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(54) **SYNCHRONOUS CONTROL METHOD BASED ON SYNCHRONOUS CONTROL SYSTEM FOR LIFTING HYDRAULIC CYLINDERS OF TUNDISH IN CONTINUOUS CASTING**

SYNCHRONES STEUERVERFAHREN AUF DER BASIS EINES SYNCHRONEN STEUERSYSTEMS ZUM HEBEN VON HYDRAULISCHEN TUNDISHZYLINDERN BEIM STRANGGIESSEN

PROCÉDÉ DE COMMANDE SYNCHRONE BASÉ SUR UN SYSTÈME DE COMMANDE SYNCHRONE POUR ÉLEVER DES CYLINDRES HYDRAULIQUES DE PANIER DE COULÉE DANS UNE COULÉE CONTINUE

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(56) References cited:

CN-A- 101 907 109
CN-A- 105 836 422
CN-A- 107 314 000
CN-B- 104 832 499
CN-U- 203 614 479
CN-U- 203 740 983
DE-A1-102006 004 308
JP-A- 2000 079 452
US-B2- 6 837 054

Description

TECHNICAL FIELD

[0001] The present disclosure relates to the hydraulic drive control field, and in particular, to a synchronization control method based on a synchronization control system for lifting hydraulic cylinders of a continuous casting tundish.

BACKGROUND

[0002] A continuous casting tundish is usually moved up or down synchronously by using four hydraulic cylinders (one master hydraulic cylinder and three slave hydraulic cylinders). At present, the lifting hydraulic cylinders of the continuous casting tundish are mainly synchronously controlled in a hydraulic cylinder synchronization control mode based on four hydraulic synchronous motors, or in a universal master/slave hydraulic cylinder synchronization control mode based on an independent PI regulator and proportion regulation valve. Synchronization control accuracy of the two multi-hydraulic cylinder synchronization control solutions is easily affected by factors such as leakage of a hydraulic system (such as internal leakage of a hydraulic cylinder), different manufacturing accuracy of hydraulic elements, and uneven load, especially the hydraulic cylinder synchronization control mode based on four hydraulic synchronous motors. The 1# and 2# continuous casting tundishes from the south section of Long Products Business Division of Masteel implement synchronous lifting of hydraulic cylinders by using four hydraulic synchronous motors. The 4# continuous casting tundish implements synchronization control of lifting hydraulic cylinders in the universal master/slave hydraulic cylinder synchronization control mode based on an independent PI regulator and proportion regulation valve. In actual production, for the 1# and 2# continuous casting tundishes, the lifting hydraulic cylinders are usually asynchronous because of abnormal working of the four hydraulic synchronous motors or internal leakage of the lifting hydraulic cylinders. For the 4# continuous casting tundish, the lifting hydraulic cylinders are also usually asynchronous because of factors such as internal leakage of the lifting hydraulic cylinders. Consequently, the continuous casting tundishes are askew or severely askew. Once a continuous casting tundish is severely askew, not only the molten steel in the tundish is very likely to overflow, causing safety accidents for human body and equipment, but also the tundish drain cannot be aligned with an inlet of a continuous casting mould, and the molten steel easily flows out of the continuous casting mould. Consequently, the continuous casting is interrupted, molten steel in a ladle is returned to a furnace, and the molten steel in the tundish is scrapped. In addition, it can be learned from the continuous casting process that if the continuous casting tundish is askew and the position of a submerged the tundish drain is not centered, molten steel in the mould is in an asymmetric flowing state, a heat center deviates, and a longitudinal crack easily occurs on a strand.

[0003] CN 203 614 479 U discloses a wheel provided with a damping device. The wheel comprises a spoke damper, wherein the spoke damper is fixed between a hub and a rim. The spoke damper comprises a working cylinder, a piston rod, a piston, an extension valve, an oil storing cylinder, a compression valve, a compensating valve, a flow valve, a guide base, a dust-proof cover and an oil seal. The piston is arranged in the working cylinder and the piston rod is fixedly arranged on the middle part of the piston. The oil seal is arranged on the top of the working cylinder, wherein the extension valve and the flow valve are arranged on the piston.

[0004] CN 203 740 983 U discloses a continuous casting machine intermediate tank car multi-cylinder synchronous lifting automatic compensation device which comprises lifting oil tanks, tank head locking compensation valve sets, throttles and an intermediate tank car main control valve set. The lifting oil tanks are connected with the intermediate tank car main control valve sets via hydraulic oil paths. The throttles are arranged on the hydraulic oil paths. One tank head locking compensation valve set is arranged at the tank head part of the lower end of the lifting oil tank.

[0005] CN 104 832 499 relates to a deviation-balancing-based lifting synchronization control method and apparatus of a tundish car. The method comprises the following steps: (1) determining proportional valve dead zones corresponding to four oil cylinders, and calculating dead zone compensation dosages of proportional valves and carrying out outputting; (2) according to deviation of a position setting value and an actual position value, calculating a single cylinder closed-loop controlling quantity and carrying out outputting; (3) on the basis of deviation of a synchronization target value and an actual position, calculating a synchronization closed-loop controlling quantity and carrying out outputting; and (4) calculating a final controlling quantity and outputting the quantity information to the four proportional valves.

[0006] DE 10 2006 004 308 discloses a lifting equipment mounted on a casting platform which runs over a casting mold of a continuous casting machine for steel. It runs on a pair of rails, and serves numbers of continuous casting plants. The design includes running drives on each side. Longitudinal and transverse beams form the carriage frame. Between the two transverse beams, only a single lifting beam picks up the distribution channel. Arms on a pair of side support bearings are supported on and fastened to the longitudinal beams. The bearings on the lifting units, comprise rollers on the same axis. The lifting units are hydraulic cylinders on the cylinder casings of the beam bearings. A lifting beam rocker for the distribution channel, has a release side. The lifting beam has two symmetrical, paired resting locations for the distribution channel. An associated spring-loading mechanism is detailed. The rocker runs on a transverse

axis parallel to the transverse beams, on the release side in the lifting carrier.

[0007] US 6 837 054 B2 describes an actuator assembly comprising a master actuator and at least one slave actuator having a cylinder containing a piston defining two chambers in the cylinder. A first chamber of the slave actuator is connected to an outlet of a directional control valve which is connected to a hydraulic control circuit and to a control member whose position determines the pressure in the first chamber of the slave actuator. A displacement of the piston of the master actuator its transferred to the control member of the control valve associated with the slave actuator by means of a mechanical transmission such as a flexible linear rolling bearing. Thus, the displacement of the piston of the slave actuator is servo-controlled to the displacement of the piston of the master actuator by controlling the position of the control member of the control valve associated with the slave actuator.

[0008] CN 105 836 422 discloses a synchronous control method for two independent motor drive type steel conveying chains. The method comprises driving type steel conveying chain synchronous control and driven type steel conveying chain synchronous control, according to the driving type steel conveying chain synchronous control and the driven type steel conveying chain synchronous control, retreating terminal position values of a main conveying chain and a slave conveying chain are 0 mm, and given position values and actual position values of the main conveying chain and the slave conveying chain are positive values or zero.

SUMMARY

[0009] The present disclosure provides a synchronization control method based on a synchronization control system for lifting hydraulic cylinders of a continuous casting tundish, to resolve an existing problem that synchronization control accuracy of a hydraulic cylinder synchronization control mode based on four hydraulic synchronous motors or a universal master/slave hydraulic cylinder synchronization control mode based on an independent PI regulator and proportion regulation valve is easily affected by factors such as leakage of a hydraulic system (such as internal leakage of a hydraulic cylinder), different manufacturing accuracy of hydraulic elements, and uneven load.

[0010] The present disclosure provides a synchronization control method based on a synchronization control system for lifting hydraulic cylinders of a continuous casting tundish, where the system includes a synchronization control subsystem for a master lifting hydraulic cylinder of a continuous casting tundish and a synchronization control subsystem for slave lifting hydraulic cylinders of a continuous casting tundish. The synchronization control subsystem for a master lifting hydraulic cylinder of a continuous casting tundish includes: a master hydraulic cylinder synchronization position deviation out-of-range control unit consisting of functional blocks LZSTC01-LZSTC11 and LZSTC24-LZSTC26; a master hydraulic cylinder synchronization position deviation velocity correction unit consisting of functional blocks LZSTC19-LZSTC23 and LZSTC51-LZSTC60; a master/slave hydraulic cylinder fault interruption control unit consisting of functional blocks LZSTC44-LZSTC46; a master hydraulic cylinder manual lifting synchronization control unit consisting of functional blocks LZSTC12-LZSTC15, LZSTC27-LZSTC30, LZSTC34-LZSTC38, and LZSTC43; a master hydraulic cylinder automatic position holding control unit consisting of functional blocks LZSTC16-LZSTC18, LZSTC31-LZSTC33, LZSTC39-LZSTC43, and LZSTC48-LZSTC50; and a master hydraulic cylinder lifting velocity closed-loop control unit consisting of functional blocks LZSTC47, LZSTC61-LZSTC63, andLZSTC67. The synchronization control subsystem for slave lifting hydraulic cylinders of a continuous casting tundish includes: a slave hydraulic cylinder synchronization position deviation out-of-range control unit consisting of functional blocks LZSTC100, LZSTC101, and LZSTC104; a slave hydraulic cylinder synchronization position deviation velocity correction unit consisting of functional blocks LZSTC116-LZSTC120 and LZSTC121-LZSTC130; a slave hydraulic cylinder manual lifting synchronization control unit consisting of functional blocks LZSTC102, LZSTC103, LZSTC105-LZSTC108, LZSTC134-LZSTC136, and LZSTC138; a slave hydraulic cylinder automatic position holding control unit consisting of functional blocks LZSTC110-LZSTC115, LZSTC131-LZSTC133, LZSTC137, and LZSTC138; and a slave hydraulic cylinder lifting velocity closed-loop control unit consisting of functional blocks LZSTC139-LZSTC142 and LZSTC146. To synchronously move the master hydraulic cylinder and the slave hydraulic cylinders up or down, the synchronization control method for the lifting hydraulic cylinders of the continuous casting tundish based on the synchronization control system for the lifting hydraulic cylinders of the continuous casting tundish includes: a synchronization control method for the master lifting hydraulic cylinder of the continuous casting tundish and a synchronization control method for the slave lifting hydraulic cylinders of the continuous casting tundish.

[0011] The synchronization control method for the master lifting hydraulic cylinder of the continuous casting tundish includes the following steps:

A1. When the continuous casting tundish moves down, the master hydraulic cylinder synchronization position deviation out-of-range control unit obtains a minimum value ΔSms.b.min of a difference between a position value of the master hydraulic cylinder and a position value of each slave hydraulic cylinder. If the value ΔSms.b.min is less than or equal to a set maximum allowable position deviation negative value, the master hydraulic cylinder stops moving down until a position deviation value between the master

hydraulic cylinder and a slowest declining slave hydraulic cylinder is greater than the set maximum allowable position deviation negative value. When the continuous casting tundish moves up, the master hydraulic cylinder synchronization position deviation out-of-range control unit obtains a maximum value ΔSms.f.max of a difference between an actual position value of the master hydraulic cylinder and an actual position value of each slave hydraulic cylinder. If the value ΔSms.f.max is greater than or equal to a set maximum allowable position deviation positive value, the master hydraulic cylinder stops moving up until a position deviation value between the master hydraulic cylinder and a slowest rising slave hydraulic cylinder is less than the set maximum allowable position deviation positive value.

A2. When the continuous casting tundish moves up or down, a synchronization position deviation value ΔSms of the master hydraulic cylinder exceeds a set range, and the master hydraulic cylinder synchronization position deviation velocity correction unit corrects a moving velocity of the master hydraulic cylinder until the position deviation value ΔSms between the master hydraulic cylinder and the slave hydraulic cylinders is within the set range again.

[0012] The master hydraulic cylinder synchronization position deviation velocity correction unit includes a master hydraulic cylinder velocity correction subunit and a master hydraulic cylinder synchronization deviation quick correction subunit.

[0013] When the continuous casting tundish moves down, and when the synchronization position deviation value ΔSms of the master hydraulic cylinder exceeds a first set range, the master hydraulic cylinder velocity correction subunit multiplies a negative value of the synchronization position deviation value ΔSms of the master hydraulic cylinder by a velocity correction coefficient of a declining synchronization position deviation of the master hydraulic cylinder as a velocity correction value of the master hydraulic cylinder. When the continuous casting tundish moves up, and when the synchronization position deviation value ΔSms of the master hydraulic cylinder exceeds the first set range, the master hydraulic cylinder velocity correction subunit multiplies the negative value of the synchronization position deviation value ΔSms of the master hydraulic cylinder by a velocity correction coefficient of a rising synchronization position deviation of the master hydraulic cylinder as a velocity correction value of the master hydraulic cylinder.

[0014] When the continuous casting tundish moves up or down, and when the synchronization position deviation value ΔSms of the master hydraulic cylinder exceeds a second set range, the master hydraulic cylinder synchronization deviation quick correction subunit uses a velocity correction value of the synchronization position deviation of the master hydraulic cylinder having a direction reverse to the synchronization position deviation value ΔSms of the master hydraulic cylinder, as the velocity correction value of the master hydraulic cylinder.

[0015] A3. For a lifting hydraulic control system of the continuous casting tundish, when a displacement sensor of the master lifting hydraulic cylinder or any slave lifting hydraulic cylinder of the tundish is faulty, a hydraulic system is faulty, or a lifting operation of the continuous casting tundish is prohibited or urgently stopped, the master/slave hydraulic cylinder fault interruption control unit controls an output of the master/slave hydraulic cylinder lifting velocity closed-loop control unit to be blocked, and a control voltage of the master/slave hydraulic cylinder proportion valve is always zero, that is, the lifting control of the master/slave hydraulic cylinder is blocked.

[0016] A4. When the lifting hydraulic control system of the continuous casting tundish is in a manual linkage mode of tundish lifting or in a manual/automatic linkage mode of tundish lifting, during a period in which a manual declining instruction for the continuous casting tundish is delivered, if the synchronization position deviation value ΔSms of the master hydraulic cylinder is greater than the set maximum allowable position deviation negative value and the master hydraulic cylinder is not at a declining end position, the master hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual declining velocity of the master/slave hydraulic cylinder to the master hydraulic cylinder lifting velocity closed-loop control unit in a released state. If the position deviation between the master hydraulic cylinder and the slowest declining slave hydraulic cylinder exceeds the set range, the position deviation between the master hydraulic cylinder and the slowest declining slave hydraulic cylinder is corrected by the master hydraulic cylinder synchronization position deviation velocity correction unit. If the position deviation between the master hydraulic cylinder and the slowest declining slave hydraulic cylinder is less than or equal to a set maximum allowable position deviation negative value, the master hydraulic cylinder stops moving down until a position deviation value between the two is greater than the set maximum allowable position deviation negative value again. During a period in which a manual rising instruction for the continuous casting tundish is delivered, if the synchronization position deviation value ΔSms of the master hydraulic cylinder is less than the set maximum allowable position deviation positive value and the master hydraulic cylinder is not at a rising end position, the master hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual rising velocity of the master/slave hydraulic cylinder to the master hydraulic cylinder lifting velocity closed-loop control unit in a released state. If the position deviation between the master hydraulic cylinder and the slowest rising slave hydraulic cylinder exceeds the set range, the position deviation between the master hydraulic cylinder and the slowest rising slave hydraulic cylinder is corrected by the master hydraulic cylinder synchronization position deviation velocity correction unit. If the position deviation between the master hydraulic cyl-

inder and the slowest rising slave hydraulic cylinder is greater than or equal to a set maximum allowable position deviation positive value, the master hydraulic cylinder stops moving up until a position deviation value between the two is less than the set maximum allowable position deviation positive value again.

[0017] A5. When a manual lifting instruction for the continuous casting tundish is terminated, if a difference between the master/slave hydraulic cylinder position holding value SZWBZ after the termination of the manual lifting instruction for the continuous casting tundish and an actual position value of the master hydraulic cylinder is greater than a set allowable position deviation positive value, a position regulator of the master hydraulic cylinder and the master hydraulic cylinder lifting velocity closed-loop control unit are in a released state. The position regulator of the master hydraulic cylinder outputs a corresponding position correction velocity reference value of the master hydraulic cylinder to reduce the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder is less than or equal to the set allowable position deviation positive value. If the difference between the master/slave hydraulic cylinder position holding value SZWBZ after the termination of the manual lifting instruction for the continuous casting tundish and the actual position value of the master hydraulic cylinder is less than the set allowable position deviation negative value, the position regulator of the master hydraulic cylinder and the master hydraulic cylinder lifting velocity closed-loop control unit are in a released state. The position regulator of the master hydraulic cylinder outputs a corresponding position correction velocity reference value of the master hydraulic cylinder to increase the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder is greater than or equal to the set allowable position deviation negative value.

[0018] A6. When no fault interruption occurs in the master and slave hydraulic cylinders, and when the master hydraulic cylinder manual lifting synchronization control unit or the master hydraulic cylinder automatic position holding control unit sends a signal for releasing the master hydraulic cylinder lifting velocity control unit, the master hydraulic cylinder lifting velocity closed-loop control subunit converts a given input velocity into a corresponding control voltage output of the proportion regulation valve of the master hydraulic cylinder, until the master hydraulic cylinder reaches a desired position and is within an allowable position deviation range, and then a signal for enabling the master hydraulic cylinder lifting velocity control unit sent by the master hydraulic cylinder manual lifting synchronization control unit or the master hydraulic cylinder automatic position holding unit is blocked.

[0019] The control method for the slave lifting hydraulic cylinders of the continuous casting tundish includes the following steps:

B1. When the continuous casting tundish moves down, the slave hydraulic cylinder synchronization position deviation out-of-range control unit obtains a difference ΔSsnm between a position value of each slave hydraulic cylinder and a position value of the master hydraulic cylinder. If a value of ΔSsnm is less than or equal to a set maximum allowable position deviation negative value, the slave hydraulic cylinder stops moving down until the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is greater than the set maximum allowable position deviation negative value.

When the continuous casting tundish moves up, the slave hydraulic cylinder synchronization position deviation out-of-range control unit obtains a difference ΔSsnm between a position value of each slave hydraulic cylinder and a position value of the master hydraulic cylinder. If a value of ΔSsnm is greater than or equal to a set maximum allowable position deviation positive value, the slave hydraulic cylinder stops moving up until the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is less than the set maximum allowable position deviation positive value.

B2. When the continuous casting tundish moves up or down, if a synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds a set range, the slave hydraulic cylinder synchronization position deviation velocity correction unit corrects a moving velocity of the slave hydraulic cylinder until the position deviation value ΔSsnm between the slave hydraulic cylinder and the master hydraulic cylinder is within the set range again.

[0020] The slave hydraulic cylinder synchronization position deviation velocity correction unit includes a slave hydraulic cylinder velocity correction subunit and a slave hydraulic cylinder synchronization deviation quick correction subunit.

[0021] When the continuous casting tundish moves down, and when the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds a first set range, the slave hydraulic cylinder velocity correction subunit multiplies a negative value of the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder by a velocity correction coefficient of a declining synchronization position deviation of the slave hydraulic cylinder as a velocity correction value of the slave hydraulic cylinder. When the continuous casting tundish moves up, and when the synchronization position

deviation value ΔSsnm of the slave hydraulic cylinder exceeds the first set range, the slave hydraulic cylinder velocity correction subunit multiplies the negative value of the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder by a velocity correction coefficient of a rising synchronization position deviation of the slave hydraulic cylinder as a velocity correction value of the slave hydraulic cylinder.

[0022] When the continuous casting tundish moves up or down, and when the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds a second set range, the slave hydraulic cylinder synchronization deviation quick correction subunit uses a velocity correction value of the synchronization position deviation of the slave hydraulic cylinder having a direction reverse to the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder, as the velocity correction value of the slave hydraulic cylinder.

[0023] B3. When the lifting hydraulic control system of the continuous casting tundish is in a manual linkage mode of tundish lifting or in a manual/automatic linkage mode of tundish lifting, during a period in which a manual declining instruction for the continuous casting tundish is delivered, if the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is greater than the set maximum allowable position deviation negative value and the master hydraulic cylinder is not at a declining end position, the slave hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual declining velocity of the master/slave hydraulic cylinder to the slave hydraulic cylinder lifting velocity closed-loop control unit in a released state. If the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds the set range, the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is corrected by the master hydraulic cylinder synchronization position deviation velocity correction unit. If the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is less than or equal to a set maximum allowable position deviation negative value, the slave hydraulic cylinder stops moving down until a position deviation value between the two is greater than the set maximum allowable position deviation negative value again. During a period in which a manual rising instruction for the continuous casting tundish is delivered, if the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is less than the set maximum allowable position deviation positive value and the master hydraulic cylinder is not at a rising end position, the slave hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual rising velocity of the master/slave hydraulic cylinder to the slave hydraulic cylinder lifting velocity closed-loop control unit in a released state. If the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds the set range, the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is corrected by the slave hydraulic cylinder synchronization position deviation velocity correction unit. If the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is greater than or equal to a set maximum allowable position deviation positive value, the slave hydraulic cylinder stops moving up until a position deviation value between the two is less than the set maximum allowable position deviation positive value again.

