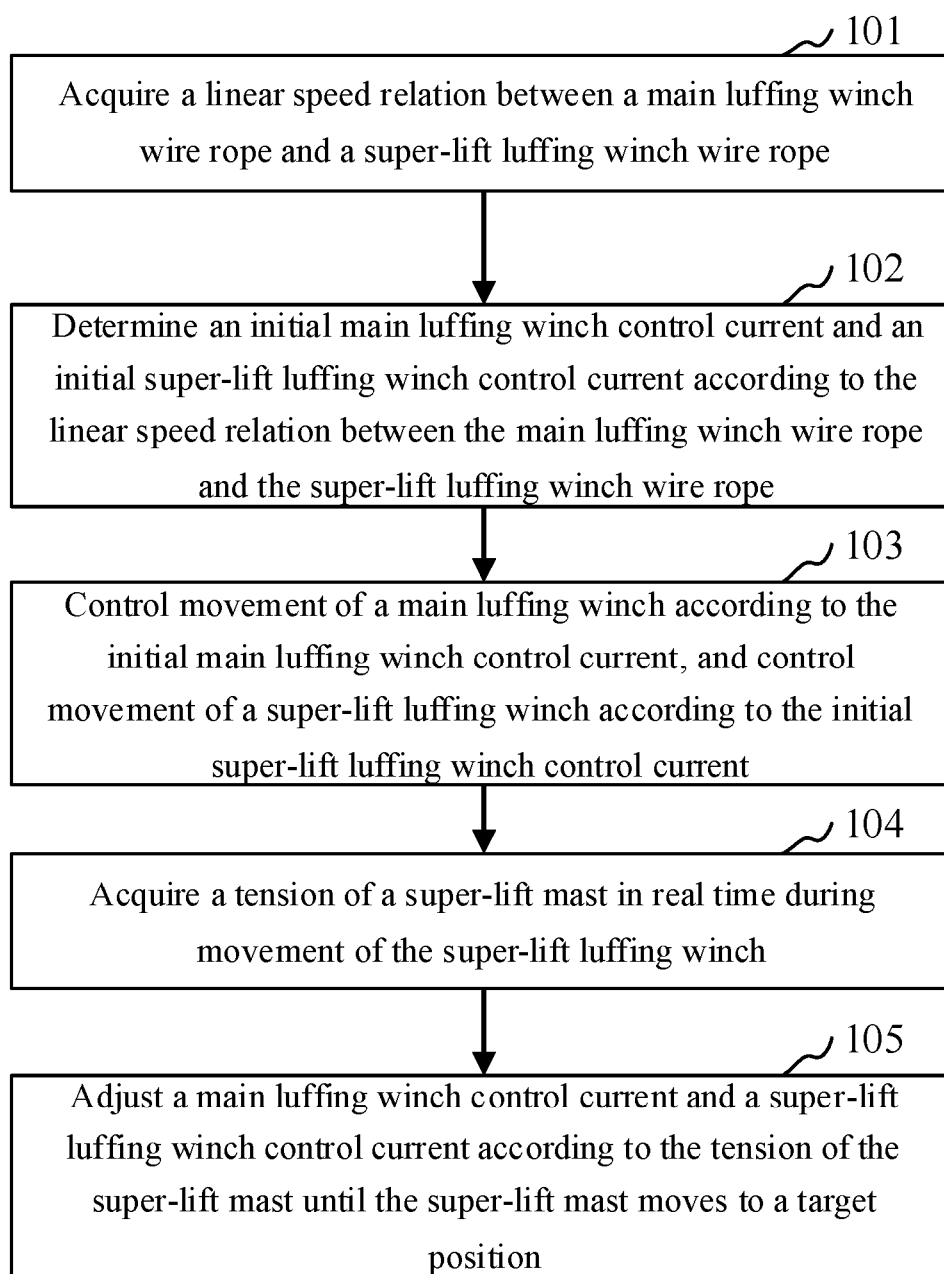


FIG. 1

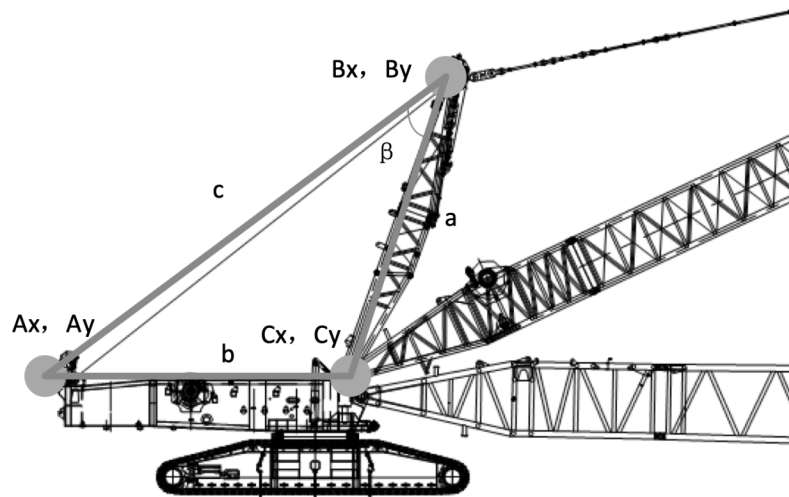


FIG. 2

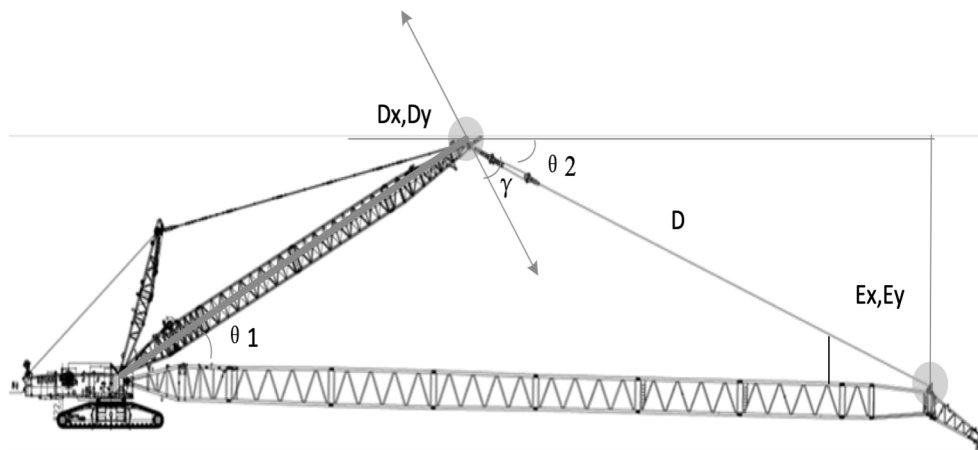


FIG. 3

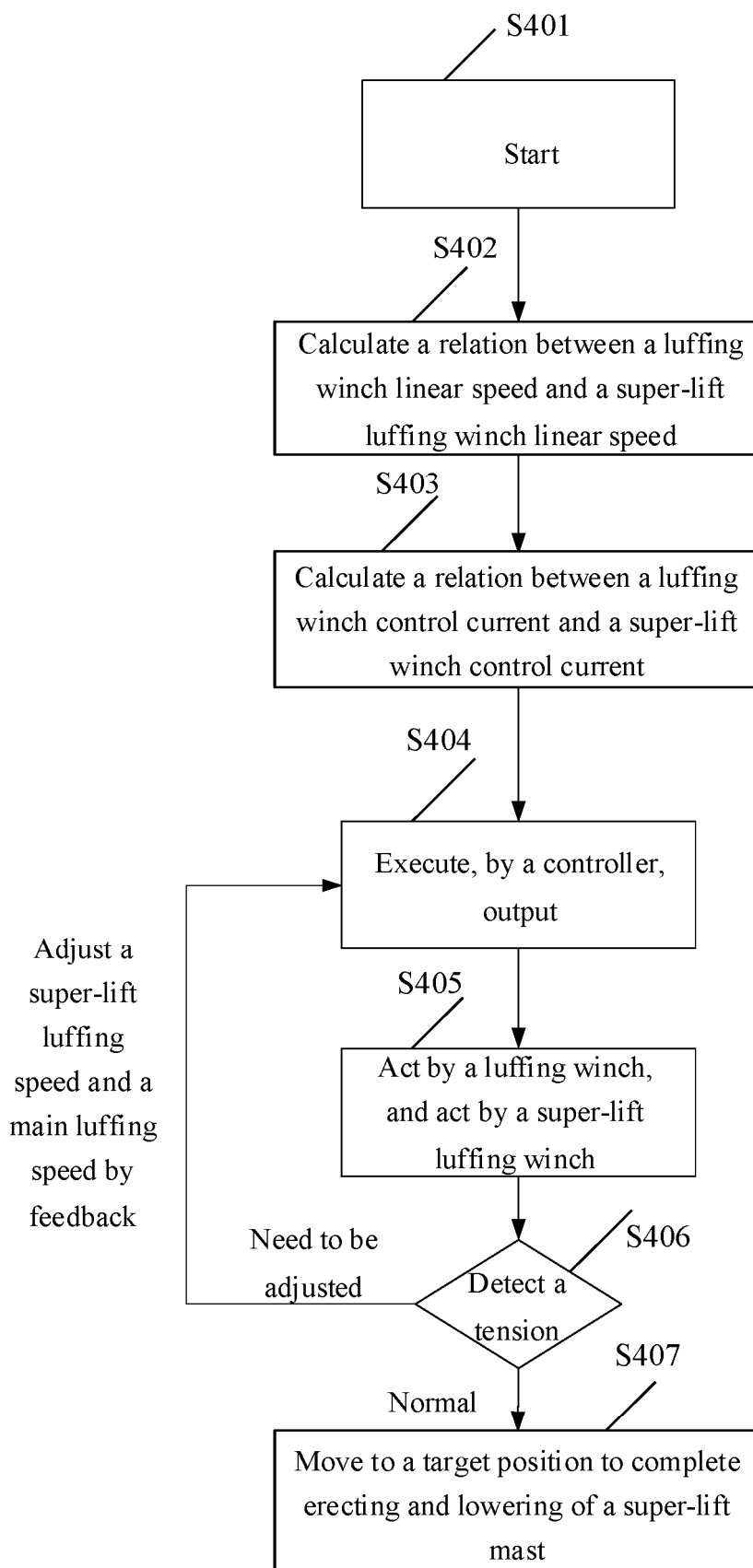


FIG. 4

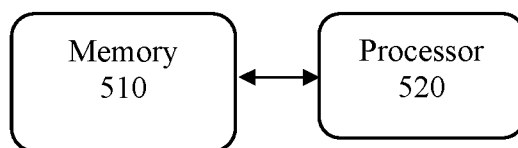


FIG. 5

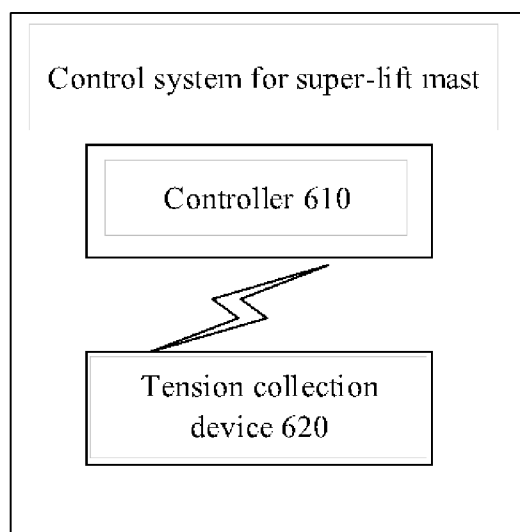


FIG. 6



FIG. 7

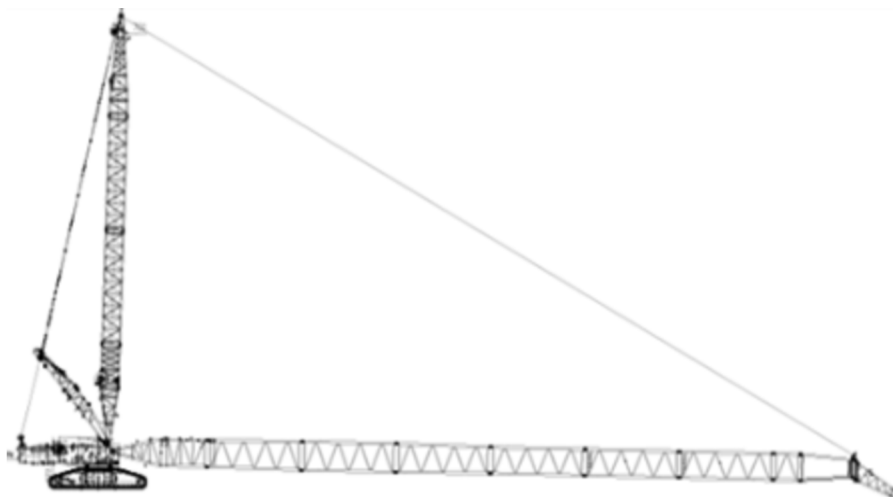


FIG. 8



FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/120461

A. CLASSIFICATION OF SUBJECT MATTER

B66C13/22(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B66C

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

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

CNXTX, ENTXT, ENTXTC, VEN, 超星读秀, DUXIU: 安装, 扳起, 倍率, 泵, 变幅, 变副, 拆卸, 拆装, 长度, 超举, 超起, 桅杆, 超升, 电流, 吊臂, 调节, 调整, 放落, 改变, 关系, 滚筒, 