[0024] B4. When a manual lifting instruction for the continuous casting tundish is terminated, if a difference between the master/slave hydraulic cylinder position holding value SZWBZ after the termination of the manual lifting instruction for the continuous casting tundish and an actual position value of the slave hydraulic cylinder is greater than a set allowable position deviation positive value, a position regulator of the slave hydraulic cylinder and the slave hydraulic cylinder lifting velocity closed-loop control unit are in a released state. The position regulator of the slave hydraulic cylinder outputs a corresponding position correction velocity reference value of the slave hydraulic cylinder to reduce the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder is less than or equal to the set allowable position deviation positive value. If the difference between the master/slave hydraulic cylinder position holding value SZWBZ after the termination of the manual lifting instruction for the continuous casting tundish and the actual position value of the slave hydraulic cylinder is less than the set allowable position deviation negative value, the position regulator of the slave hydraulic cylinder and the slave hydraulic cylinder lifting velocity closed-loop control unit are in a released state. The position regulator of the slave hydraulic cylinder outputs a corresponding position correction velocity reference value of the slave hydraulic cylinder to increase the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder is greater than or equal to the set allowable position deviation negative value.

[0025] B5. When no fault interruption occurs in the master and slave hydraulic cylinders, and when the slave hydraulic cylinder manual lifting synchronization control unit or the slave hydraulic cylinder automatic position holding control unit sends a signal for releasing the slave hydraulic cylinder lifting velocity control unit, the slave hydraulic cylinder lifting velocity closed-loop control subunit converts a given input velocity into a corresponding control voltage output of the proportion regulation valve of the slave hydraulic cylinder, until the slave hydraulic cylinder reaches a desired position and is within an allowable position deviation range, and then a signal for enabling the slave hydraulic cylinder lifting velocity con-

trol unit sent by the slave hydraulic cylinder manual lifting synchronization control unit or the slave hydraulic cylinder automatic position holding unit is blocked.

[0026] According to the synchronization control method for the lifting hydraulic cylinders of the continuous casting tundish in the embodiments of the present disclosure, the master hydraulic cylinder synchronization position deviation velocity correction unit and the slave hydraulic cylinder synchronization position deviation velocity correction unit correct the position deviation exceeding the set range between the master hydraulic cylinder and the slave hydraulic cylinder in real time. If the deviation between the two continues to increase beyond the set maximum allowable position deviation, the master hydraulic cylinder synchronization position deviation out-of-range control unit and the slave hydraulic cylinder synchronization position deviation out-of-range control unit control the fast moving master hydraulic cylinder or slave hydraulic cylinder to stop moving, until the position deviation between the two is less than the set maximum allowable position deviation again. In addition, the master hydraulic cylinder automatic position holding control unit and the slave hydraulic cylinder automatic position holding control unit are used to avoid position deviation of the master hydraulic cylinder and the slave hydraulic cylinder without a manual instruction. Therefore, according to the synchronization control method for the lifting hydraulic cylinders of the continuous casting tundish, the lifting hydraulic cylinders of the continuous casting tundish can be synchronously moved, there is relatively high fault tolerance during operation of the lifting hydraulic cylinders of the continuous casting tundish, and the lifting hydraulic cylinders of the continuous casting tundish can be synchronously moved in cases of leakage of a hydraulic cylinder, different manufacturing accuracy of hydraulic elements, and uneven load.

BRIEF DESCRIPTION OF DRAWINGS

[0027]

FIG. 1 is a diagram of a hydraulic system for a continuous casting tundish lifting mechanism according to an embodiment of the present disclosure;

FIG. 2 is a schematic structural diagram of a synchronization control subsystem for a master lifting hydraulic cylinder of a continuous casting tundish according to an embodiment of the present disclosure; and

FIG. 3 is a schematic structural diagram of a synchronization control subsystem for a slave lifting hydraulic cylinder of a continuous casting tundish according to an embodiment of the present disclosure.

DESCRIPTION OF EMBODIMENTS

[0028] To make the objects, technical solutions, and advantages of the present disclosure clearer, the following further describes the present disclosure in detail with reference to the accompanying drawings and embodiments. It should be understood that the specific embodiments described herein are merely intended to explain the present disclosure and are not intended to limit the present disclosure.

[0029] FIG. 1 is a diagram of a hydraulic system for a continuous casting tundish lifting mechanism according to an embodiment of the present disclosure. FIG. 2 is a schematic structural diagram of a synchronization control subsystem for a master lifting hydraulic cylinder of a continuous casting tundish according to an embodiment of the present disclosure. FIG. 3 is a schematic structural diagram of a synchronization control subsystem for a slave lifting hydraulic cylinder of a continuous casting tundish according to an embodiment of the present disclosure. For ease of description, only a part related to the embodiments of the present disclosure is shown.

[0030] In FIG. 2 and FIG. 3, SUB represents a subtractor; NSW represents a "digital input switch" functional block, where when I = '1', Y = X2 and when 1 = '0', Y = X1; NCM represents a "numeric comparison" functional block, where when X1 > X2, QU is '1', when X1 = X2, QE is '1', and when X1 < X2, QL is '1'; RSR represents an "RS trigger with a preferential reset end R" functional block, where when S is '1' and R is '0', Q is '1' and QN is '0', when S is '1' and R is '1', Q is '0' and QN is '1', when S is '0' and R is '0', Q and QN remain unchanged, and when S is '0' and R is '1', Q is '0' and QN is '1'; RGJ represents an "integrator" functional block; PIC represents a PI regulator functional block; ADD represents an adder; OR represents an "OR" gate; AND represents an "AND" gate; NOT represents a "NOT" gate; SZWBZ represents position holding values of master and slave lifting hydraulic cylinders of a continuous casting tundish; Sm.act represents an actual position value of the master hydraulic cylinder; Ss1.act, Ss2.act, and Ss3.act represent actual position values of a first, a second, and a third slave lifting hydraulic cylinders of the continuous casting tundish, respectively; ΔSms.b.min represents a minimum value of a difference between the actual position value of the master hydraulic cylinder and the actual position value of each slave hydraulic cylinder when the continuous casting tundish moves down (namely, a position deviation value between the master hydraulic cylinder and a slowest declining slave hydraulic cylinder when the continuous casting tundish moves down);

[0031] ΔSms.f.max represents a maximum value of a difference between the actual position value of the master hydraulic cylinder and the actual position value of each slave hydraulic cylinder when the continuous casting tundish moves up (namely, a position deviation value between the master hydraulic cylinder and a slowest rising slave hydraulic cylinder when the continuous casting tundish moves up); ΔSms represents a synchronization position deviation value of the master hydraulic cylinder (namely, a position deviation value between the master hydraulic cylinder and the slowest rising or declining

slave hydraulic cylinder); and ΔSsnm represents a synchronization position deviation value of the slave hydraulic cylinder (Sn) (namely, a position deviation value between the slave hydraulic cylinder and the master hydraulic cylinder).

[0032] The synchronization control systems for the master and slave lifting hydraulic cylinders of the continuous casting tundish are shown in FIG. 2 and FIG. 3. In the control systems, declining end position values of the master and slave lifting hydraulic cylinders are all 0 mm, and position holding values and actual position values of the master and slave lifting hydraulic cylinders are all positive values or zero.

[0033] The synchronization control system for the lifting hydraulic cylinders of the continuous casting tundish includes: a synchronization control subsystem for the master lifting hydraulic cylinder of the continuous casting tundish and a synchronization control subsystem for the slave lifting hydraulic cylinders of the continuous casting tundish. The synchronization control subsystem for the master lifting hydraulic cylinder of the continuous casting tundish mainly includes six control units: a master hydraulic cylinder synchronization position deviation out-of-range control unit consisting of functional blocks LZSTC01-LZSTC11 and LZSTC24-LZSTC26; a master hydraulic cylinder synchronization position deviation velocity correction unit consisting of functional blocks LZSTC19-LZSTC23 and LZSTC51-LZSTC60; a master hydraulic cylinder manual lifting synchronization control unit consisting of functional blocks LZSTC12-LZSTC15, LZSTC27-LZSTC30, LZSTC34-LZSTC38, and LZSTC43; a master hydraulic cylinder automatic position holding control unit consisting of functional blocks LZSTC16-LZSTC18, LZSTC31-LZSTC33, LZSTC39-LZSTC43, and LZSTC48-LZSTC50; a master/slave hydraulic cylinder fault interruption control unit consisting of functional blocks LZSTC44-LZSTC46; and a master hydraulic cylinder lifting velocity closed-loop control unit consisting of functional blocks LZSTC47, LZSTC61-LZSTC63, and LZSTC67.

[0034] To synchronously move the master hydraulic cylinder and the slave hydraulic cylinders up or down, the synchronization control method for the lifting hydraulic cylinders of the continuous casting tundish based on the synchronization control system for the lifting hydraulic cylinders of the continuous casting tundish includes: a synchronization control method for the master lifting hydraulic cylinder of the continuous casting tundish and a synchronization control method for the slave lifting hydraulic cylinders of the continuous casting tundish. The synchronization control method for the master lifting hydraulic cylinder of the continuous casting tundish includes the following steps:

A1. When the master and slave hydraulic cylinders move up or down, if a position deviation between the master hydraulic cylinder and a slowest slave hydraulic cylinder in a desired moving direction during the rising movement is greater than or equal to a set maximum allowable position deviation positive value (for example, 6 mm), or a position deviation between the master hydraulic cylinder and a slowest slave hydraulic cylinder in a desired moving direction during the declining movement is less than or equal to a set maximum allowable position deviation negative value (for example, -6 mm), the master hydraulic cylinder is controlled to stop moving until the position deviation between the two is within the set maximum allowable position deviation again. Then, the master hydraulic cylinder increases, at a set acceleration, a velocity to a set velocity, and continues to move toward the desired direction, so that the position deviation between the master hydraulic cylinder and the slowest slave hydraulic cylinder in the desired moving direction is controlled to be within the maximum allowable position deviation. Based on this, a master hydraulic cylinder synchronization position deviation out-of-range control unit is designed in the synchronization control subsystem for the master hydraulic cylinder. In this unit, the functional blocks LZSTC01-LZSTC07 obtain a minimum value (namely, ΔSms.b.min) of a difference between a position value of the master hydraulic cylinder and a position value of each slave hydraulic cylinder during the declining movement of the continuous casting tundish; the functional blocks LZSTC01-LZSTC03 and LZSTC08-LZSTC11 obtain a maximum value (namely, ΔSms.f.max) of a difference between an actual position value of the master hydraulic cylinder and an actual position value of each slave hydraulic cylinder during the rising movement of the continuous casting tundish. In this way, when the continuous casting tundish moves down, if a value of ΔSms.b.min is less than or equal to the set maximum allowable position deviation negative value (for example, -6 mm), an output end QU of the functional block LZSTC26 is changed from the '1' state to the '0' state, so that the master hydraulic cylinder stops moving down until the position deviation value between the master hydraulic cylinder and the slowest declining slave hydraulic cylinder is greater than the set maximum allowable position deviation negative value (for example, -6 mm, that is, the position deviation between the master hydraulic cylinder and the slowest declining slave hydraulic cylinder is less than 6 mm). When the continuous casting tundish moves up, if a value of ΔSms.f.max is greater than or equal to the set maximum allowable position deviation positive value (for example, 6 mm), an output end QL of the functional block LZSTC25 is changed from the '1' state to the '0' state, so that the master hydraulic cylinder stops moving up until the position deviation value between the master hydraulic cylinder and the slowest rising slave hydraulic cylinder is less than the set maximum allowable position deviation positive value (for example, 6 mm).

A2. When the master hydraulic cylinder moves synchronously with the slave hydraulic cylinder, if the master hydraulic cylinder urgently stops frequently because the position deviation exceeds the maximum allowable position deviation, the master hydraulic cylinder is prone to position oscillation during synchronous movement. This causes position oscillation of the slave hydraulic cylinder. For this reason, both the master hydraulic cylinder synchronization position deviation out-of-range control unit and the master hydraulic cylinder synchronization position deviation velocity correction unit are designed in the synchronization control subsystem for the master lifting hydraulic cylinder of the continuous casting tundish. During synchronous movement of the master and slave hydraulic cylinders, once a synchronization position deviation value ΔSms of the master hydraulic cylinder exceeds a set range, the master hydraulic cylinder synchronization position deviation velocity correction unit corrects a moving velocity of the master hydraulic cylinder in a timely manner, until the position deviation value between the master hydraulic cylinder and the slave hydraulic cylinder is within the set range again. This can significantly reduce a probability that the position deviation value ΔSms of the master hydraulic cylinder reaches or exceeds the maximum allowable position deviation. The master hydraulic cylinder synchronization position deviation velocity correction unit includes two subunits: a master hydraulic cylinder velocity correction subunit that consists of the functional blocks LZSTC19-LZSTC23 and LZSTC51-LZSTC56 and is inversely proportional to the synchronization position deviation value ΔSms of the master hydraulic cylinder; and a master hydraulic cylinder synchronization deviation quick correction subunit consisting of the functional blocks LZSTC57-LZSTC60. In the master hydraulic cylinder velocity correction subunit that is inversely proportional to the synchronization position deviation value ΔSms of the master hydraulic cylinder, an input end X2 of the functional block LZSTC56 is equal to a negative value of the synchronization position deviation value ΔSms of the master hydraulic cylinder multiplied by a set coefficient (which is also referred to as a velocity correction coefficient of a synchronization position deviation of the master hydraulic cylinder). Considering that there is a major difference between a rising velocity and a declining velocity of the continuous casting tundish (the rising velocity is usually approximately twice the declining velocity), in this case, to control both the rising synchronization position deviation and the declining synchronization position deviation of the master hydraulic cylinder to be within a set allowable range, different velocity correction coefficients of a synchronization position deviation are used for synchronization control of the rising and declining of the master hydraulic cylinder, that is, a velocity correction coefficient of a rising synchronization position deviation of the master hydraulic cylinder and a velocity correction coefficient of a declining synchronization position deviation of the master hydraulic cylinder. For this reason, a function of selecting a velocity correction coefficient of a synchronization position deviation of the master hydraulic cylinder consisting of the functional blocks LZSTC19-LZSTC23 and LZSTC54 is set in the master hydraulic cylinder velocity correction subunit that is inversely proportional to the synchronization position deviation value ΔSms of the master hydraulic cylinder. When the master hydraulic cylinder moves up, an output end Q of the functional block LZSTC23 in this phase is in the '1' state. In this case, a control end I of the "digital input switch" functional block LZSTC54 in this phase is also in the '1' state. Therefore, the velocity correction coefficient of a synchronization position deviation of the master hydraulic cylinder is the velocity correction coefficient (for example, 20) of a rising synchronization position deviation of the master hydraulic cylinder. When the master hydraulic cylinder moves down or stops moving, the output end Q of the functional block LZSTC23 in this phase is in the '0' state. In this case, the control end I of the "digital input switch" functional block LZSTC54 in this phase is also in the '0' state. Therefore, the velocity correction coefficient of a synchronization position deviation of the master hydraulic cylinder is the velocity correction coefficient (for example, 10) of a declining synchronization position deviation of the master hydraulic cylinder. In this way, when the synchronization position deviation value ΔSms of the master hydraulic cylinder exceeds a first set range (for example, ±0.5 mm), a control end I of the functional block LZSTC56 is changed from the '0' state to the '1' state. Therefore, an output value of an output end Y of the functional block LZSTC56 is equal to an input value of an input end X2 of the functional block LZSTC56. In this way, the subunit outputs a velocity correction value that is inversely proportional to the synchronization position deviation value ΔSms of the master hydraulic cylinder. This portion of velocity correction value gradually decreases the synchronization position deviation between the master hydraulic cylinder and the slowest moving slave hydraulic cylinder, until the position deviation value ΔSms of the master hydraulic cylinder is within the first set range (for example, ±0.5 mm) again. When the continuous casting tundish moves up or down, if the synchronization position deviation value ΔSms of the master hydraulic cylinder exceeds a second set range, the master hydraulic cylinder synchronization deviation quick correction subunit uses a velocity correction value of the synchronization position deviation of the master hydraulic cylinder having a direction reverse to the synchronization position deviation value ΔSms of the master hydraulic cylinder, as the velocity cor-

rection value of the master hydraulic cylinder. To be specific, when the synchronization position deviation value ΔSms of the master hydraulic cylinder is positive and is greater than a positive end value (for example, 2 mm) of the second set range, a control end I of the functional block LZSTC58 in the master hydraulic cylinder synchronization position deviation quick correction subunit is changed from the '0' state to the '1' state. Therefore, an output value of an output end Y of the functional block LZSTC58 is equal to an input value (for example, -2 V) of an input end X2 of the functional block LZSTC58. This portion of velocity correction value quickly decreases the synchronization position deviation value ΔSms (>0) of the master hydraulic cylinder, until the position deviation value ΔSms of the master hydraulic cylinder is less than the positive end value (for example, 2 mm) of the second set range. When the synchronization position deviation value ΔSms of the master hydraulic cylinder is negative and is less than a negative end value (for example, -2 mm) of the second set range, a control end I of the functional block LZSTC60 in the master hydraulic cylinder synchronization position deviation quick correction subunit is changed from the '0' state to the '1' state. Therefore, an output value of an output end Y of the functional block LZSTC60 is equal to an input value (for example, 2 V) of an input end X2 of the functional block LZSTC60. This portion of velocity correction value quickly increases the synchronization position deviation value ΔSms (<0) of the master hydraulic cylinder, until the position deviation value ΔSms of the master hydraulic cylinder is greater than the negative end value (for example, -2 mm) of the second set range. It can be learned from the foregoing description that the master hydraulic cylinder synchronization position deviation velocity correction unit can correct the velocity of the master hydraulic cylinder in a timely manner before the synchronization position deviation exceeds a limit (for example, ±6 mm). This can avoid urgent stop of the master hydraulic cylinder during synchronous movement because a position deviation between the master hydraulic cylinder and a slowest rising/declining slave hydraulic cylinder exceeds a set maximum allowable position deviation value.

A3. To prevent a lifting hydraulic control system of the continuous casting tundish from rising or declining the tundish in a faulty state, a master/slave hydraulic cylinder lifting fault interruption control unit is designed in the synchronization control subsystem for the master hydraulic cylinder. For a lifting hydraulic control system of the continuous casting tundish, when a displacement sensor of the master lifting hydraulic cylinder or any slave lifting hydraulic cylinder of the tundish is faulty, a hydraulic system is faulty, or a lifting operation of the continuous casting tundish is prohibited or urgently stopped, an output end Q of the functional block LZSTC46 in this unit is changed from the '1' state to the '0' state. In this way, an output of the master/slave hydraulic cylinder lifting velocity control unit is blocked, and a control voltage of the master/slave hydraulic cylinder proportion valve is always zero, that is, the lifting control of the master/slave hydraulic cylinder is blocked.

A4. For the master hydraulic cylinder manual lifting synchronization control unit, when the lifting hydraulic control system of the continuous casting tundish is in a manual linkage mode of tundish lifting or in a manual/automatic linkage mode of tundish lifting, during a period in which a manual declining instruction for the continuous casting tundish is delivered, a value of an output end Y (point A in FIG. 2) of the functional block LZSTC14 in this unit is equal to a set value (for example, -2 V) of a declining velocity of the master hydraulic cylinder, and an output end QL of the functional block LZSTC15 is in the '1' state. In this case, if the position deviation value (namely, ΔSms.b.min) between the master hydraulic cylinder and the slowest declining slave hydraulic cylinder is greater than the set maximum allowable position deviation negative value (for example, -6 mm) and the master hydraulic cylinder is not at the declining end position, output ends Q of the functional blocks LZSTC30, LZSTC37, and LZSTC43 in the master hydraulic cylinder manual lifting synchronization control unit are in the '1' state. Therefore, a value of an output end Y of the functional block LZSTC38 is equal to a value of an output end Y of the functional block LZSTC14 (namely, a set value of a declining velocity of the master/slave hydraulic cylinder, for example, -2 V). The master hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual declining velocity of the master/slave hydraulic cylinder to the master hydraulic cylinder lifting velocity closed-loop control unit. In addition, an output end Q of the functional block LZSTC43 in the master hydraulic cylinder manual lifting synchronization control unit is in the '1' state, so that the master hydraulic cylinder lifting velocity closed-loop control unit is in a released state. When the continuous casting tundish moves down, the position deviation value between the master hydraulic cylinder and the slowest declining slave hydraulic cylinder is corrected by the master hydraulic cylinder synchronization deviation velocity correction unit. If the position deviation value between the two is less than or equal to the set maximum allowable position deviation negative value (for example, -6 mm), the master hydraulic cylinder stops moving down until the position deviation value between the two is greater than the set maximum allowable position deviation negative value (for example, -6 mm) again. During a period in which a manual rising instruction for the continuous casting tundish is delivered, a value of an output end Y (point A in FIG. 2) of the functional

block LZSTC14 in this unit is equal to a set value (for example, 4 V) of a rising velocity of the master/slave hydraulic cylinder, and an output end QU of the functional block LZSTC15 is in the '1' state. In this case, if the position deviation value (namely, ΔSms.f.max) between the master hydraulic cylinder and the slowest rising slave hydraulic cylinder is less than the set maximum allowable position deviation positive value (for example, 6 mm) and the master hydraulic cylinder is not at the rising end position, output ends Q of the functional blocks LZSTC29, LZSTC37, and LZSTC43 in the master hydraulic cylinder manual lifting synchronization control unit are in the '1' state. Therefore, a value of an output end Y of the functional block LZSTC38 is equal to a value of an output end Y of the functional block LZSTC14 (namely, a set value of a rising velocity of the master/slave hydraulic cylinder, for example, 4 V). The master hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual rising velocity of the master/slave hydraulic cylinder to the master hydraulic cylinder lifting velocity closed-loop control unit. In addition, an output end Q of the functional block LZSTC43 in the master hydraulic cylinder manual lifting synchronization control unit is in the '1' state, so that the master hydraulic cylinder lifting velocity closed-loop control unit is in a released state. When the continuous casting tundish moves up, the position deviation value between the master hydraulic cylinder and the slowest rising slave hydraulic cylinder is corrected by the master hydraulic cylinder synchronization deviation velocity correction unit. If the position deviation value between the two is greater than or equal to the set maximum allowable position deviation positive value (for example, 6 mm), the master hydraulic cylinder stops moving up until the position deviation value between the two is less than the set maximum allowable position deviation positive value (for example, 6 mm) again.

A5. After the continuous casting tundish moves up or down to a desired working position, the operator terminates the manual lifting instruction for the continuous casting tundish, and proportion valves for lifting control of the master and slave hydraulic cylinders are all in a neutral position self-locking state. In this case, if specific internal leakage occurs in the master hydraulic cylinder, the master hydraulic cylinder moves down to some extent after a specific period of time, causing an actual position of the master hydraulic cylinder to deviate from the desired working position. To avoid position deviation of the master hydraulic cylinder without a manual instruction, a master hydraulic cylinder automatic position holding control unit is designed in the synchronization control subsystem for the master hydraulic cylinder. When a manual lifting instruction for the continuous casting tundish is terminated, an output end Q of the functional block LZSTC17 in this unit is changed from the '0' state to the '1' state, and a value of an output end Y of the "digital input switch" functional block LZSTC18 (that is, a master/slave hydraulic cylinder position holding value SZWBZ) is always equal to a value entered at an input end X1 of the functional block at a moment at which the manual lifting instruction for the continuous casting tundish is terminated (that is, an actual position value of the master hydraulic cylinder corresponding to the moment at which the manual lifting instruction is terminated). In this way, when a lifting operation mode of the continuous casting tundish is the manual/automatic linkage mode, the manual lifting instruction for the continuous casting tundish is terminated, and no fault interruption occurs in the master and slave hydraulic cylinders, if a difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder is greater than the set allowable position deviation positive value (for example, 3 mm) after the manual lifting instruction for the continuous casting tundish is terminated, an output end Q of the functional block LZSTC49 in this unit is in the '1' state, so that an enabling control end (EN) of the "PI regulator" functional block LZSTC50 (namely, a position regulator of the master hydraulic cylinder) in this unit is in the '1' state and the position regulator of the master hydraulic cylinder is in a released state; and an output end Q of the functional block LZSTC43 in this unit is in the '1' state, so that the master hydraulic cylinder lifting velocity closed-loop control unit is also in a released state. Therefore, when there is a deviation between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder, the position regulator of the master hydraulic cylinder outputs a corresponding position correction velocity reference value of the master hydraulic cylinder to reduce the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder, until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder is less than or equal to the set allowable position deviation positive value (for example, 3 mm). Similarly, when a lifting operation mode of the continuous casting tundish is the manual/automatic linkage mode, the manual lifting instruction for the continuous casting tundish is terminated, and no fault interruption occurs in the master and slave hydraulic cylinders, if a difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder is less than the set allowable position deviation negative value (for example, -3 mm) after the manual lifting instruction for the continuous casting tundish is terminated, an output end Q of the functional block

LZSTC49 in this unit is in the '1' state, so that an enabling control end (EN) of the "PI regulator" functional block LZSTC50 (namely, a position regulator of the master hydraulic cylinder) in this unit is in the T 1' state and the position regulator of the master hydraulic cylinder is in a released state; and an output end Q of the functional block LZSTC43 in this unit is in the '1' state, so that the master hydraulic cylinder lifting velocity closed-loop control unit is also in a released state. Therefore, when there is a deviation between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder, the position regulator of the master hydraulic cylinder outputs a corresponding position correction velocity reference value of the master hydraulic cylinder to increase the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder, until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder is greater than or equal to the set allowable position deviation negative value (for example, -3 mm).

A6. When the master hydraulic cylinder manual lifting synchronization control unit or the master hydraulic cylinder automatic position holding control unit sends, by setting the output end Q of the functional block LZSTC43 to '1', a signal for releasing the master hydraulic cylinder lifting velocity closed-loop control unit (namely, a signal for enabling the master hydraulic cylinder lifting velocity control unit), a velocity-given integral functional block LZSTC62 and a velocity regulator functional block LZSTC63 in the master hydraulic cylinder lifting velocity closed-loop control unit are in a released state. Therefore, when a given velocity entered at an input end X of the velocity-given integral functional block LZSTC62 in this unit is not zero, this unit outputs, by using a functional block LZSTC67, a corresponding control voltage of the proportion regulation valve of the master hydraulic cylinder, until the master hydraulic cylinder reaches a desired position and is within an allowable position deviation range, and then a signal for enabling the master hydraulic cylinder lifting velocity control unit sent by the master hydraulic cylinder manual lifting synchronization control unit or the master hydraulic cylinder automatic position holding unit is blocked.

[0035] The synchronization control subsystem for the master lifting hydraulic cylinder of the continuous casting tundish includes a proportion regulation valve positive/negative dead zone compensation subunit of the master hydraulic cylinder consisting of functional blocks LZSTC64-LZSTC67. The synchronization control method for the master lifting hydraulic cylinder of the continuous casting tundish further includes:

A7. Usually, there is a specific dead zone between a control voltage of a proportion regulation valve of a hydraulic cylinder and an opening degree of the proportion valve, that is, when the control voltage of the proportion regulation valve reaches a specific value, the opening degree of the proportion regulation valve changes and is approximately proportional to the control voltage of the proportion regulation valve. Therefore, a proportion regulation valve positive/negative dead zone compensation unit of the master hydraulic cylinder is disposed to improve a control response of a proportion regulation valve of the master hydraulic cylinder. When the value of the output end Y of the velocity regulator functional block LZSTC63 (namely, the control voltage of the proportion regulation valve of the master hydraulic cylinder) in the master hydraulic cylinder lifting velocity control unit is greater than zero, a control end I of the functional block LZSTC65 in the proportion regulation valve positive/negative dead zone compensation subunit of the master hydraulic cylinder is in the '1' state, and an output end Y of the functional block LZSTC65 outputs a positive proportion regulation valve dead zone compensation voltage (for example, 1 V). In this way, a control voltage of the proportion regulation valve that is output by the velocity regulator functional block is added to the positive proportion regulation valve dead zone compensation voltage to serve as the control voltage of the proportion regulation valve of the master hydraulic cylinder, thereby speeding up regulation of a positive opening degree of the proportion regulation valve of the master hydraulic cylinder. When the value of the output end Y of the velocity regulator functional block LZSTC63 (namely, the control voltage of the proportion regulation valve of the master hydraulic cylinder) in the master hydraulic cylinder lifting velocity closed-loop control unit is less than zero, a control end I of the functional block LZSTC66 in the proportion regulation valve positive/negative dead zone compensation subunit of the master hydraulic cylinder is in the '1' state, and an output end Y of the functional block LZSTC66 outputs a negative proportion regulation valve dead zone compensation voltage (for example, -1 V). In this way, a control voltage of the proportion regulation valve that is output by the velocity regulator functional block is added to the negative proportion regulation valve dead zone compensation voltage to serve as the control voltage of the proportion regulation valve of the master hydraulic cylinder, thereby speeding up regulation of a negative opening degree of the proportion regulation valve of the master hydraulic cylinder.

[0036] The synchronization control subsystem for the slave lifting hydraulic cylinders of the continuous casting tundish mainly includes five control units: a slave hydraulic cylinder synchronization position deviation out-of-range control unit consisting of functional blocks LZSTC100, LZSTC101, and LZSTC104; a slave hydraulic cylinder synchronization position deviation velocity correction unit consisting of functional blocks LZSTC116-

LZSTC120 and LZSTC121-LZSTC130; a slave hydraulic cylinder manual lifting synchronization control unit consisting of functional blocks LZSTC102, LZSTC103, LZSTC105-LZSTC108, LZSTC134-LZSTC136, and LZSTC138; a slave hydraulic cylinder automatic position holding control unit consisting of functional blocks LZSTC110-LZSTC115, LZSTC131-LZSTC133, LZSTC137, and LZSTC138; and a slave hydraulic cylinder lifting velocity closed-loop control unit consisting of functional blocks LZSTC139-LZSTC142 and LZSTC146.

[0037] The control method for the slave lifting hydraulic cylinders of the continuous casting tundish includes the following steps:

B1. When the master and slave hydraulic cylinders synchronously move up or down, if a position deviation between a slave hydraulic cylinder and the master hydraulic cylinder in a desired moving direction during the rising movement is greater than or equal to a set maximum allowable position deviation positive value (for example, 6 mm), or a position deviation between the slave hydraulic cylinder and the master hydraulic cylinder in a desired moving direction during the declining movement is less than or equal to a set maximum allowable position deviation negative value (for example, -6 mm), the slave hydraulic cylinder is controlled to stop moving until the position deviation between the two is less than the set maximum allowable position deviation again. Then, the slave hydraulic cylinder increases, at a set acceleration, a velocity to a set velocity, and continues to move toward the desired direction, so that the position deviation between the slave hydraulic cylinder and the master hydraulic cylinder in the desired moving direction is controlled to be within the maximum allowable position deviation. Based on this, a slave hydraulic cylinder synchronization position deviation out-of-range control unit is designed in the synchronization control subsystem for the slave hydraulic cylinder. When the continuous casting tundish moves down, if a synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is less than or equal to a set maximum allowable position deviation negative value (for example, -6 mm), an output end QU of the functional block LZSTC104 is changed from the '1' state to the '0' state, so that the slave hydraulic cylinder stops moving down until the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is greater than the set maximum allowable position deviation negative value (for example, -6 mm, that is, the position deviation between the slave hydraulic cylinder and the master hydraulic cylinder is less than 6 mm). When the continuous casting tundish moves up, if a value of ΔSsnm is greater than or equal to a set maximum allowable position deviation positive value (for example, 6 mm), an output end QL of the functional block LZSTC101 is changed from the T 1' state to the '0' state, so that the slave hydraulic cylinder stops moving up until the position deviation value between the slave hydraulic cylinder and the master hydraulic cylinder is less than the set maximum allowable position deviation positive value (for example, 6 mm).

B2. When the slave hydraulic cylinder moves synchronously with the master hydraulic cylinder, if the slave hydraulic cylinder urgently stops frequently because the position deviation exceeds the maximum allowable position deviation, the slave hydraulic cylinder is prone to position oscillation during synchronous movement. This causes position oscillation of the master hydraulic cylinder. For this reason, both the slave hydraulic cylinder synchronization position deviation out-of-range control unit and the slave hydraulic cylinder synchronization position deviation velocity correction unit are designed in the synchronization control subsystem for the slave lifting hydraulic cylinders of the continuous casting tundish. During synchronous movement of the master and slave hydraulic cylinders, once a synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds a set range (for example, ±0.5 mm), the slave hydraulic cylinder synchronization position deviation velocity correction unit corrects a moving velocity of the slave hydraulic cylinder in a timely manner, until the position deviation value between the slave hydraulic cylinder and the master hydraulic cylinder is within the set range again. This can significantly reduce a probability that the position deviation between the slave hydraulic cylinder and the master hydraulic cylinder reaches or exceeds the maximum allowable position deviation. The slave hydraulic cylinder synchronization position deviation velocity correction unit includes two subunits: a slave hydraulic cylinder velocity correction subunit that consists of the functional blocks LZSTC116-LZSTC120 and LZSTC121-LZSTC126 and is inversely proportional to the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder; and a slave hydraulic cylinder synchronization deviation quick correction subunit consisting of the functional blocks LZSTC127-LZSTC130. In the slave hydraulic cylinder velocity correction subunit that is inversely proportional to the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder, an input end X2 of the functional block LZSTC126 is equal to a negative value of the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder multiplied by a set coefficient (which is also referred to as a velocity correction coefficient of a synchronization position deviation of the slave hydraulic cylinder). Considering that there is a major difference between a rising velocity and a declining velocity of the continuous casting tundish (the rising velocity is usually approximately twice the

declining velocity), in this case, to control both the rising synchronization position deviation and the declining synchronization position deviation of the slave hydraulic cylinder to be within a set allowable range, different velocity correction coefficients of a synchronization position deviation are used for synchronization control of the rising and declining of the slave hydraulic cylinder, that is, a velocity correction coefficient of a rising synchronization position deviation of the slave hydraulic cylinder and a velocity correction coefficient of a declining synchronization position deviation of the slave hydraulic cylinder. For this reason, a function of selecting a velocity correction coefficient of a synchronization position deviation of the slave hydraulic cylinder consisting of the functional blocks LZSTC116-LZSTC120 and LZSTC124 is set in the slave hydraulic cylinder velocity correction subunit that is inversely proportional to the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder. When the slave hydraulic cylinder moves up, an output end Q of the functional block LZSTC120 in this phase is in the '1' state. In this case, a control end I of the "digital input switch" functional block LZSTC124 in this phase is also in the '1' state. Therefore, the velocity correction coefficient of a synchronization position deviation of the slave hydraulic cylinder is the velocity correction coefficient (for example, 20) of a rising synchronization position deviation of the slave hydraulic cylinder. When the slave hydraulic cylinder moves down or stops moving, the output end Q of the functional block LZSTC120 in this phase is in the '0' state. In this case, the control end I of the "digital input switch" functional block LZSTC124 in this phase is also in the '0' state. Therefore, the velocity correction coefficient of a synchronization position deviation of the slave hydraulic cylinder is the velocity correction coefficient (for example, 10) of a declining synchronization position deviation of the slave hydraulic cylinder. In this way, when the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds a first set range (for example, ±0.5 mm), a control end I of the functional block LZSTC126 is changed from the '0' state to the '1' state. Therefore, an output value of an output end Y of the functional block LZSTC126 is equal to an input value of an input end X2 of the functional block LZSTC126. In this way, the subunit outputs a velocity correction value that is inversely proportional to the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder. This portion of velocity correction value gradually decreases the synchronization position deviation between the slave hydraulic cylinder and the master hydraulic cylinder, until the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is within the first set range (for example, ±0.5 mm) again.

When the continuous casting tundish moves up or down, and when the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds a second set range, the slave hydraulic cylinder synchronization deviation quick correction subunit uses a velocity correction value of the synchronization position deviation of the slave hydraulic cylinder having a direction reverse to the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder, as the velocity correction value of the slave hydraulic cylinder. To be specific, when the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is positive and is greater than a positive end value (for example, 2 mm) of the second set range, a control end I of the functional block LZSTC128 in the slave hydraulic cylinder synchronization position deviation quick correction subunit is changed from the '0' state to the '1' state. Therefore, an output value of an output end Y of the functional block LZSTC128 is equal to an input value (for example, -2 V) of an input end X2 of the functional block LZSTC128. This portion of velocity correction value quickly decreases the synchronization position deviation value ΔSsnm (>0) of the slave hydraulic cylinder, until the position deviation value ΔSsnm of the slave hydraulic cylinder is less than the positive end value (for example, 2 mm) of the second set range. When the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is negative and is less than a negative end value (for example, -2 mm) of the second set range, a control end I of the functional block LZSTC130 in the slave hydraulic cylinder synchronization position deviation quick correction subunit is changed from the '0' state to the T 1' state. Therefore, an output value of an output end Y of the functional block LZSTC130 is equal to an input value (for example, 2 V) of an input end X2 of the functional block LZSTC130. This portion of velocity correction value quickly increases the synchronization position deviation value ΔSsnm (<0) of the slave hydraulic cylinder, until the position deviation value ΔSsnm of the slave hydraulic cylinder is greater than the negative end value (for example, -2 mm) of the second set range. It can be learned from the foregoing description that the slave hydraulic cylinder synchronization position deviation velocity correction unit can correct the velocity of the slave hydraulic cylinder in a timely manner before the synchronization position deviation exceeds a limit (for example, ±6 mm). This can avoid urgent stop of the slave hydraulic cylinder during synchronous movement because a position deviation between the slave hydraulic cylinder and the master hydraulic cylinder exceeds a maximum allowable position deviation value.

B3. For the slave hydraulic cylinder manual lifting synchronization control unit, when the lifting hydraulic control system of the continuous casting tundish is in a manual linkage mode of tundish lifting or in a

manual/automatic linkage mode of tundish lifting, during a period in which a manual declining instruction for the continuous casting tundish is delivered, if the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is greater than the set maximum allowable position deviation negative value (for example, -6 mm) and the slave hydraulic cylinder is not at the declining end position, output ends Q of the functional blocks LZSTC106, LZSTC135, and LZSTC138 in the slave hydraulic cylinder manual lifting synchronization control unit are in the '1' state. Therefore, a value of an output end Y of the functional block LZSTC136 is equal to a value of an output end Y of the functional block LZSTC14 in the synchronization control subsystem for the master hydraulic cylinder (namely, a set value of a declining velocity of the master/slave hydraulic cylinder, for example, -2 V). The slave hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual declining velocity of the master/slave hydraulic cylinder to the slave hydraulic cylinder lifting velocity closed-loop control unit. In addition, an output end Q of the functional block LZSTC138 in the slave hydraulic cylinder manual lifting synchronization control unit is in the '1' state, so that the slave hydraulic cylinder lifting velocity closed-loop control unit is in a released state. When the continuous casting tundish moves down, the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is corrected by the slave hydraulic cylinder synchronization deviation velocity correction unit. If a value of ΔSsnm is less than or equal to the set maximum allowable position deviation negative value (for example, -6 mm), the slave hydraulic cylinder stops moving down until the value of ΔSsnm is greater than the set maximum allowable position deviation negative value (for example, -6 mm) again. During a period in which a manual rising instruction for the continuous casting tundish is delivered, if the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is less than the set maximum allowable position deviation positive value (for example, 6 mm) and the slave hydraulic cylinder is not at the end position, output ends Q of the functional blocks LZSTC103, LZSTC135, and LZSTC138 in the slave hydraulic cylinder manual lifting synchronization control unit are in the '1' state. Therefore, a value of an output end Y of the functional block LZSTC136 is equal to a value of an output end Y of the functional block LZSTC14 in the synchronization control subsystem for the master hydraulic cylinder (namely, a set value of a rising velocity of the master/slave hydraulic cylinder, for example, 4 V). The slave hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual declining velocity of the master/slave hydraulic cylinder to the slave hydraulic cylinder lifting velocity closed-loop control unit. In addition, an output end Q of the functional block LZSTC138 in the slave hydraulic cylinder manual lifting synchronization control unit is in the T 1' state, so that the slave hydraulic cylinder lifting velocity closed-loop control unit is in a released state. When the continuous casting tundish moves up, the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is corrected by the slave hydraulic cylinder synchronization deviation velocity correction unit. If a value of ΔSsnm is greater than or equal to the set maximum allowable position deviation positive value (for example, 6 mm), the slave hydraulic cylinder stops moving up until the value of ΔSsnm is less than the set maximum allowable position deviation positive value (for example, 6 mm) again.