滑轮, 夹角, 减小, 角度, 绞盘, 卷筒, 卷扬, 控制, 力, 落臂, 落下, 马达, 排量, 匹配, 起臂, 倾角, 伸缩臂, 绳, 速度, 抬起, 同步, 下落, 增大, 增加, 主臂, 转速, career, current, lift+, super, velocity, windlass, accommodat+, adjust+, winch?, chang+, rate?, roll+, regulat+, speed?, capstan?,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 117755986 A (HUNAN ZOOMLION HEAVY INDUSTRY SCIENCE & TECHNOLOGY TRACK CRANE CO., LTD.) 26 March 2024 (2024-03-26) description, paragraphs 55-151, and figures 1-9	1-10
A	CN 214611189 U (ZHEJIANG SANY EQUIPMENT CO., LTD.) 05 November 2021 (2021-11-05) description, paragraphs 30-96, and figures 1-4	1-10
A	CN 113860176 A (ZOOMLION HEAVY INDUSTRY SCIENCE & TECHNOLOGY CO., LTD.) 31 December 2021 (2021-12-31) entire document	1-10
A	CN 112209248 A (ZOOMLION HEAVY INDUSTRY SCIENCE & TECHNOLOGY CO., LTD.) 12 January 2021 (2021-01-12) entire document	1-10
A	JP 2017137171 A (KOBELCO CRANES CO., LTD.) 10 August 2017 (2017-08-10) entire document	1-10

☒ 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
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"D" document cited by the applicant in the international application	"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
"E" earlier application or patent but published on or after the international filing date	"&" document member of the same patent family
"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)	
"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

12 December 2024

Date of mailing of the international search report

23 December 2024

Name and mailing address of the ISA/CN

China National Intellectual Property Administration (ISA/
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Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/120461

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/CN2024/120461

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
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CN	214611189	U	05 November 2021	CN	112723172	A	30 April 2021
				WO	2022151683	A1	21 July 2022
				KR	20230128371	A	04 September 2023
				EP	4276048	A1	15 November 2023
CN	113860176	A	31 December 2021	CN	113860176	B	08 November 2022
CN	112209248	A	12 January 2021	None			
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REFERENCES CITED IN THE DESCRIPTION

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