B4. After the continuous casting tundish moves up or down to a desired working position, the operator terminates the manual lifting instruction for the continuous casting tundish, and proportion valves for lifting control of the master and slave hydraulic cylinders are all in a neutral position self-locking state. In this case, if specific internal leakage occurs in the slave hydraulic cylinder, the slave hydraulic cylinder moves down to some extent after a specific period of time, causing an actual position of the slave hydraulic cylinder to deviate from the desired working position. To avoid position deviation of the slave hydraulic cylinder without a manual instruction, a slave hydraulic cylinder automatic position holding control unit is designed in the synchronization control subsystem for the slave hydraulic cylinder. When a lifting operation mode of the continuous casting tundish is the manual/automatic linkage mode, the manual lifting instruction for the continuous casting tundish is terminated, and no fault interruption occurs in the master and slave hydraulic cylinders, if a difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder is greater than the set allowable position deviation positive value (for example, 3 mm) after the manual lifting instruction for the continuous casting tundish is terminated, an output end Q of the functional block LZSTC114 in this unit is in the '1' state, so that an enabling control end (EN) of the "PI regulator" functional block LZSTC115 (namely, a position regulator of the slave hydraulic cylinder (Sn)) in this unit is in the '1' state and the position regulator of the slave hydraulic cylinder (Sn) is in a released state; and an output end Q of the functional block LZSTC138 in this unit is in the '1' state, so that the slave hydraulic cylinder lifting velocity closed-loop control unit is also in a released state. Therefore, when there is a deviation between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder, the position regulator of the slave hydraulic cylinder outputs a corresponding position correction velocity reference value of the slave

hydraulic cylinder to reduce the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder, until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder is less than or equal to the set allowable position deviation positive value (for example, 3 mm). Similarly, when a lifting operation mode of the continuous casting tundish is the manual/automatic linkage mode, the manual lifting instruction for the continuous casting tundish is terminated, and no fault interruption occurs in the master and slave hydraulic cylinders, if the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder is less than the set allowable position deviation negative value (for example, -3 mm) after the manual lifting instruction for the continuous casting tundish is terminated, an output end Q of the functional block LZSTC114 in this unit is in the '1' state, so that an enabling control end (EN) of the "PI regulator" functional block LZSTC115 (namely, a position regulator of the slave hydraulic cylinder) in this unit is in the '1' state and the position regulator of the slave hydraulic cylinder is in a released state; and an output end Q of the functional block LZSTC138 in this unit is in the '1' state, so that the slave hydraulic cylinder lifting velocity closed-loop control unit is also in a released state. Therefore, when there is a deviation between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder, the position regulator of the slave hydraulic cylinder outputs a corresponding position correction velocity reference value of the slave hydraulic cylinder to increase the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder, until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder is greater than or equal to the set allowable position deviation negative value (for example, -3 mm).

B5. When no fault interruption occurs in the master and slave hydraulic cylinders, and when the slave hydraulic cylinder manual lifting synchronization control unit or the slave hydraulic cylinder automatic position holding control unit sends, by setting the output end Q of the functional block LZSTC138 to '1', a signal for releasing the slave hydraulic cylinder lifting velocity control unit (namely, a signal for enabling the slave hydraulic cylinder lifting velocity control unit), a velocity-given integral functional block LZSTC141 and a velocity regulator functional block LZSTC142 in the slave hydraulic cylinder lifting velocity closed-loop control unit are in a released state. Therefore, when a given velocity entered at an input end X of the velocity-given integral functional block LZSTC142 in this unit is not zero, this unit outputs, by using a functional block LZSTC146, a corresponding control voltage of the proportion regulation valve of the slave hydraulic cylinder, until the slave hydraulic cylinder reaches a desired position and is within an allowable position deviation range, and then a signal for enabling the slave hydraulic cylinder lifting velocity control unit sent by the slave hydraulic cylinder manual lifting synchronization control unit or the slave hydraulic cylinder automatic position holding unit is blocked.

The synchronization control subsystem for the slave lifting hydraulic cylinder of the continuous casting tundish includes a proportion regulation valve positive/negative dead zone compensation unit of the slave hydraulic cylinder consisting of functional blocks LZSTC143-LZSTC146. The synchronization control method for the slave lifting hydraulic cylinders of the continuous casting tundish further includes:

B6. Usually, there is a specific dead zone between a control voltage of a proportion regulation valve of a hydraulic cylinder and an opening degree of the proportion valve, that is, when the control voltage of the proportion regulation valve reaches a specific value, the opening degree of the proportion regulation valve changes and is approximately proportional to the control voltage of the proportion regulation valve. Therefore, a proportion regulation valve positive/negative dead zone compensation unit is disposed in the slave hydraulic cylinder lifting velocity control unit to improve a control response of a proportion regulation valve of the slave hydraulic cylinder. When the value of the output end Y of the velocity regulator functional block LZSTC142 (namely, the control voltage of the proportion regulation valve of the slave hydraulic cylinder) in the slave hydraulic cylinder lifting velocity closed-loop control unit is greater than zero, a control end I of the functional block LZSTC144 in the proportion regulation valve positive/negative dead zone compensation unit of the slave hydraulic cylinder is in the '1' state, and an output end Y of the functional block LZSTC144 outputs a positive proportion regulation valve dead zone compensation voltage (for example, 1 V). In this way, a control voltage of the proportion regulation valve that is output by the velocity regulator functional block is added to the positive proportion regulation valve dead zone compensation voltage to serve as the control voltage of the proportion regulation valve of the slave hydraulic cylinder, thereby speeding up regulation of a positive opening degree of the proportion regulation valve of the slave hydraulic cylinder. When the value of the output end Y of the velocity regulator functional block LZSTC142 (namely, the control voltage of the proportion regulation valve of the slave hydraulic cylinder) in the slave hydraulic

cylinder lifting velocity control unit is less than zero, a control end I of the functional block LZSTC145 in the proportion regulation valve positive/negative dead zone compensation subunit of the slave hydraulic cylinder is in the '1' state, and an output end Y of the functional block LZSTC145 outputs a negative proportion regulation valve dead zone compensation voltage (for example, -1 V). In this way, a control voltage of the proportion regulation valve that is output by the velocity regulator functional block is added to the negative proportion regulation valve dead zone compensation voltage to serve as the control voltage of the proportion regulation valve of the slave hydraulic cylinder, thereby speeding up regulation of a negative opening degree of the proportion regulation valve of the slave hydraulic cylinder.

[0038] According to the synchronization control method for the lifting hydraulic cylinders of the continuous casting tundish in the embodiments of the present disclosure, the master hydraulic cylinder synchronization position deviation velocity correction unit and the slave hydraulic cylinder synchronization position deviation velocity correction unit correct the position deviation exceeding the set range between the master hydraulic cylinder and the slave hydraulic cylinder in real time. If the deviation between the two continues to increase to the set maximum allowable position deviation, the master hydraulic cylinder synchronization position deviation out-of-range control unit and the slave hydraulic cylinder synchronization position deviation out-of-range control unit control the fast moving master hydraulic cylinder or slave hydraulic cylinder to stop moving, until the position deviation between the two is less than the set maximum allowable position deviation again. In addition, the master hydraulic cylinder automatic position holding control unit and the slave hydraulic cylinder automatic position holding control unit are used to avoid position deviation of the master hydraulic cylinder and the slave hydraulic cylinder without a manual instruction. Therefore, according to the synchronization control method for the lifting hydraulic cylinders of the continuous casting tundish, the lifting hydraulic cylinders of the continuous casting tundish can be synchronously moved, there is relatively high fault tolerance during operation of the lifting hydraulic cylinders of the continuous casting tundish, and the lifting hydraulic cylinders of the continuous casting tundish can be synchronously moved in cases of leakage of a hydraulic cylinder, different manufacturing accuracy of hydraulic elements, and uneven load.

[0039] What is described above is merely a preferred embodiment of the present disclosure, and is not intended to limit the present disclosure.

Claims

1. A synchronization control method based on a synchronization control system for lifting hydraulic cylinders of a continuous casting tundish, wherein the synchronization control system for the hydraulic cylinders comprises a synchronization control subsystem for a master lifting hydraulic cylinder of the continuous casting tundish and a synchronization control subsystem for slave lifting hydraulic cylinders of the continuous casting tundish, wherein the synchronization control subsystem for the master lifting hydraulic cylinder of the continuous casting tundish comprises a master hydraulic cylinder synchronization position deviation out-of-range control unit and a master hydraulic cylinder synchronization position deviation velocity correction unit; the synchronization control subsystem for the slave lifting hydraulic cylinders of the continuous casting tundish comprises a slave hydraulic cylinder synchronization position deviation out-of-range control unit and a slave hydraulic cylinder synchronization position deviation velocity correction unit; and the synchronization control method for the lifting hydraulic cylinders of the continuous casting tundish based on the synchronization control system for the lifting hydraulic cylinders of the continuous casting tundish comprises:

   1) when the continuous casting tundish moves down, the master hydraulic cylinder synchronization position deviation out-of-range control unit obtains a minimum value ΔSms.b.min of a difference between a position value of the master hydraulic cylinder and a position value of each slave hydraulic cylinder; if a value of ΔSms.b.min is less than or equal to a set maximum allowable position deviation negative value, the master hydraulic cylinder stops moving down until a position deviation value between the master hydraulic cylinder and a slowest declining slave hydraulic cylinder is greater than the set maximum allowable position deviation negative value; when the continuous casting tundish moves down, the slave hydraulic cylinder synchronization position deviation out-of-range control unit obtains a difference ΔSsnm between a position value of each slave hydraulic cylinder and a position value of the master hydraulic cylinder; if a value of ΔSsnm is less than or equal to a set maximum allowable position deviation negative value, the slave hydraulic cylinder stops moving down until the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is greater than the set maximum allowable position deviation negative value;

   2) when the continuous casting tundish moves up, the master hydraulic cylinder synchroniza-

tion position deviation out-of-range control unit obtains a maximum value ΔSms.f.max of a difference between an actual position value of the master hydraulic cylinder and an actual position value of each slave hydraulic cylinder; if a value of ΔSms.f.max is greater than or equal to a set maximum allowable position deviation positive value, the master hydraulic cylinder stops moving up until a position deviation value between the master hydraulic cylinder and a slowest rising slave hydraulic cylinder is less than the set maximum allowable position deviation positive value; when the continuous casting tundish moves up, the slave hydraulic cylinder synchronization position deviation out-of-range control unit obtains a difference ΔSsnm between a position value of each slave hydraulic cylinder and a position value of the master hydraulic cylinder; if a value of ΔSsnm is greater than or equal to a set maximum allowable position deviation positive value, the slave hydraulic cylinder stops moving up until the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is less than the set maximum allowable position deviation positive value;

3) when the continuous casting tundish moves up or down, a synchronization position deviation value ΔSms of the master hydraulic cylinder exceeds a set range, and the master hydraulic cylinder synchronization position deviation velocity correction unit corrects a moving velocity of the master hydraulic cylinder until the position deviation value ΔSms between the master hydraulic cylinder and the slave hydraulic cylinder is within the set range again; and

4) when the continuous casting tundish moves up or down, if a synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds a set range, the slave hydraulic cylinder synchronization position deviation velocity correction unit corrects a moving velocity of the slave hydraulic cylinder until the position deviation value ΔSsnm between the slave hydraulic cylinder and the master hydraulic cylinder is within the set range again.

2. The synchronization control method based on a synchronization control system for lifting hydraulic cylinders of a continuous casting tundish according to claim 1, wherein

1) the master hydraulic cylinder synchronization position deviation velocity correction unit comprises a master hydraulic cylinder velocity correction subunit and a master hydraulic cylinder synchronization deviation quick correction subunit; when the continuous casting tundish moves down, and when the synchronization position deviation value ΔSms of the master hydraulic cylinder exceeds a first set range, the master hydraulic cylinder velocity correction subunit multiplies a negative value of the synchronization position deviation value ΔSms of the master hydraulic cylinder by a velocity correction coefficient of a declining synchronization position deviation of the master hydraulic cylinder as a velocity correction value of the master hydraulic cylinder; when the continuous casting tundish moves up, and when the synchronization position deviation value ΔSms of the master hydraulic cylinder exceeds the first set range, the master hydraulic cylinder velocity correction subunit multiplies the negative value of the synchronization position deviation value ΔSms of the master hydraulic cylinder by a velocity correction coefficient of a rising synchronization position deviation of the master hydraulic cylinder as a velocity correction value of the master hydraulic cylinder; when the continuous casting tundish moves up or down, if the synchronization position deviation value ΔSms of the master hydraulic cylinder exceeds a second set range, the master hydraulic cylinder synchronization deviation quick correction subunit uses a velocity correction value of the synchronization position deviation of the master hydraulic cylinder having a direction reverse to the synchronization position deviation value ΔSms of the master hydraulic cylinder, as the velocity correction value of the master hydraulic cylinder;

2) the slave hydraulic cylinder synchronization position deviation velocity correction unit comprises a slave hydraulic cylinder velocity correction subunit and a slave hydraulic cylinder synchronization deviation quick correction subunit; when the continuous casting tundish moves down, and when the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds the first set range, the slave hydraulic cylinder velocity correction subunit multiplies a negative value of the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder by a velocity correction coefficient of a declining synchronization position deviation of the slave hydraulic cylinder as a velocity correction value of the slave hydraulic cylinder; when the continuous casting tundish moves up, and when the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds the first set range, the slave hydraulic cylinder velocity correction subunit multiplies the negative value of the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder by a velocity correction coefficient of a rising synchronization position deviation of the slave hydraulic cylinder as a ve-

locity correction value of the slave hydraulic cylinder; and

3) when the continuous casting tundish moves up or down, and when the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds the second set range, the slave hydraulic cylinder synchronization deviation quick correction subunit uses a velocity correction value of the synchronization position deviation of the slave hydraulic cylinder having a direction reverse to the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder, as the velocity correction value of the slave hydraulic cylinder.

3. The synchronization control method based on a synchronization control system for lifting hydraulic cylinders of a continuous casting tundish according to claim 1, wherein a master hydraulic cylinder fault interruption control unit, a slave hydraulic cylinder fault interruption control unit, a master hydraulic cylinder lifting velocity closed-loop control unit, and a slave hydraulic cylinder lifting velocity closed-loop control unit are additionally disposed in the synchronization control subsystem for a master lifting hydraulic cylinder of the continuous casting tundish and the synchronization control subsystem for slave lifting hydraulic cylinders of the continuous casting tundish in claim 1; for the lifting hydraulic control system of the continuous casting tundish, when a displacement sensor of the master lifting hydraulic cylinder or any slave lifting hydraulic cylinder of the tundish is faulty, a hydraulic system is faulty, or a lifting operation of the continuous casting tundish is prohibited or urgently stopped, the master hydraulic cylinder fault interruption control unit controls an output of the master hydraulic cylinder lifting velocity closed-loop control unit to be blocked, the slave hydraulic cylinder fault interruption control unit controls an output of the slave hydraulic cylinder lifting velocity closed-loop control unit to be blocked, and control voltages of proportion valves of the master and slave hydraulic cylinders are always zero, that is, the lifting control of the master and slave hydraulic cylinders is blocked.

4. The synchronization control method based on a synchronization control system for lifting hydraulic cylinders of a continuous casting tundish according to claim 1, wherein a master hydraulic cylinder manual lifting synchronization control unit, a slave hydraulic cylinder manual lifting synchronization control unit, a master hydraulic cylinder lifting velocity closed-loop control unit, and a slave hydraulic cylinder lifting velocity closed-loop control unit are additionally disposed in the synchronization control subsystem for a master lifting hydraulic cylinder of the continuous casting tundish and the synchronization control subsystem for slave lifting hydraulic cylinders of the continuous casting tundish in claim 1;

1) when the lifting hydraulic control system of the continuous casting tundish is in a manual linkage mode of tundish lifting or in a manual/automatic linkage mode of tundish lifting, during a period in which a manual declining instruction for the continuous casting tundish is delivered, if the synchronization position deviation value ΔSms of the master hydraulic cylinder is greater than the set maximum allowable position deviation negative value and the master hydraulic cylinder is not at a declining end position, the master hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual declining velocity of the master/slave hydraulic cylinder to the master hydraulic cylinder lifting velocity closed-loop control unit in a released state; if the position deviation between the master hydraulic cylinder and the slowest declining slave hydraulic cylinder exceeds the set range, the position deviation between the master hydraulic cylinder and the slowest declining slave hydraulic cylinder is corrected by the master hydraulic cylinder synchronization position deviation velocity correction unit; if the position deviation between the master hydraulic cylinder and the slowest declining slave hydraulic cylinder is less than or equal to a set maximum allowable position deviation negative value, the master hydraulic cylinder stops moving down until a position deviation value between the two is greater than the set maximum allowable position deviation negative value again; during a period in which a manual rising instruction for the continuous casting tundish is delivered, if the synchronization position deviation value ΔSms of the master hydraulic cylinder is less than the set maximum allowable position deviation positive value and the master hydraulic cylinder is not at a rising end position, the master hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual rising velocity of the master/slave hydraulic cylinder to the master hydraulic cylinder lifting velocity closed-loop control unit in a released state; if the position deviation between the master hydraulic cylinder and the slowest rising slave hydraulic cylinder exceeds the set range, the position deviation between the master hydraulic cylinder and the slowest rising slave hydraulic cylinder is corrected by the master hydraulic cylinder synchronization position deviation velocity correction unit; if the position deviation between the master hydraulic cylinder and the slowest rising slave hydraulic cylinder is greater than or equal to a set maximum allowable position deviation

positive value, the master hydraulic cylinder stops moving up until a position deviation value between the two is less than the set maximum allowable position deviation positive value again; and

2) when the lifting hydraulic control system of the continuous casting tundish is in a manual linkage mode of tundish lifting or in a manual/automatic linkage mode of tundish lifting, during a period in which a manual declining instruction for the continuous casting tundish is delivered, if the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is greater than the set maximum allowable position deviation negative value and the master hydraulic cylinder is not at a declining end position, the slave hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual declining velocity of the master/slave hydraulic cylinder to the slave hydraulic cylinder lifting velocity closed-loop control unit in a released state; if the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds the set range, the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is corrected by the master hydraulic cylinder synchronization position deviation velocity correction unit; if the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is less than or equal to a set maximum allowable position deviation negative value, the slave hydraulic cylinder stops moving down until a position deviation value between the two is greater than the set maximum allowable position deviation negative value again; during a period in which a manual rising instruction for the continuous casting tundish is delivered, if the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is less than the set maximum allowable position deviation positive value and the master hydraulic cylinder is not at a rising end position, the slave hydraulic cylinder manual lifting synchronization control unit outputs a set value of a manual rising velocity of the master/slave hydraulic cylinder to the slave hydraulic cylinder lifting velocity closed-loop control unit in a released state; if the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder exceeds the set range, the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is corrected by the slave hydraulic cylinder synchronization position deviation velocity correction unit; if the synchronization position deviation value ΔSsnm of the slave hydraulic cylinder is greater than or equal to a set maximum allowable position deviation positive value, the slave hydraulic cylinder stops moving up until a position deviation value between the two is less than the set maximum allowable position deviation positive value again.

5. The synchronization control method based on a synchronization control system for lifting hydraulic cylinders of a continuous casting tundish according to claim 1, wherein a master hydraulic cylinder automatic position holding control unit, a slave hydraulic cylinder automatic position holding control unit, a master hydraulic cylinder lifting velocity closed-loop control unit, and a slave hydraulic cylinder lifting velocity closed-loop control unit are additionally disposed in the synchronization control subsystem for a master lifting hydraulic cylinder of the continuous casting tundish and the synchronization control subsystem for slave lifting hydraulic cylinders of the continuous casting tundish in claim 1;

1) when a manual lifting instruction for the continuous casting tundish is terminated, if a difference between the master/slave hydraulic cylinder position holding value SZWBZ after the termination of the manual lifting instruction for the continuous casting tundish and an actual position value of the master hydraulic cylinder is greater than a set allowable position deviation positive value, a position regulator of the master hydraulic cylinder and the master hydraulic cylinder lifting velocity closed-loop control unit are in a released state; the position regulator of the master hydraulic cylinder outputs a corresponding position correction velocity reference value of the master hydraulic cylinder to reduce the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder is less than or equal to the set allowable position deviation positive value; if the difference between the master/slave hydraulic cylinder position holding value SZWBZ after the termination of the manual lifting instruction for the continuous casting tundish and the actual position value of the master hydraulic cylinder is less than the set allowable position deviation negative value, the position regulator of the master hydraulic cylinder and the master hydraulic cylinder lifting velocity closed-loop control unit are in a released state; the position regulator of the master hydraulic cylinder outputs a corresponding position correction velocity reference value of the master hydraulic cylinder to increase the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the

master hydraulic cylinder until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the master hydraulic cylinder is greater than or equal to the set allowable position deviation negative value; and

2) when a manual lifting instruction for the continuous casting tundish is terminated, if a difference between the master/slave hydraulic cylinder position holding value SZWBZ after the termination of the manual lifting instruction for the continuous casting tundish and an actual position value of the slave hydraulic cylinder is greater than a set allowable position deviation positive value, a position regulator of the slave hydraulic cylinder and the slave hydraulic cylinder lifting velocity closed-loop control unit are in a released state; the position regulator of the slave hydraulic cylinder outputs a corresponding position correction velocity reference value of the slave hydraulic cylinder to reduce the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder is less than or equal to the set allowable position deviation positive value; if the difference between the master/slave hydraulic cylinder position holding value SZWBZ after the termination of the manual lifting instruction for the continuous casting tundish and the actual position value of the slave hydraulic cylinder is less than the set allowable position deviation negative value, the position regulator of the slave hydraulic cylinder and the slave hydraulic cylinder lifting velocity closed-loop control unit are in a released state; the position regulator of the slave hydraulic cylinder outputs a corresponding position correction velocity reference value of the slave hydraulic cylinder to increase the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder until the difference between the master/slave hydraulic cylinder position holding value SZWBZ and the actual position value of the slave hydraulic cylinder is greater than or equal to the set allowable position deviation negative value.

6. The synchronization control method based on a synchronization control system for lifting hydraulic cylinders of a continuous casting tundish according to claim 1, wherein a master hydraulic cylinder automatic position holding control unit, a slave hydraulic cylinder automatic position holding control unit, a master hydraulic cylinder lifting velocity closed-loop control unit, a slave hydraulic cylinder lifting velocity closed-loop control unit, a master hydraulic cylinder manual lifting synchronization control unit, and a slave hydraulic cylinder manual lifting synchronization control unit are additionally disposed in the synchronization control subsystem for a master lifting hydraulic cylinder of the continuous casting tundish and the synchronization control subsystem for slave lifting hydraulic cylinders of the continuous casting tundish in claim 1;

1) when no fault interruption occurs in the master and slave hydraulic cylinders, and when the master hydraulic cylinder manual lifting synchronization control unit or the master hydraulic cylinder automatic position holding control unit sends a signal for releasing the master hydraulic cylinder lifting velocity control unit, the master hydraulic cylinder lifting velocity closed-loop control subunit converts a given input velocity into a corresponding control voltage output of the proportion regulation valve of the master hydraulic cylinder, until the master hydraulic cylinder reaches a desired position and is within an allowable position deviation range, and then a signal for enabling the master hydraulic cylinder lifting velocity control unit sent by the master hydraulic cylinder manual lifting synchronization control unit or the master hydraulic cylinder automatic position holding unit is blocked; and

2) when no fault interruption occurs in the master and slave hydraulic cylinders, and when the slave hydraulic cylinder manual lifting synchronization control unit or the slave hydraulic cylinder automatic position holding control unit sends a signal for releasing the slave hydraulic cylinder lifting velocity control unit, the slave hydraulic cylinder lifting velocity closed-loop control subunit converts a given input velocity into a corresponding control voltage output of the proportion regulation valve of the slave hydraulic cylinder, until the slave hydraulic cylinder reaches a desired position and is within an allowable position deviation range, and then a signal for enabling the slave hydraulic cylinder lifting velocity control unit sent by the slave hydraulic cylinder manual lifting synchronization control unit or the slave hydraulic cylinder automatic position holding unit is blocked.

7. The synchronization control method based on a synchronization control system for lifting hydraulic cylinders of a continuous casting tundish according to claim 1, wherein the synchronization control subsystem for the master lifting hydraulic cylinder of the continuous casting tundish comprises a proportion regulation valve positive/negative dead zone com-

pensation unit of the master hydraulic cylinder consisting of functional blocks LZSTC64-LZSTC67, the synchronization control subsystem for slave lifting hydraulic cylinders of the continuous casting tundish comprises a proportion regulation valve positive/negative dead zone compensation unit of the slave hydraulic cylinder consisting of functional blocks LZSTC143-LZSTC146, and the synchronization control method for the master lifting hydraulic cylinder of the continuous casting tundish further comprises:

1) when no fault interruption occurs in the master and slave hydraulic cylinders, and when the control voltage of the proportion regulation valve of the master hydraulic cylinder is greater than zero, the proportion regulation valve positive/negative dead zone compensation unit of the master hydraulic cylinder outputs a positive proportion regulation valve dead zone compensation voltage, and a control voltage of the proportion regulation valve that is output by the velocity regulator functional block is added to the positive proportion regulation valve dead zone compensation voltage to serve as the control voltage of the proportion regulation valve of the master hydraulic cylinder, thereby speeding up regulation of a positive opening degree of the proportion regulation valve of the master hydraulic cylinder; when the control voltage of the proportion regulation valve of the master hydraulic cylinder is less than zero, the proportion regulation valve positive/negative dead zone compensation subunit of the master hydraulic cylinder outputs a negative proportion regulation valve dead zone compensation voltage, and a control voltage of the proportion regulation valve that is output by the velocity regulator functional block is added to the negative proportion regulation valve dead zone compensation voltage to serve as the control voltage of the proportion regulation valve of the master hydraulic cylinder, thereby speeding up regulation of a negative opening degree of the proportion regulation valve of the master hydraulic cylinder; and

2) when the control voltage of the proportion regulation valve of the slave hydraulic cylinder is greater than zero, the proportion regulation valve positive/negative dead zone compensation unit of the slave hydraulic cylinder outputs a positive proportion regulation valve dead zone compensation voltage, and a control voltage of the proportion regulation valve that is output by the velocity regulator functional block is added to the positive proportion regulation valve dead zone compensation voltage to serve as the control voltage of the proportion regulation valve of the slave hydraulic cylinder, thereby speeding up regulation of a positive opening degree of the proportion regulation valve of the slave hydraulic cylinder; when the control voltage of the proportion regulation valve of the slave hydraulic cylinder is less than zero, the proportion regulation valve positive/negative dead zone compensation subunit of the slave hydraulic cylinder outputs a negative proportion regulation valve dead zone compensation voltage, and a control voltage of the proportion regulation valve that is output by the velocity regulator functional block is added to the negative proportion regulation valve dead zone compensation voltage to serve as the control voltage of the proportion regulation valve of the slave hydraulic cylinder, thereby speeding up regulation of a negative opening degree of the proportion regulation valve of the slave hydraulic cylinder.

8. The synchronization control method based on a synchronization control system for lifting hydraulic cylinders of a continuous casting tundish according to claims 1, 3, 4, 5, and 6, wherein the master hydraulic cylinder synchronization position deviation out-of-range control unit consists of functional blocks LZSTC01-LZSTC11 and LZSTC24-LZSTC26; the master hydraulic cylinder synchronization position deviation velocity correction unit consists of functional blocks LZSTC19-LZSTC23 and LZSTC51-LZSTC60; the master/slave hydraulic cylinder fault interruption control unit consists of functional blocks LZSTC44-LZSTC46; the master hydraulic cylinder manual lifting synchronization control unit consists of functional blocks LZSTC12-LZSTC15, LZSTC27-LZSTC30, LZSTC34-LZSTC38, and LZSTC43; the master hydraulic cylinder automatic position holding control unit consists of functional blocks LZSTC16-LZSTC18, LZSTC31-LZSTC33, LZSTC39-LZSTC43, and LZSTC48-LZSTC50; the master hydraulic cylinder lifting velocity closed-loop control unit consists of functional blocks LZSTC47, LZSTC61-LZSTC63, and LZSTC67; the slave hydraulic cylinder synchronization position deviation out-of-range control unit consists of functional blocks LZSTC100, LZSTC101, and LZSTC104; the slave hydraulic cylinder synchronization position deviation velocity correction unit consists of functional blocks LZSTC116-LZSTC120 and LZSTC121-LZSTC130; the slave hydraulic cylinder manual lifting synchronization control unit consists of functional blocks LZSTC102, LZSTC103, LZSTC105-LZSTC108, LZSTC134-LZSTC136, and LZSTC138; the slave hydraulic cylinder automatic position holding control unit consists of functional blocks LZSTC110-LZSTC115, LZSTC131-LZSTC133, LZSTC137, and LZSTC138; and the slave hydraulic cylinder lifting velocity closed-loop control unit consists of functional blocks LZSTC139-LZSTC142 and

LZSTC146.

Patentansprüche

1. Ein Synchronisationssteuerungsverfahren auf der Grundlage eines Synchronisationssteuersystems für Hubhydraulikzylinder eines Stranggießverteilers, wobei das Synchronisationssteuersystem für die Hydraulikzylinder ein Synchronisationssteuerungs-Teilsystem für einen Master-Hubhydraulikzylinder des Stranggießverteilers und ein Synchronisationssteuerungs-Teilsystem für Slave-Hubhydraulikzylinder des Stranggießverteilers umfasst, wobei das Synchronisationssteuerungs-Teilsystem für den Master-Hubhydraulikzylinder des Stranggießverteilers eine Master-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Steuereinheit und eine Master-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit umfasst; das Synchronisationssteuerungs-Teilsystem für die Slave-Hubhydraulikzylinder des Stranggießverteilers umfasst eine Slave-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Steuereinheit und eine Slave-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit; und das Synchronisationssteuerungsverfahren für Hubhydraulikzylinder eines Stranggießverteilers auf der Grundlage eines Synchronisationssteuerungssystems für Hubhydraulikzylinder eines Stranggießverteilers umfasst:

   1) Wenn sich der Stranggießverteiler nach unten bewegt, erhält die Master-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Steuereinheit einen Mindestwert ΔSms.b.min einer Differenz zwischen einem Positionswert des Master-Hydraulikzylinders und einem Positionswert eines jeden Slave-Hydraulikzylinders; wenn ein Wert von ΔSms.b.min kleiner oder gleich einem eingestellten maximal zulässigen negativen Positionsabweichungswert ist, stoppt der Master-Hydraulikzylinder die Abwärtsbewegung, bis ein Positionsabweichungswert zwischen dem Master-Hydraulikzylinder und einem am langsamsten absinkenden Slave-Hydraulikzylinder größer als der eingestellte maximal zulässige negative Positionsabweichungswert ist; wenn sich der Stranggießverteiler nach unten bewegt, erhält die Slave-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Steuereinheit eine Differenz ΔSsnm zwischen einem Positionswert eines jeden Slave-Hydraulikzylinder und einem Positionswert des Master-Hydraulikzylinders; wenn ein Wert von ΔSsnm kleiner oder gleich einem eingestellten maximal zulässigen negativen Positionsabweichungswert ist, stoppt der Slave-Hydraulikzylinder die Abwärtsbewegung, bis der Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders größer als der eingestellte maximal zulässige negative Positionsabweichungswert ist;

   2) wenn sich der Stranggießverteiler nach oben bewegt, erhält die Master-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Steuereinheit einen Maximalwert ΔSms.f.max einer Differenz zwischen einem aktuellen Positionswert des Master-Hydraulikzylinders und einem aktuellen Positionswert eines jeden Slave-Hydraulikzylinders; wenn ein Wert von ΔSms.f.max größer oder gleich einem eingestellten maximal zulässigen positiven Positionsabweichungswert ist, stoppt der Master-Hydraulikzylinder die Aufwärtsbewegung, bis ein Positionsabweichungswert zwischen dem Master-Hydraulikzylinder und einem am langsamsten aufsteigenden Slave-Hydraulikzylinder kleiner als der eingestellte maximal zulässige positive Positionsabweichungswert ist; wenn sich der Stranggießverteiler nach oben bewegt, erhält die Slave-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Steuereinheit eine Differenz ΔSsnm zwischen einem Positionswert eines jeden Slave-Hydraulikzylinder und einem Positionswert des Master-Hydraulikzylinders; wenn ein Wert von ΔSsnm größer oder gleich einem eingestellten maximal zulässigen positiven Positionsabweichungswert ist, stoppt der Slave-Hydraulikzylinder die Aufwärtsbewegung, bis der Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders kleiner als der eingestellte maximal zulässige positive Positionsabweichungswert ist;

   3) wenn sich der Stranggießverteiler nach oben oder unten bewegt, verlässt ein Synchronisations-Positionsabweichungswert ΔSms des Master-Hydraulikzylinders einen eingestellten Bereich, und die Master-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit korrigiert eine Bewegungsgeschwindigkeit des Master-Hydraulikzylinders, bis der Positionsabweichungswert ΔSms zwischen dem Master-Hydraulikzylinder und dem Slave-Hydraulikzylinder wieder innerhalb des eingestellten Bereichs liegt; und

   4) wenn sich der Stranggießverteiler nach oben oder unten bewegt und ein Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders einen eingestellten Bereich verlässt, korrigiert die Slave-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit eine Bewegungsgeschwindigkeit des Slave-Hydraulikzylinders, bis der Positionsabweichungswert ΔS-

snm zwischen dem Slave-Hydraulikzylinder und dem Master-Hydraulikzylinder wieder innerhalb des eingestellten Bereichs liegt.

2. Synchronisationssteuerungsverfahren auf der Grundlage eines Synchronisationssteuersystems für Hubhydraulikzylinder eines Stranggießverteilers nach Anspruch 1, wobei

1) die Master-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit eine Master-Hydraulikzylinder-Geschwindigkeitskorrektur-Untereinheit und eine Master-Hydraulikzylinder-Synchronisationsabweichungs-Schnellkorrektur-Untereinheit umfasst; wenn sich der Stranggießverteiler nach unten bewegt und wenn der Synchronisations-Positionsabweichungswert ΔSms des Master-Hydraulikzylinders einen ersten eingestellten Bereich verlässt, multipliziert die Master-Hydraulikzylinder-Geschwindigkeitskorrektur-Untereinheit einen negativen Wert des Synchronisations-Positionsabweichungswerts ΔSms des Master-Hydraulikzylinders mit einem Geschwindigkeitskorrekturkoeffizienten einer abnehmenden Synchronisations-Positionsabweichung des Master-Hydraulikzylinders zu einem Geschwindigkeitskorrekturwert des Master-Hydraulikzylinders; wenn sich der Stranggießverteiler nach oben bewegt und wenn der Synchronisations-Positionsabweichungswert ΔSms des Master-Hydraulikzylinders den ersten eingestellten Bereich verlässt, multipliziert die Master-Hydraulikzylinder-Geschwindigkeitskorrektur-Untereinheit den negativen Wert des Synchronisations-Positionsabweichungswertes ΔSms des Master-Hydraulikzylinders mit einem Geschwindigkeitskorrekturkoeffizienten einer ansteigenden Synchronisations-Positionsabweichung des Master-Hydraulikzylinders zu einem Geschwindigkeitskorrekturwert des Master-Hydraulikzylinders; wenn sich der Stranggießverteiler aufwärts oder abwärts bewegt und wenn der Synchronisations-Positionsabweichungswert ΔSms des Master-Hydraulikzylinders einen zweiten eingestellten Bereich verlässt, verwendet die Master-Hydraulikzylinder-Synchronisationsabweichungs-Schnellkorrektur-Untereinheit einen Geschwindigkeitskorrekturwert der Synchronisations-Positionsabweichung des Master-Hydraulikzylinders, der eine zum Synchronisations-Positionsabweichungswert ΔSms des Master-Hydraulikzylinders umgekehrte Richtung hat, als Geschwindigkeitskorrekturwert des Master-Hydraulikzylinders;

2) die Slave-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit eine Slave-Hydraulikzylinder-Geschwindigkeitskorrektur-Untereinheit und eine Slave-Hydraulikzylinder-Synchronisationsabweichungs-Schnellkorrektur-Untereinheit umfasst; wenn sich der Stranggießverteiler nach unten bewegt und wenn der Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders den ersten eingestellten Bereich verlässt, multipliziert die Slave-Hydraulikzylinder-Geschwindigkeitskorrektur-Untereinheit einen negativen Wert des Synchronisations-Positionsabweichungswertes ΔSsnm des Slave-Hydraulikzylinders mit einem Geschwindigkeitskorrekturkoeffizienten einer abnehmenden Synchronisations-Positionsabweichung des Slave-Hydraulikzylinders zu einem Geschwindigkeitskorrekturwert des Slave-Hydraulikzylinders; wenn sich der Stranggießverteiler nach oben bewegt und wenn der Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders den ersten eingestellten Bereich verlässt, multipliziert die Slave-Hydraulikzylinder-Geschwindigkeitskorrektur-Untereinheit den negativen Wert des Synchronisations-Positionsabweichungswerts ΔSsnm des Slave-Hydraulikzylinders mit einem Geschwindigkeitskorrekturkoeffizienten einer ansteigenden Synchronisations-Positionsabweichung des Slave-Hydraulikzylinders zu einem Geschwindigkeitskorrekturwert des Slave-Hydraulikzylinders; und

3) wenn sich der Stranggießverteiler aufwärts oder abwärts bewegt und wenn der Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders den zweiten eingestellten Bereich verlässt, verwendet die Slave-Hydraulikzylinder-Synchronisationsabweichungs-Schnellkorrektur-Untereinheit einen Geschwindigkeitskorrekturwert der Synchronisations-Positionsabweichung des Slave-Hydraulikzylinders, der eine zum Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders umgekehrte Richtung hat, als Geschwindigkeitskorrekturwert des Slave-Hydraulikzylinders.

3. Synchronisationssteuerungsverfahren auf der Grundlage eines Synchronisationssteuersystems für Hubhydraulikzylinder eines Stranggießverteilers nach Anspruch 1, wobei eine Master-Hydraulikzylinder-Fehlerunterbrechungs-Steuereinheit, eine Slave-Hydraulikzylinder-Fehlerunterbrechungs-Steuereinheit, eine Master-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit und eine Slave-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit zusätzlich in dem Synchronisationssteuerungs-Teilsystem für einen Master-Hubhydraulikzylinder des Stranggießverteilers und dem Synchronisations-

steuerungs-Teilsystem für einen Slave-Hubhydraulikzylinder des Stranggießverteilers in Anspruch 1 angeordnet sind; für das Steuerungssystem für hydraulischen Hub des Stranggießverteilers, wenn ein Abstandssensor des Master-Hubhydraulikzylinders oder eines Slave-Hubhydraulikzylinders des Verteilers fehlerhaft ist, ein hydraulisches System fehlerhaft ist oder ein Hubvorgang des Stranggießverteilers verboten ist oder dringend gestoppt wird, steuert die Master-Hydraulikzylinder-Fehlerunterbrechungs-Steuereinheit einen Ausgang der Master-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit so, dass er blockiert wird, und steuert die Slave-Hydraulikzylinder-Fehlerunterbrechungs-Steuereinheit einen Ausgang der Slave-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit so, dass er blockiert wird, und dass die Steuerspannungen der Proportionalventile der Master- und Slave-Hydraulikzylinder immer Null sind, d.h. die Hubsteuerungen der Master- und Slave-Hydraulikzylinder gesperrt sind.

4. Synchronisationssteuerungsverfahren auf der Grundlage eines Synchronisationssteuersystems für Hubhydraulikzylinder eines Stranggießverteilers nach Anspruch 1, wobei eine manuelle Master-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit, eine manuelle Slave-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit, eine Master-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit und eine Slave-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit zusätzlich in dem Synchronisationssteuerungs-Teilsystem für einen Master-Hubhydraulikzylinder des Stranggießverteilers und einem Synchronisationssteuerungs-Teilsystem für Slave-Hydraulikzylinder des Stranggießverteilers nach Anspruch 1 angeordnet sind;

1) wenn sich das Steuerungssystem für hydraulischen Hub eines Stranggießverteilers in einem manuellen Verknüpfungsmodus zum Heben des Verteilers oder in einem manuellen/automatischen Verknüpfungsmodus zum Heben des Verteilers befindet, gibt während eines Zeitraums, in dem ein manueller Abfahrbefehl für den Stranggießverteiler gegeben wird, wenn der Synchronisations-Positionsabweichungswert ΔSms des Master-Hydraulikzylinders größer ist als der eingestellte maximal zulässige negative Positionsabweichungswert und der Master-Hydraulikzylinder sich nicht in einer Abwärts-Endposition befindet, die manuelle Master-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit einen eingestellten Wert einer manuellen Abfallgeschwindigkeit des Master-/Slave-Hydraulikzylinders an die Master-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit in einem freigegebenen Zustand aus; wenn die Positionsabweichung zwischen dem Master-Hydraulikzylinder und dem am langsamsten absinkenden Slave-Hydraulikzylinder den eingestellten Bereich verlässt, wird die Positionsabweichung zwischen dem Master-Hydraulikzylinder und dem am langsamsten abfallenden Slave-Hydraulikzylinder durch die Master-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit korrigiert; wenn die Positionsabweichung zwischen dem Master-Hydraulikzylinder und dem am langsamsten abfallenden Slave-Hydraulikzylinder kleiner oder gleich einem eingestellten maximal zulässigen negativen Positionsabweichungswert ist, hält der Master-Hydraulikzylinder die Abwärtsbewegung an, bis ein Positionsabweichungswert zwischen den beiden wieder größer als der eingestellte maximal zulässige negative Positionsabweichungswert wird; während eines Zeitraums, in dem ein manueller Hubbefehl für den Stranggießverteiler gegeben wird, wenn der Synchronisations-Positionsabweichungswert ΔSms des Master-Hydraulikzylinders kleiner als der eingestellte maximal zulässige positive Positionsabweichungswert ist und der Master-Hydraulikzylinder sich nicht in einer Aufwärts-Endposition befindet, gibt die Master-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit einen eingestellten Wert einer manuellen Hubgeschwindigkeit des Master-/Slave-Hydraulikzylinders an die Master-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit in einem freigegebenen Zustand aus; wenn die Positionsabweichung zwischen dem Master-Hydraulikzylinder und dem am langsamsten ansteigenden Slave-Hydraulikzylinder den eingestellten Bereich verlässt, wird die Positionsabweichung zwischen dem Master-Hydraulikzylinder und dem am langsamsten ansteigenden Slave-Hydraulikzylinder durch die Master-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit korrigiert; wenn die Positionsabweichung zwischen dem Master-Hydraulikzylinder und dem am langsamsten ansteigenden Slave-Hydraulikzylinder größer oder gleich einem eingestellten maximal zulässigen positiven Positionsabweichungswert ist, stoppt der Master-Hydraulikzylinder die Aufwärtsbewegung, bis ein Positionsabweichungswert zwischen den beiden wieder kleiner als der eingestellte maximal zulässige positive Positionsabweichungswert ist; und

2) wenn sich das Steuerungssystem für hydraulischen Hub eines Stranggießverteilers in einem manuellen Verknüpfungsmodus zum Heben des Verteilers oder in einem manuellen/automatischen Verknüpfungsmodus zum Heben des Verteilers befindet, gibt während eines Zeit-

raums, in dem ein manueller Abfahrbefehl für den Stranggießverteiler gegeben wird, wenn der Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders größer ist als der eingestellte maximal zulässige negative Positionsabweichungswert und der Master-Hydraulikzylinder sich nicht in einer Abwärts-Endposition befindet, die manuelle Slave-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit einen eingestellten Wert einer manuellen Abfallgeschwindigkeit des Master-/Slave-Hydraulikzylinders an die Slave-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit in einem freigegebenen Zustand aus; wenn der Wert der Synchronisations-Positionsabweichung ΔSsnm des Slave-Hydraulikzylinders den eingestellten Bereich verlässt, wird der Wert der Synchronisations-Positionsabweichung ΔSsnm des Slave-Hydraulikzylinders durch die Master-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit korrigiert; wenn der Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders kleiner oder gleich einem eingestellten maximal zulässigen negativen Positionsabweichungswert ist, stoppt der Slave-Hydraulikzylinder die Abwärtsbewegung, bis ein Positionsabweichungswert zwischen den beiden wieder größer als der eingestellte maximal zulässige negative Positionsabweichungswert wird; während eines Zeitraums, in dem ein manueller Hubbefehl für den Stranggießverteiler gegeben wird, wenn der Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders kleiner als der eingestellte maximal zulässige positive Positionsabweichungswert ist und der Master-Hydraulikzylinder sich nicht in einer Aufwärts-Endposition befindet, gibt die manuelle Slave-Hydraulikzylinder-Hub-Synchronisationssteuereinheit einen eingestellten Wert einer manuellen Hubgeschwindigkeit des Master-/Slave-Hydraulikzylinders an die Slave-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit in einem freigegebenen Zustand aus; wenn der Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders den eingestellten Bereich verlässt, wird der Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders durch die Slave-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit korrigiert; wenn der Synchronisations-Positionsabweichungswert ΔSsnm des Slave-Hydraulikzylinders größer oder gleich einem eingestellten maximal zulässigen positiven Positionsabweichungswert ist, stoppt der Slave-Hydraulikzylinder die Aufwärtsbewegung, bis ein Positionsabweichungswert zwischen den beiden wieder kleiner als der eingestellte maximal zulässige positive Positionsabweichungswert ist.

5. Synchronisationssteuerungsverfahren auf der Grundlage eines Synchronisationssteuersystems für Hubhydraulikzylinder eines Stranggießverteilers nach Anspruch 1, wobei in dem Synchronisationssteuerungs-Teilsystem für einen Master-Hubhydraulikzylinder des Stranggießverteilers und dem Synchronisationssteuerungs-Teilsystem für einen Slave-Hubhydraulikzylinder des Stranggießverteilers nach Anspruch 1 zusätzlich eine Master-Hydraulikzylinder-Positionshalte-Steuereinheit, eine Slave-Hydraulikzylinder-Positionshalte-Steuereinheit, eine Master-Hydraulikzylinder-Hubgeschwindigkeits-Regeleinheit und eine Slave-Hydraulikzylinder-Hubgeschwindigkeits-Regeleinheit angeordnet sind;

1) wenn ein manueller Hubbefehl für den Stranggießverteiler beendet wird, und wenn eine Differenz zwischen dem Positionshaltewert SZWBZ des Master/Slave-Hydraulikzylinders nach der Beendigung des manuellen Hubbefehls für den Stranggießverteiler und einem Positions-Istwert des Master-Hydraulikzylinders größer als ein eingestellter zulässiger positiver Positionsabweichungswert ist, befinden sich ein Positionsregler des Master-Hydraulikzylinders und die Master-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit in einem freigegebenen Zustand; der Positionsregler des Master-Hydraulikzylinders gibt einen entsprechenden Positionskorrektur-Geschwindigkeits-Sollwert des Master-Hydraulikzylinders aus, um die Differenz zwischen dem Positionshaltewert SZWBZ des Master/Slave-Hydraulikzylinders und dem Positions-Istwert des Master-Hydraulikzylinders zu verringern, bis die Differenz zwischen dem Positionshaltewert SZWBZ des Master/Slave-Hydraulikzylinders und dem Positions-Istwert des Master-Hydraulikzylinders kleiner als oder gleich dem eingestellten zulässigen positiven Positionsabweichungswert ist; wenn die Differenz zwischen dem Positionshaltewert SZWBZ des Master/Slave-Hydraulikzylinders nach Beendigung des manuellen Hubbefehls für den Stranggießverteiler und dem Positions-Istwert des Master-Hydraulikzylinders kleiner als der eingestellte zulässige negative Positionsabweichungswert ist, befinden sich der Positionsregler des Master-Hydraulikzylinders und die Master-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit in einem freigegebenen Zustand; der Positionsregler des Master-Hydraulikzylinders gibt einen entsprechenden Positionskorrektur-Geschwindigkeits-Sollwert

des Master-Hydraulikzylinders aus, um die Differenz zwischen dem Positionshaltewert SZWBZ des Master/Slave-Hydraulikzylinders und dem Positions-Istwert des Master-Hydraulikzylinders zu vergrößern, bis die Differenz zwischen dem Positionshaltewert SZWBZ des Master/Slave-Hydraulikzylinders und dem Positions-Istwert des Master-Hydraulikzylinders größer oder gleich dem eingestellten zulässigen negativen Positionsabweichungswert ist; und

2) wenn ein manueller Hubbefehl für den Stranggießverteiler beendet wird, und wenn eine Differenz zwischen dem Positionshaltewert SZWBZ des Master/Slave-Hydraulikzylinders nach der Beendigung des manuellen Hubbefehls für den Stranggießverteiler und einem Positions-Istwert des Slave-Hydraulikzylinders größer als ein eingestellter zulässiger positiver Positionsabweichungswert ist, befinden sich ein Positionsregler des Slave-Hydraulikzylinders und die Slave-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit in einem freigegebenen Zustand; der Positionsregler des Slave-Hydraulikzylinders gibt einen entsprechenden Positionskorrektur-Geschwindigkeits-Sollwert des Slave-Hydraulikzylinders aus, um die Differenz zwischen dem Positionshaltewert SZWBZ des Master/Slave-Hydraulikzylinders und dem Positions-Istwert des Slave-Hydraulikzylinders zu verringern, bis die Differenz zwischen dem Positionshaltewert SZWBZ des Master/Slave-Hydraulikzylinders und dem Positions-Istwert des Slave-Hydraulikzylinders kleiner oder gleich dem eingestellten zulässigen positiven Positionsabweichungswert ist; wenn die Differenz zwischen dem Positionshaltewert SZWBZ des Master-/Slave-Hydraulikzylinders nach Beendigung des manuellen Hubbefehls für den Stranggießverteiler und dem Positions-Istwert des Slave-Hydraulikzylinders kleiner als der eingestellte zulässige negative Positionsabweichungswert ist, befinden sich der Positionsregler des Slave-Hydraulikzylinders und die Slave-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit in einem freigegebenen Zustand; der Positionsregler des Slave-Hydraulikzylinders gibt einen entsprechenden Positionskorrektur-Geschwindigkeits-Sollwert des Slave-Hydraulikzylinders aus, um die Differenz zwischen dem Positionshaltewert SZWBZ des Master-/Slave-Hydraulikzylinders und dem Positions-Istwert des Slave-Hydraulikzylinders zu vergrößern, bis die Differenz zwischen dem Positionshaltewert SZWBZ des Master-/Slave-Hydraulikzylinders und dem Positions-Istwert des Slave-Hydraulikzylinders größer als oder gleich dem eingestellten zulässigen negativen Positionsabweichungswert ist.

6. Synchronisationssteuerungsverfahren auf der Grundlage eines Synchronisationssteuersystems für Hubhydraulikzylinder eines Stranggießverteilers nach Anspruch 1, wobei eine automatische Positionshaltesteuereinheit für den Master-Hydraulikzylinder, eine automatische Positionshaltesteuereinheit für den Slave-Hydraulikzylinder, eine Master-Hydraulikzylinder-Hubgeschwindigkeits-Regeleinheit, eine Slave-Hydraulikzylinder-Hubgeschwindigkeits-Regeleinheit, eine manuelle Master-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit und manuelle Slave-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit zusätzlich in dem Synchronisationssteuerungs-Teilsystem für einen Master-Hubhydraulikzylinder des Stranggießverteilers und dem Synchronisationssteuerungs-Teilsystem für einen Slave-Hubhydraulikzylinder des Stranggießverteilers nach Anspruch 1 angeordnet sind;

1) wenn keine Fehlerunterbrechung in den Master- und Slave-Hydraulikzylindern auftritt und wenn die manuelle Master-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit oder die automatische Positionshaltesteuereinheit für den Master-Hydraulikzylinder ein Signal zur Freigabe der Master-Hydraulikzylinder-Hubgeschwindigkeits-Regeleinheit sendet, wandelt die Master-Hydraulikzylinder-Hubgeschwindigkeits-Regeleinheit eine gegebene Eingangsgeschwindigkeit in eine entsprechende Steuerspannungsausgabe für das Proportionalregelventil des Master-Hydraulikzylinders um, bis der Master-Hydraulikzylinder eine gewünschte Position erreicht und sich innerhalb eines zulässigen Positionsabweichungsbereichs befindet, und dann wird das Signal zur Freigabe der Master-Hydraulikzylinder-Hubgeschwindigkeits-Regeleinheit, das von der manuellen Master-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit oder der automatischen Positionshaltesteuereinheit für den Master-Hydraulikzylinder gesendet wird, blockiert; und

2) wenn keine Fehlerunterbrechung in den Master- und Slave-Hydraulikzylindern auftritt und wenn die manuelle Slave-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit oder die automatische Positionshaltesteuereinheit für den Slave-Hydraulikzylinder ein Signal zur Freigabe der Master-Hydraulikzylinder-Hubgeschwindigkeits-Regeleinheit sendet, wandelt die Slave-Hydraulikzylinder-Hubgeschwindigkeits-Regeleinheit eine gegebene Eingangsgeschwindigkeit in eine entsprechende Steuerspannungsausgabe für das Proportionalregelventil des Slave-Hydraulikzylinders um, bis der Slave-Hydraulikzylinder eine gewünschte Position erreicht und sich innerhalb eines zulässigen

Positionsabweichungsbereichs befindet, und dann wird das Signal zur Freigabe der Slave-Hydraulikzylinder-Hubgeschwindigkeits-Regeleinheit, das von der manuellen Slave-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit oder der automatischen Positionshaltesteuereinheit für den Slave-Hydraulikzylinder gesendet wird, blockiert.

7. Synchronisationssteuerungsverfahren auf der Grundlage eines Synchronisationssteuersystems für Hubhydraulikzylinder eines Stranggießverteilers nach Anspruch 1, wobei das Synchronisationssteuerungs-Teilsystem für einen Master-Hubhydraulikzylinder des Stranggießverteilers eine Positiv/Negativ-Totzonen-Kompensationseinheit für das Proportionalregelungsventil des Master-Hydraulikzylinders bestehend aus den Funktionsblöcken LZSTC64-LZSTC67 umfasst, das Synchronisationssteuerungs-Teilsystem für einen Slave-Hubhydraulikzylinder des Stranggießverteilers eine Positiv/Negativ-Totzonen-Kompensationseinheit für das Proportionalregelungsventil des Slave-Hydraulikzylinders bestehend aus den Funktionsblöcken LZSTC143-LZSTC146 umfasst, und das Synchronisationssteuerungsverfahren für den Master-Hubhydraulikzylinder des Stranggießverteilers ferner umfasst:

1) wenn keine Fehlerunterbrechung in den Master- und Slave-Hydraulikzylindern auftritt und wenn die Steuerspannung des Proportionalregelventils des Master-Hydraulikzylinders größer als Null ist, gibt die Positiv/Negativ-Totzonen-Kompensationseinheit für das Proportionalregelungsventil des Master-Hydraulikzylinders eine positive Proportionalregelventil-Totzonen-Kompensationsspannung aus, und eine Steuerspannung des Proportionalregelventils, die von dem Geschwindigkeitsregler-Funktionsblock ausgegeben wird, wird zu der positiven Proportionalregelventil-Totzonen-Kompensationsspannung addiert, um als Steuerspannung des Proportionalregelventils des Master-Hydraulikzylinders zu dienen, wodurch die Regelung zu einem positiven Öffnungsgrad des Proportionalregelventils des Master-Hydraulikzylinders beschleunigt wird; wenn die Steuerspannung des Proportionalregelventils des Master-Hydraulikzylinders kleiner als Null ist, gibt die Positiv/Negativ-Totzonen-Kompensationseinheit für das Proportionalregelungsventil des Master-Hydraulikzylinders eine negative Proportionalregelventil-Totzonen-Kompensationsspannung aus, und eine Steuerspannung des Proportionalregelventils, die von dem Geschwindigkeitsregler-Funktionsblock ausgegeben wird, wird zu der negativen Proportionalregelventil-Totzonen-Kompensationsspannung addiert, um als Steuerspannung des Proportionalregelventils des Master-Hydraulikzylinders zu dienen, wodurch die Regelung zu einem negativen Öffnungsgrad des Proportionalregelventils des Master-Hydraulikzylinders beschleunigt wird; und

2) wenn die Steuerspannung des Proportionalregelventils des Master-Hydraulikzylinders größer als Null ist, gibt die Positiv/Negativ-Totzonen-Kompensationseinheit für das Proportionalregelungsventil des Slave-Hydraulikzylinders eine positive Proportionalregelventil-Totzonen-Kompensationsspannung aus, und eine Steuerspannung des Proportionalregelventils, die von dem Geschwindigkeitsregler-Funktionsblock ausgegeben wird, wird zu der positiven Proportionalregelventil-Totzonen-Kompensationsspannung addiert, um als Steuerspannung des Proportionalregelventils des Slave-Hydraulikzylinders zu dienen, wodurch die Regelung zu einem positiven Öffnungsgrad des Proportionalregelventils des Slave-Hydraulikzylinders beschleunigt wird; wenn die Steuerspannung des Proportionalregelventils des Slave-Hydraulikzylinders kleiner als Null ist, gibt die Positiv/Negativ-Totzonen-Kompensationseinheit für das Proportionalregelungsventil des Slave-Hydraulikzylinders eine negative Proportionalregelventil-Totzonen-Kompensationsspannung aus, und eine Steuerspannung des Proportionalregelventils, die von dem Geschwindigkeitsregler-Funktionsblock ausgegeben wird, wird zu der negativen Proportionalregelventil-Totzonen-Kompensationsspannung addiert, um als Steuerspannung des Proportionalregelventils des Slave-Hydraulikzylinders zu dienen, wodurch die Regelung zu einem negativen Öffnungsgrad des Proportionalregelventils des Slave-Hydraulikzylinders beschleunigt wird.

8. Synchronisationssteuerungsverfahren auf der Grundlage eines Synchronisationssteuersystems für Hubhydraulikzylinder eines Stranggießverteilers nach den Ansprüchen 1, 3, 4, 5 und 6, wobei die Master-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Steuereinheit die Funktionsblöcke LZSTC01-LZSTC11 und LZSTC24-LZSTC26 umfasst; die Master-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit umfasst die Funktionsblöcke LZSTC19-LZSTC23 und LZSTC51-LZSTC60; die Master/Slave-Hydraulikzylinder-Fehlerunterbrechungs-Steuereinheit umfasst die Funktionsblöcke LZSTC44-LZSTC46; die manuelle Master-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit umfasst die Funktionsblöcke LZSTC12-LZSTC15, LZSTC27-LZSTC30, LZSTC34-LZSTC38 und LZSTC43; die automatische Positionshaltesteuer-

einheit für den Master-Hydraulikzylinder umfasst die Funktionsblöcke LZSTC16-LZSTC18, LZSTC31-LZSTC33, LZSTC39-LZSTC43 und LZSTC48-LZSTC50; die Master-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit umfasst die Funktionsblöcke LZSTC47, LZSTC61-LZSTC63 und LZSTC67; die Slave-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Steuereinheit umfasst die Funktionsblöcke LZSTC100, LZSTC101 und LZSTC104; die Slave-Hydraulikzylinder-Synchronisations-Positionsabweichungs-Geschwindigkeitskorrektureinheit umfasst die Funktionsblöcke LZSTC116-LZSTC120 und LZSTC121-LZSTC130; die manuelle Slave-Hydraulikzylinder-Hub-Synchronisationssteuerungseinheit umfasst die Funktionsblöcke LZSTC102, LZSTC103, LZSTC105-LZSTC108, LZSTC134-LZSTC136 und LZSTC138; die automatische Positionshaltesteuereinheit für den Slave-Hydraulikzylinder umfasst die Funktionsblöcke LZSTC110-LZSTC115, LZSTC131-LZSTC133, LZSTC137 und LZSTC138; und die Slave-Hydraulikzylinder-Hubgeschwindigkeits-Steuereinheit umfasst die Funktionsblöcke LZSTC139-LZSTC142 und LZSTC146.

Revendications

1. Procédé de commande de synchronisation reposant sur un système de commande de synchronisation pour des vérins hydrauliques de levage d'un répartiteur de coulée continue, le système de commande de synchronisation pour les vérins hydrauliques comprenant un sous-système de commande de synchronisation pour un vérin hydraulique de levage maître du répartiteur de coulée continue et un sous-système de commande de synchronisation pour des vérins hydrauliques de levage esclaves du répartiteur de coulée continue, le sous-système de commande de synchronisation pour le vérin hydraulique de levage maître du répartiteur de coulée continue comprenant une unité de commande de sortie de plage d'écart de position de synchronisation de vérin hydraulique maître et une unité de correction de vitesse d'écart de position de synchronisation de vérin hydraulique maître ; le sous-système de commande de synchronisation pour les vérins hydrauliques de levage esclaves du répartiteur de coulée continue comprenant une unité de commande de sortie de plage d'écart de position de synchronisation de vérin hydraulique esclave et une unité de correction de vitesse d'écart de position de synchronisation de vérin hydraulique esclave ; et le procédé de commande de synchronisation pour les vérins hydrauliques de levage du répartiteur de coulée continue reposant sur le système de commande de synchronisation pour les vérins hydrauliques de levage du répartiteur de coulée continue comprenant :

1) lorsque le répartiteur de coulée continue descend, l'unité de commande de sortie de plage d'écart de position de synchronisation de vérin hydraulique maître obtient une valeur minimale ΔSms.b.min d'une différence entre une valeur de position du vérin hydraulique maître et une valeur de position de chaque vérin hydraulique esclave ; si une valeur de ΔSms.b.min est inférieure ou égale à une valeur négative d'écart de position maximale admissible définie, le vérin hydraulique maître arrête de descendre jusqu'à ce qu'une valeur d'écart de position entre le vérin hydraulique maître et le vérin hydraulique esclave descendant le plus lentement soit supérieure à la valeur négative d'écart de position maximale admissible définie ; lorsque le répartiteur de coulée continue descend, l'unité de commande de sortie de plage d'écart de position de synchronisation de vérin hydraulique esclave obtient une différence ΔSsnm entre une valeur de position de chaque vérin hydraulique esclave et une valeur de position du vérin hydraulique maître ; si une valeur de ΔSsnm est inférieure ou égale à une valeur négative d'écart de position maximale admissible définie, le vérin hydraulique esclave arrête de descendre jusqu'à ce que la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave soit supérieure à la valeur négative d'écart de position maximale admissible définie ;

2) lorsque le répartiteur de coulée continue monte, l'unité de commande de sortie de plage d'écart de position de synchronisation de vérin hydraulique maître obtient une valeur maximale ΔSms.f.max d'une différence entre une valeur de position réelle du vérin hydraulique maître et une valeur de position réelle de chaque vérin hydraulique esclave ; si une valeur de ΔSms.f.max est supérieure ou égale à une valeur positive d'écart de position maximale admissible définie, le vérin hydraulique maître arrête de monter jusqu'à ce qu'une valeur d'écart de position entre le vérin hydraulique maître et le vérin hydraulique esclave montant le plus lentement soit inférieure à la valeur positive d'écart de position maximale admissible définie ; lorsque le répartiteur de coulée continue monte, l'unité de commande de sortie de plage d'écart de position de synchronisation de vérin hydraulique esclave obtient une différence ΔSsnm entre une valeur de position de chaque vérin hydraulique esclave et une valeur de position du vérin hydraulique maître ; si une valeur de ΔSsnm est supérieure ou égale à une valeur positive d'écart de position maximale admissible définie, le vérin hydraulique esclave arrête de monter jusqu'à ce que la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique

esclave soit inférieure à la valeur positive d'écart de position maximale admissible définie ;

3) lorsque le répartiteur de coulée continue monte ou descend, une valeur ΔSms d'écart de position de synchronisation du vérin hydraulique maître dépasse une plage définie, et l'unité de correction de vitesse d'écart de position de synchronisation de vérin hydraulique maître corrige une vitesse de déplacement du vérin hydraulique maître jusqu'à ce que la valeur ΔSms d'écart de position entre le vérin hydraulique maître et le vérin hydraulique esclave soit à nouveau comprise dans la plage définie ; et

4) lorsque le répartiteur de coulée continue monte ou descend, si une valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave dépasse une plage définie, l'unité de correction de vitesse d'écart de position de synchronisation de vérin hydraulique esclave corrige une vitesse de déplacement du vérin hydraulique esclave jusqu'à ce que la valeur ΔSsnm d'écart de position entre le vérin hydraulique esclave et le vérin hydraulique maître soit à nouveau comprise dans la plage définie.

2. Procédé de commande de synchronisation reposant sur un système de commande de synchronisation pour des vérins hydrauliques de levage d'un répartiteur de coulée continue selon la revendication 1, dans lequel

1) l'unité de correction de vitesse d'écart de position de synchronisation de vérin hydraulique maître comprend une sous-unité de correction de vitesse de vérin hydraulique maître et une sous-unité de correction rapide d'écart de synchronisation de vérin hydraulique maître ; lorsque le répartiteur de coulée continue descend, et lorsque la valeur ΔSms d'écart de position de synchronisation du vérin hydraulique maître dépasse une première plage définie, la sous-unité de correction de vitesse de vérin hydraulique maître multiplie une valeur négative de la valeur ΔSms d'écart de position de synchronisation du vérin hydraulique maître par un coefficient de correction de vitesse d'un écart de position de synchronisation de descente du vérin hydraulique maître comme valeur de correction de vitesse du vérin hydraulique maître ; lorsque le répartiteur de coulée continue monte, et lorsque la valeur ΔSms d'écart de position de synchronisation du vérin hydraulique maître dépasse la première plage définie, la sous-unité de correction de vitesse de vérin hydraulique maître multiplie la valeur négative de la valeur ΔSms d'écart de position de synchronisation du vérin hydraulique maître par un coefficient de correction de vitesse d'un écart de position de synchronisation de montée du vérin hydraulique maître comme valeur de correction de vitesse du vérin hydraulique maître ; lorsque le répartiteur de coulée continue monte ou descend, si la valeur ΔSms d'écart de position de synchronisation du vérin hydraulique maître dépasse une seconde plage définie, la sous-unité de correction rapide d'écart de synchronisation du vérin hydraulique maître utilise une valeur de correction de vitesse de l'écart de position de synchronisation du vérin hydraulique maître ayant une direction inverse à la valeur ΔSms d'écart de position de synchronisation du vérin hydraulique maître comme valeur de correction de vitesse du vérin hydraulique maître ;

2) l'unité de correction de vitesse d'écart de position de synchronisation de vérin hydraulique esclave comprend une sous-unité de correction de vitesse de vérin hydraulique esclave et une sous-unité de correction rapide d'écart de synchronisation de vérin hydraulique esclave ; lorsque le répartiteur de coulée continue descend, et lorsque la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave dépasse la première plage définie, la sous-unité de correction de vitesse de vérin hydraulique esclave multiplie une valeur négative de la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave par un coefficient de correction de vitesse d'un écart de position de synchronisation de descente du vérin hydraulique esclave comme valeur de correction de vitesse du vérin hydraulique esclave ; lorsque le répartiteur de coulée continue monte, et lorsque la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave dépasse la première plage définie, la sous-unité de correction de vitesse de vérin hydraulique esclave multiplie la valeur négative de la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave par un coefficient de correction de vitesse d'un écart de position de synchronisation de montée du vérin hydraulique esclave comme valeur de correction de vitesse du vérin hydraulique esclave ; et

3) lorsque le répartiteur de coulée continue monte ou descend, et lorsque la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave dépasse la seconde plage définie, la sous-unité de correction rapide d'écart de synchronisation du vérin hydraulique esclave utilise une valeur de correction de vitesse de l'écart de position de synchronisation du vérin hydraulique esclave ayant une direction inverse à la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave comme valeur de correction de vitesse du vérin hydraulique esclave.

3. Procédé de commande de synchronisation reposant sur un système de commande de synchronisation pour des vérins hydrauliques de levage d'un répartiteur de coulée continue selon la revendication 1, dans lequel une unité de commande d'interruption pour panne de vérin hydraulique maître, une unité de commande d'interruption pour panne de vérin hydraulique esclave, une unité de commande en boucle fermée de vitesse de levage de vérin hydraulique maître, et une unité de commande en boucle fermée de vitesse de levage de vérin hydraulique esclave sont également disposées dans le sous-système de commande de synchronisation pour un vérin hydraulique de levage maître du répartiteur de coulée continue et le sous-système de commande de synchronisation pour des vérins hydrauliques de levage esclaves du répartiteur de coulée continue selon la revendication 1 ; pour le système de commande hydraulique de levage du répartiteur de coulée continue, lorsqu'un capteur de déplacement du vérin hydraulique de levage maître ou de l'un quelconque des vérins hydrauliques de levage esclaves du répartiteur est en panne, un système hydraulique est en panne, ou une opération de levage du répartiteur de coulée continue est bloquée ou arrêtée d'urgence, l'unité de commande d'interruption pour panne de vérin hydraulique maître commande une sortie de l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique maître de sorte qu'elle soit bloquée, l'unité de commande d'interruption pour panne de vérin hydraulique esclave commande une sortie de l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique esclave de sorte qu'elle soit bloquée, et des tensions de commande de vannes proportionnelles des vérins hydrauliques maître et esclaves sont toujours nulles, c'est-à-dire que la commande de levage des vérins hydrauliques maître et esclaves est bloquée.

4. Procédé de commande de synchronisation reposant sur un système de commande de synchronisation pour des vérins hydrauliques de levage d'un répartiteur de coulée continue selon la revendication 1, dans lequel une unité de commande de synchronisation de levage manuel de vérin hydraulique maître, une unité de commande de synchronisation de levage manuel de vérin hydraulique esclave, une unité de commande en boucle fermée de vitesse de levage de vérin hydraulique maître, et une unité de commande en boucle fermée de vitesse de levage de vérin hydraulique esclave sont également disposées dans le sous-système de commande de synchronisation pour un vérin hydraulique de levage maître du répartiteur de coulée continue et le sous-système de commande de synchronisation pour des vérins hydrauliques de levage esclaves du répartiteur de coulée continue selon la revendication 1 ;

1) lorsque le système de commande hydraulique de levage du répartiteur de coulée continue est dans un mode de liaison manuel de levage de répartiteur ou dans un mode de liaison manuel/automatique de levage de répartiteur, pendant une période durant laquelle une instruction de descente manuelle pour le répartiteur de coulée continue est transmise, si la valeur ΔSms d'écart de position de synchronisation du vérin hydraulique maître est supérieure à la valeur négative d'écart de position maximale admissible définie et le vérin hydraulique maître ne se trouve pas dans une position d'extrémité de descente, l'unité de commande de synchronisation de levage manuel de vérin hydraulique maître transmet une valeur définie d'une vitesse de descente manuelle du vérin hydraulique maître/esclave à l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique maître dans un état débloqué ; si l'écart de position entre le vérin hydraulique maître et le vérin hydraulique esclave descendant le plus lentement dépasse la plage définie, l'écart de position entre le vérin hydraulique maître et le vérin hydraulique esclave descendant le plus lentement est corrigé par l'unité de correction de vitesse d'écart de position de synchronisation de vérin hydraulique maître ; si l'écart de position entre le vérin hydraulique maître et le vérin hydraulique esclave descendant le plus lentement est inférieur ou égal à une valeur négative d'écart de position maximale admissible définie, le vérin hydraulique maître arrête de descendre jusqu'à ce qu'une valeur d'écart de position entre les deux vérins soit à nouveau supérieure à la valeur négative d'écart de position maximale admissible définie ; pendant une période durant laquelle une instruction de montée manuelle pour le répartiteur de coulée continue est transmise, si la valeur ΔSms d'écart de position de synchronisation du vérin hydraulique maître est inférieure à la valeur positive d'écart de position maximale admissible définie et le vérin hydraulique maître ne se trouve pas dans une position d'extrémité de montée, l'unité de commande de synchronisation de levage manuel de vérin hydraulique maître transmet une valeur définie d'une vitesse de montée manuelle du vérin hydraulique maître/esclave à l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique maître dans un état débloqué ; si l'écart de position entre le vérin hydraulique maître et le vérin hydraulique esclave montant le plus lentement dépasse la plage définie, l'écart de position entre le vérin hydraulique maître et le vérin hydraulique esclave montant le plus lentement est corrigé par l'unité de correction de vitesse d'écart de position de synchronisation

de vérin hydraulique maître ; si l'écart de position entre le vérin hydraulique maître et le vérin hydraulique esclave montant le plus lentement est supérieur ou égal à une valeur positive d'écart de position maximale admissible définie, le vérin hydraulique maître arrête de monter jusqu'à ce qu'une valeur d'écart de position entre les deux vérins soit à nouveau inférieure à la valeur positive d'écart de position maximale admissible définie ; et

2) lorsque le système de commande hydraulique de levage du répartiteur de coulée continue est dans un mode de liaison manuel de levage de répartiteur ou dans un mode de liaison manuel/automatique de levage de répartiteur, pendant une période durant laquelle une instruction de descente manuelle pour le répartiteur de coulée continue est transmise, si la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave est supérieure à la valeur négative d'écart de position maximale admissible définie et le vérin hydraulique maître ne se trouve pas dans une position d'extrémité de descente, l'unité de commande de synchronisation de levage manuel de vérin hydraulique esclave transmet une valeur définie d'une vitesse de descente manuelle du vérin hydraulique maître/esclave à l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique esclave dans un état débloqué ; si la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave dépasse la plage définie, la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave est corrigée par l'unité de correction de vitesse d'écart de position de synchronisation de vérin hydraulique maître ; si la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave est inférieure ou égale à une valeur négative d'écart de position maximale admissible définie, le vérin hydraulique esclave arrête de descendre jusqu'à ce qu'une valeur d'écart de position entre les deux vérins soit à nouveau supérieure à la valeur négative d'écart de position maximale admissible définie ; pendant une période durant laquelle une instruction de montée manuelle pour le répartiteur de coulée continue est transmise, si la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave est inférieure à la valeur positive d'écart de position maximale admissible définie et le vérin hydraulique maître ne se trouve pas dans une position d'extrémité de montée, l'unité de commande de synchronisation de levage manuel de vérin hydraulique esclave transmet une valeur définie d'une vitesse de montée manuelle du vérin hydraulique maître/esclave à l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique esclave dans un état débloqué ; si la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave dépasse la plage définie, la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave est corrigée par l'unité de correction de vitesse d'écart de position de synchronisation de vérin hydraulique esclave ; si la valeur ΔSsnm d'écart de position de synchronisation du vérin hydraulique esclave est supérieure ou égale à une valeur positive d'écart de position maximale admissible définie, le vérin hydraulique esclave arrête de monter jusqu'à ce qu'une valeur d'écart de position entre les deux vérins soit à nouveau inférieure à la valeur positive d'écart de position maximale admissible définie.

5. Procédé de commande de synchronisation reposant sur un système de commande de synchronisation pour des vérins hydrauliques de levage d'un répartiteur de coulée continue selon la revendication 1, dans lequel une unité de commande de conservation automatique de position de vérin hydraulique maître, une unité de commande de conservation automatique de position de vérin hydraulique esclave, une unité de commande en boucle fermée de vitesse de levage de vérin hydraulique maître, et une unité de commande en boucle fermée de vitesse de levage de vérin hydraulique esclave sont également disposées dans le sous-système de commande de synchronisation pour un vérin hydraulique de levage maître du répartiteur de coulée continue et le sous-système de commande de synchronisation pour des vérins hydrauliques de levage esclaves du répartiteur de coulée continue selon la revendication 1 ;

1) lorsqu'une instruction de levage manuel pour le répartiteur de coulée continue cesse, si une différence entre la valeur SZWBZ de conservation de position de vérin hydraulique maître/esclave après la cessation de l'instruction de levage manuel pour le répartiteur de coulée continue et une valeur de position réelle du vérin hydraulique maître est supérieure à une valeur positive d'écart de position admissible définie, un régulateur de position du vérin hydraulique maître et l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique maître sont dans un état débloqué ; le régulateur de position du vérin hydraulique maître génère une valeur de référence de vitesse de correction de position correspondante du vérin hydraulique maître pour réduire la différence entre la valeur SZWBZ de conservation de position de vérin hydraulique maître/esclave et la valeur de position réelle du vérin hydraulique maître jusqu'à ce que la différence entre la valeur SZWBZ de conservation

de position de vérin hydraulique maître/esclave et la valeur de position réelle du vérin hydraulique maître soit inférieure ou égale à la valeur positive d'écart de position admissible définie ; si la différence entre la valeur SZWBZ de conservation de position de vérin hydraulique maître/esclave après la cessation de l'instruction de levage manuel pour le répartiteur de coulée continue et la valeur de position réelle du vérin hydraulique maître est inférieure à la valeur négative d'écart de position admissible définie, le régulateur de position du vérin hydraulique maître et l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique maître sont dans un état débloqué ; le régulateur de position du vérin hydraulique maître génère une valeur de référence de vitesse de correction de position correspondante du vérin hydraulique maître pour augmenter la différence entre la valeur SZWBZ de conservation de position de vérin hydraulique maître/esclave et la valeur de position réelle du vérin hydraulique maître jusqu'à ce que la différence entre la valeur SZWBZ de conservation de position de vérin hydraulique maître/esclave et la valeur de position réelle du vérin hydraulique maître soit supérieure ou égale à la valeur négative d'écart de position admissible définie ; et

2) lorsqu'une instruction de levage manuel pour le répartiteur de coulée continue cesse, si une différence entre la valeur SZWBZ de conservation de position de vérin hydraulique maître/esclave après la cessation de l'instruction de levage manuel pour le répartiteur de coulée continue et une valeur de position réelle du vérin hydraulique esclave est supérieure à une valeur positive d'écart de position admissible définie, un régulateur de position du vérin hydraulique esclave et l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique esclave sont dans un état débloqué ; le régulateur de position du vérin hydraulique esclave génère une valeur de référence de vitesse de correction de position correspondante du vérin hydraulique esclave pour réduire la différence entre la valeur SZWBZ de conservation de position de vérin hydraulique maître/esclave et la valeur de position réelle du vérin hydraulique esclave jusqu'à ce que la différence entre la valeur SZWBZ de conservation de position de vérin hydraulique maître/esclave et la valeur de position réelle du vérin hydraulique esclave soit inférieure ou égale à la valeur positive d'écart de position admissible définie ; si la différence entre la valeur SZWBZ de conservation de position de vérin hydraulique maître/esclave après la cessation de l'instruction de levage manuel pour le répartiteur de coulée continue et la valeur de position réelle du vérin hydraulique esclave est inférieure à la valeur négative d'écart de position admissible définie, le régulateur de position du vérin hydraulique esclave et l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique esclave sont dans un état débloqué ; le régulateur de position du vérin hydraulique esclave génère une valeur de référence de vitesse de correction de position correspondante du vérin hydraulique esclave pour augmenter la différence entre la valeur SZWBZ de conservation de position de vérin hydraulique maître/esclave et la valeur de position réelle du vérin hydraulique esclave jusqu'à ce que la différence entre la valeur SZWBZ de conservation de position de vérin hydraulique maître/esclave et la valeur de position réelle du vérin hydraulique esclave soit supérieure ou égale à la valeur négative d'écart de position admissible définie.

6. Procédé de commande de synchronisation reposant sur un système de commande de synchronisation pour des vérins hydrauliques de levage d'un répartiteur de coulée continue selon la revendication 1, dans lequel une unité de commande de conservation automatique de position de vérin hydraulique maître, une unité de commande de conservation automatique de position de vérin hydraulique esclave, une unité de commande en boucle fermée de vitesse de levage de vérin hydraulique maître, une unité de commande en boucle fermée de vitesse de levage de vérin hydraulique esclave, une unité de commande de synchronisation de levage manuel de vérin hydraulique maître, et une unité de commande de synchronisation de levage manuel de vérin hydraulique esclave sont également disposées dans le sous-système de commande de synchronisation pour un vérin hydraulique de levage maître du répartiteur de coulée continue et le sous-système de commande de synchronisation pour des vérins hydrauliques de levage esclaves du répartiteur de coulée continue selon la revendication 1 ;

1) lorsqu'aucune interruption pour panne ne se produit dans les vérins hydrauliques maître et esclaves, et lorsque l'unité de commande de synchronisation de levage manuel de vérin hydraulique maître ou l'unité de commande de conservation automatique de position de vérin hydraulique maître envoie un signal pour débloquer l'unité de commande de vitesse de levage de vérin hydraulique maître, la sous-unité de commande en boucle fermée de vitesse de levage de vérin hydraulique maître convertit une vitesse en entrée donnée en une sortie de tension de commande correspondante de la vanne de régulation proportionnelle du vérin hydraulique maître, jusqu'à ce que le vérin hydraulique

maître atteigne une position souhaitée et se trouve dans une plage d'écart de position admissible, puis un signal d'activation de l'unité de commande de vitesse de levage de vérin hydraulique maître envoyé par l'unité de commande de synchronisation de levage manuel de vérin hydraulique maître ou l'unité de conservation automatique de position de vérin hydraulique maître est bloqué ; et

2) lorsqu'aucune interruption pour panne ne se produit dans les vérins hydrauliques maître et esclaves, et lorsque l'unité de commande de synchronisation de levage manuel de vérin hydraulique esclave ou l'unité de commande de conservation automatique de position de vérin hydraulique esclave envoie un signal pour débloquer l'unité de commande de vitesse de levage de vérin hydraulique esclave, la sous-unité de commande en boucle fermée de vitesse de levage de vérin hydraulique esclave convertit une vitesse en entrée donnée en une sortie de tension de commande correspondante de la vanne de régulation proportionnelle du vérin hydraulique esclave, jusqu'à ce que le vérin hydraulique esclave atteigne une position souhaitée et se trouve dans une plage d'écart de position admissible, puis un signal d'activation de l'unité de commande de vitesse de levage de vérin hydraulique esclave envoyé par l'unité de commande de synchronisation de levage manuel de vérin hydraulique esclave ou l'unité de conservation automatique de position de vérin hydraulique maître est bloqué.

7. Procédé de commande de synchronisation reposant sur un système de commande de synchronisation pour des vérins hydrauliques de levage d'un répartiteur de coulée continue selon la revendication 1, dans lequel le sous-système de commande de synchronisation pour le vérin hydraulique de levage maître du répartiteur de coulée continue comprend une unité de compensation de zone morte positive/négative de vanne de régulation proportionnelle du vérin hydraulique maître constituée des blocs fonctionnels LZSTC64 à LZSTC67, le sous-système de commande de synchronisation pour les vérins hydrauliques de levage esclaves du répartiteur de coulée continue comprend une unité de compensation de zone morte positive/négative de vanne de régulation proportionnelle du vérin hydraulique esclave constituée des blocs fonctionnels LZSTC143 à LZSTC146, et le procédé de commande de synchronisation pour le vérin hydraulique de levage maître du répartiteur de coulée continue comprend, en outre :

1) lorsqu'aucune interruption pour panne ne se produit dans les vérins hydrauliques maître et esclaves, et lorsque la tension de commande de la vanne de régulation proportionnelle du vérin hydraulique maître est supérieure à zéro, l'unité de compensation de zone morte positive/négative de vanne de régulation proportionnelle du vérin hydraulique maître génère une tension de compensation de zone morte de vanne de régulation proportionnelle positive, et une tension de commande de la vanne de régulation proportionnelle qui est générée par le bloc fonctionnel régulateur de vitesse est ajoutée à la tension de compensation de zone morte de vanne de régulation proportionnelle positive pour servir de tension de commande de la vanne de régulation proportionnelle du vérin hydraulique maître, de façon à accélérer une régulation d'un degré d'ouverture positif de la vanne de régulation proportionnelle du vérin hydraulique maître ; lorsque la tension de commande de la vanne de régulation proportionnelle du vérin hydraulique maître est inférieure à zéro, la sous-unité de compensation de zone morte positive/négative de vanne de régulation proportionnelle du vérin hydraulique maître génère une tension de compensation de zone morte de vanne de régulation proportionnelle négative, et une tension de commande de la vanne de régulation proportionnelle qui est générée par le bloc fonctionnel régulateur de vitesse est ajoutée à la tension de compensation de zone morte de vanne de régulation proportionnelle négative pour servir de tension de commande de la vanne de régulation proportionnelle du vérin hydraulique maître, de façon à accélérer une régulation d'un degré d'ouverture négatif de la vanne de régulation proportionnelle du vérin hydraulique maître ; et

2) lorsque la tension de commande de la vanne de régulation proportionnelle du vérin hydraulique esclave est supérieure à zéro, l'unité de compensation de zone morte positive/négative de vanne de régulation proportionnelle du vérin hydraulique esclave génère une tension de compensation de zone morte de vanne de régulation proportionnelle positive, et une tension de commande de la vanne de régulation proportionnelle qui est générée par le bloc fonctionnel régulateur de vitesse est ajoutée à la tension de compensation de zone morte de vanne de régulation proportionnelle positive pour servir de tension de commande de la vanne de régulation proportionnelle du vérin hydraulique esclave, de façon à accélérer une régulation d'un degré d'ouverture positif de la vanne de régulation proportionnelle du vérin hydraulique esclave ; lorsque la tension de commande de la vanne de régulation proportionnelle du vérin hydraulique esclave est inférieure à zéro, la sous-unité de compensation de zone morte positive/négative

de vanne de régulation proportionnelle du vérin hydraulique esclave génère une tension de compensation de zone morte de vanne de régulation proportionnelle négative, et une tension de commande de la vanne de régulation proportionnelle qui est générée par le bloc fonctionnel régulateur de vitesse est ajoutée à la tension de compensation de zone morte de vanne de régulation proportionnelle négative pour servir de tension de commande de la vanne de régulation proportionnelle du vérin hydraulique esclave, de façon à accélérer une régulation d'un degré d'ouverture négatif de la vanne de régulation proportionnelle du vérin hydraulique esclave.

8. Procédé de commande de synchronisation reposant sur un système de commande de synchronisation pour des vérins hydrauliques de levage d'un répartiteur de coulée continue selon les revendications 1, 3, 4, 5 et 6, dans lequel l'unité de commande de sortie de plage d'écart de position de synchronisation de vérin hydraulique maître est constituée des blocs fonctionnels LZSTC01 à LZSTC11 et LZSTC24 à LZSTC26 ; l'unité de correction de vitesse d'écart de position de synchronisation de vérin hydraulique maître est constituée des blocs fonctionnels LZSTC19 à LZSTC23 et LZSTC51 à LZSTC60 ; l'unité de commande d'interruption pour panne de vérin hydraulique maître/esclave est constituée des blocs fonctionnels LZSTC44 à LZSTC46 ; l'unité de commande de synchronisation de levage manuel de vérin hydraulique maître est constituée des blocs fonctionnels LZSTC12 à LZSTC15, LZSTC27 à LZSTC30, LZSTC34 à LZSTC38, et LZSTC43 ; l'unité de commande de conservation automatique de position de vérin hydraulique maître est constituée des blocs fonctionnels LZSTC16 à LZSTC18, LZSTC31 à LZSTC33, LZSTC39 à LZSTC43, et LZSTC48 à LZSTC50 ; l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique maître est constituée des blocs fonctionnels LZSTC47, LZSTC61 à LZSTC63 et LZSTC67 ; l'unité de commande de sortie de plage d'écart de position de synchronisation de vérin hydraulique esclave est constituée des blocs fonctionnels LZSTC100, LZSTC101 et LZSTC104 ; l'unité de correction de vitesse d'écart de position de synchronisation de vérin hydraulique esclave est constituée des blocs fonctionnels LZSTC116 à LZSTC120 et LZSTC121 à LZSTC130 ; l'unité de commande de synchronisation de levage manuel de vérin hydraulique esclave est constituée des blocs fonctionnels LZSTC102, LZSTC103, LZSTC105 à LZSTC108, LZSTC134 à LZSTC136, et LZSTC138 ; l'unité de commande de conservation automatique de position de vérin hydraulique esclave est constituée des blocs fonctionnels LZSTC110 à LZSTC115, LZSTC131 à LZSTC133, LZSTC137, et LZSTC138 ; et l'unité de commande en boucle fermée de vitesse de levage de vérin hydraulique esclave est constituée des blocs fonctionnels LZSTC139 à LZSTC142 et LZSTC146.

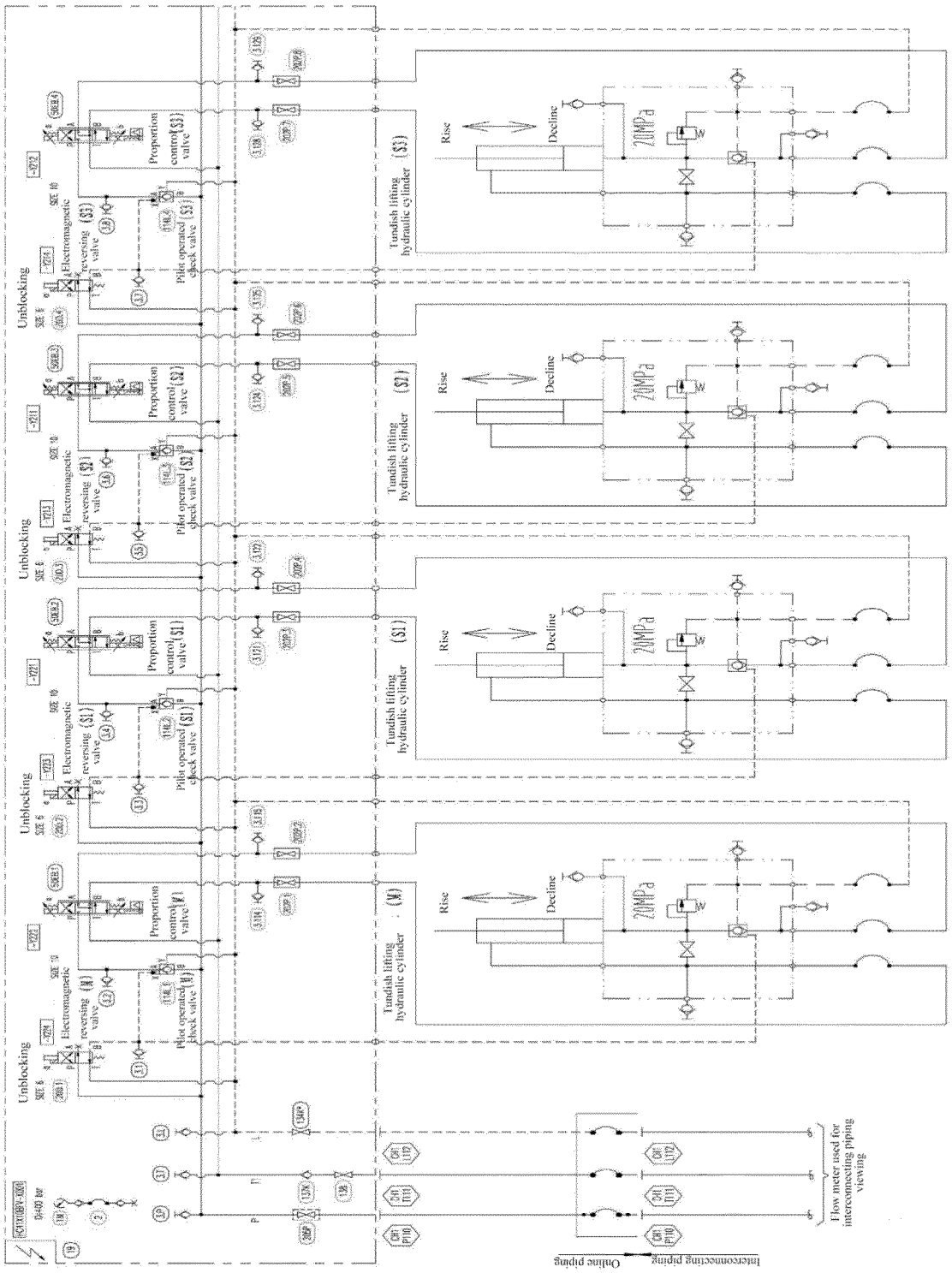
Unblocking
Proportion control valve
Electromagnetic reversing valve
Pilot operated check valve
Tundish lifting hydraulic cylinder
Rise
Decline
20MPa
Flow meter used for interconnecting piping viewing
Interconnecting piping
Online piping

FIG. 1

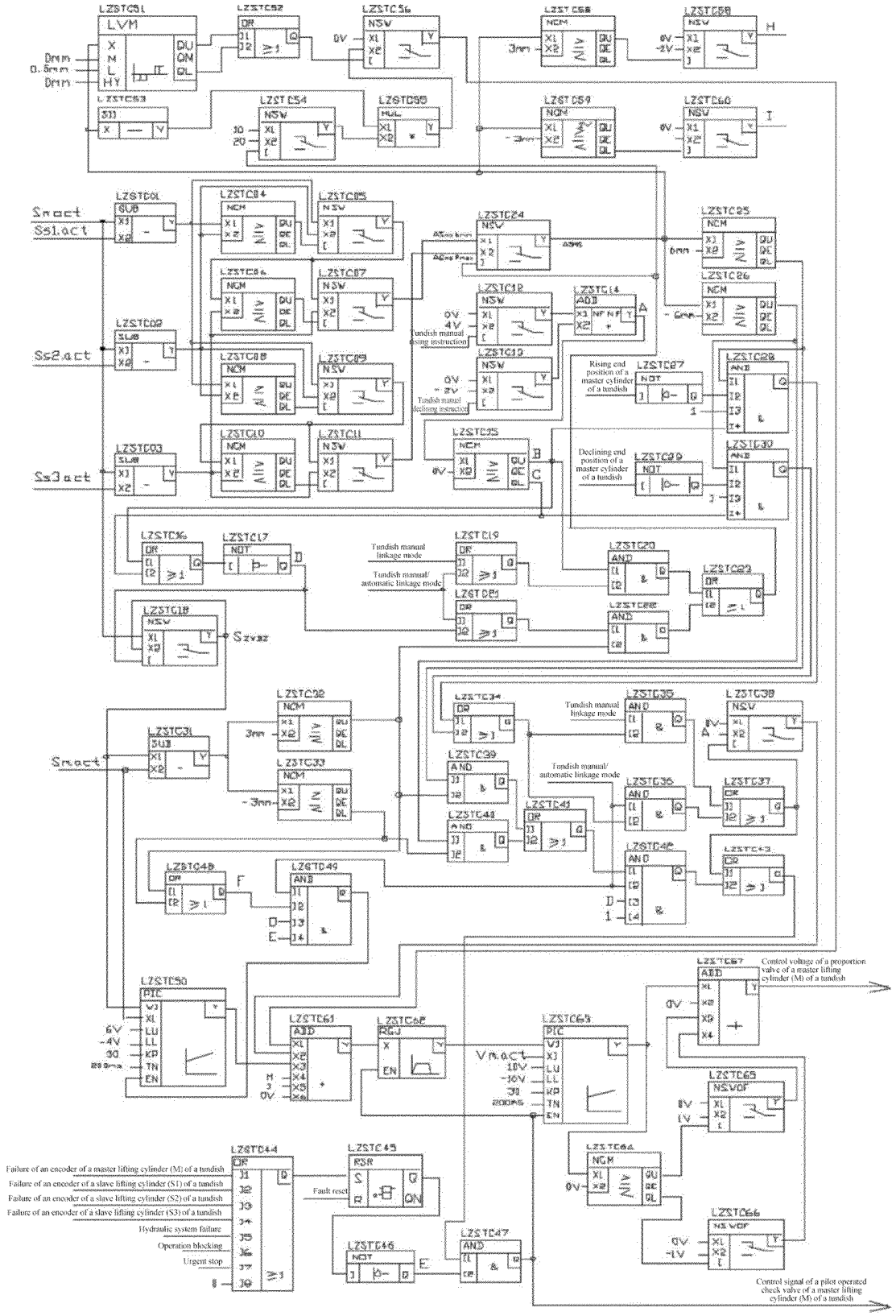
Failure of an encoder of a master lifting cylinder (M) of a tundish
Failure of an encoder of a slave lifting cylinder (S1) of a tundish
Failure of an encoder of a slave lifting cylinder (S2) of a tundish
Failure of an encoder of a slave lifting cylinder (S3) of a tundish
Hydraulic system failure
Operation blocking
Urgent stop
Fault reset
Tundish manual linkage mode
Tundish manual/ automatic linkage mode
Rising end position of a master cylinder of a tundish
Declining end position of a master cylinder of a tundish
Control voltage of a proportion valve of a master lifting cylinder (M) of a tundish
Control signal of a pilot operated check valve of a master lifting cylinder (M) of a tundish

FIG. 2

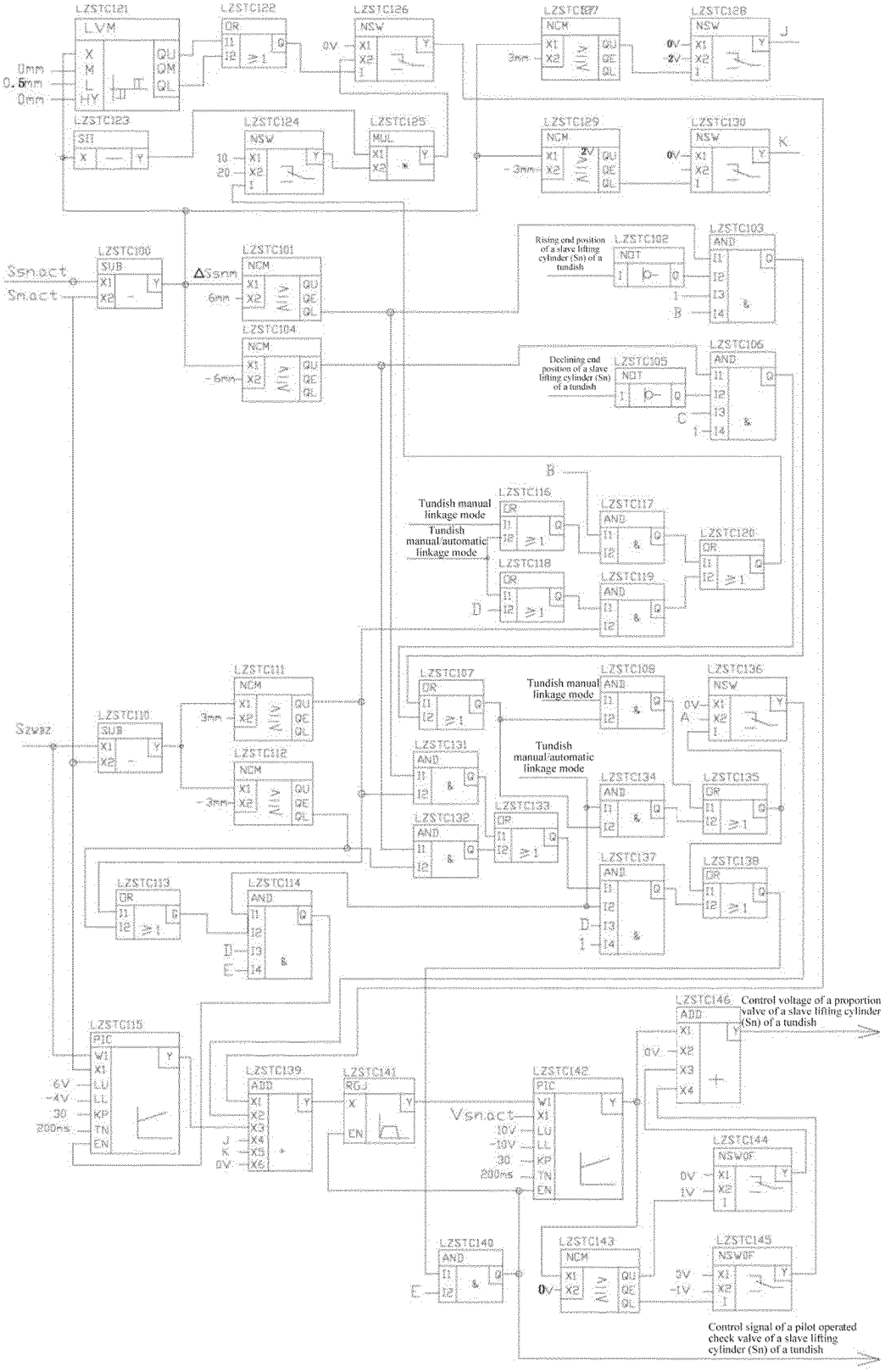
LZSTC121
LVM
0mm
0.5mm
0mm
LZSTC122
OR
LZSTC126
NSW
0V
LZSTC127
NCM
3mm
LZSTC128
NSW
0V
2V
J
LZSTC123
SII
LZSTC124
NSW
10
20
LZSTC125
MUL
LZSTC129
NCM
2V
-3mm
LZSTC130
NSW
0V
K
LZSTC100
SUB
Ssn.act
Sn.act
LZSTC101
NCM
ΔSsnm
6mm
LZSTC104
NCM
-6mm
Rising end position of a slave lifting cylinder (Sn) of a tundish
LZSTC102
NOT
LZSTC103
AND
Declining end position of a slave lifting cylinder (Sn) of a tundish
LZSTC105
NOT
LZSTC106
AND
B
C
Tundish manual linkage mode
Tundish manual/automatic linkage mode
LZSTC116
OR
LZSTC117
AND
LZSTC120
OR
LZSTC118
OR
LZSTC119
AND
D
LZSTC111
NCM
3mm
LZSTC110
SUB
Szwz
LZSTC112
NCM
-3mm
LZSTC107
OR
Tundish manual linkage mode
LZSTC108
AND
LZSTC136
NSW
0V
A
LZSTC131
AND
Tundish manual/automatic linkage mode
LZSTC132
AND
LZSTC133
OR
LZSTC134
AND
LZSTC135
OR
LZSTC137
AND
LZSTC138
OR
LZSTC113
OR
LZSTC114
AND
D
E
LZSTC115
PIC
W1
X1
LU
LL
KP
TN
EN
6V
-4V
30
200ms
LZSTC139
ADD
X1
X2
X3
X4
X5
X6
J
K
0V
LZSTC141
RDJ
X
EN
Vsn.act
LZSTC142
PIC
10V
-10V
30
200ms
LZSTC146
ADD
Control voltage of a proportion valve of a slave lifting cylinder (Sn) of a tundish
0V
LZSTC144
NSWOF
0V
1V
LZSTC140
AND
E
LZSTC143
NCM
0V
LZSTC145
NSWOF
5V
-1V
Control signal of a pilot operated check valve of a slave lifting cylinder (Sn) of a tundish

FIG. 3

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 203614479 U **[0003]**
- CN 203740983 U **[0004]**
- CN 104832499 **[0005]**
- DE 102006004308 **[0006]**
- US 6837054 B2 **[0007]**
- CN 105836422 **[0008]**