



(11) **EP 2 620 405 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:
14.10.2015 Bulletin 2015/42

(51) Int Cl.:
B66C 13/20 (2006.01) **B66C 23/28** (2006.01)
B66C 23/62 (2006.01) **B66C 23/32** (2006.01)

(21) Application number: **11859735.0**

(86) International application number:
PCT/CN2011/078540

(22) Date of filing: **17.08.2011**

(87) International publication number:
WO 2012/116537 (07.09.2012 Gazette 2012/36)

(54) **LIFTING STRUCTURE OF TOWER CRANE, HYDRAULIC SYSTEM OF LIFTING STRUCTURE, AND LIFTING METHOD**

HEBESTRUKTUR FÜR EINEN KRAN, HYDRAULIKSYSTEM FÜR DIE HEBESTRUKTUR UND HEBEVERFAHREN

STRUCTURE DE LEVAGE DE GRUE À TOUR, SYSTÈME HYDRAULIQUE DE STRUCTURE DE LEVAGE ET PROCÉDÉ DE LEVAGE

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(30) Priority: **02.03.2011 CN 201110050632**

(43) Date of publication of application:
31.07.2013 Bulletin 2013/31

(73) Proprietor: **Zoomlion Heavy Industry Science & Technology Co., Ltd.**
Yuelu District,
Changsha,
Hunan 410013 (CN)

(72) Inventors:
• **ZHANG, Yiliang**
Changsha
Hunan 410013 (CN)
• **HU, Shenglei**
Changsha
Hunan 410013 (CN)
• **LIANG, Sha**
Changsha
Hunan 410013 (CN)
• **LI, Bai**
Changsha
Hunan 410013 (CN)
• **MAO, Kuai**
Changsha
Hunan 410013 (CN)

- **WU, Mao**
Changsha
Hunan 410013 (CN)
- **LI, Yuli**
Changsha
Hunan 410013 (CN)
- **CHEN, Longjian**
Changsha
Hunan 410013 (CN)
- **ZHOU, Hanlin**
Changsha
Hunan 410013 (CN)
- **YU, Lekang**
Yuelu District
Changsha, Hunan 410013 (CN)

(74) Representative: **Jennings, Nigel Robin et al**
Kilburn & Strode LLP
20 Red Lion Street
London WC1R 4PJ (GB)

(56) References cited:
EP-A1- 0 516 938 **CN-U- 201 495 049**
CN-U- 202 016 806 **CN-Y- 2 333 687**
CN-Y- 2 466 125 **CN-Y- 2 488 893**
CN-Y- 2 658 453 **CN-Y- 201 225 344**
DE-A1- 2 253 201 **DE-A1- 2 253 201**
DE-U1-202005 009 236 **JP-A- 2 086 597**
JP-A- 8 245 176

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 2 620 405 B1

Description

Field of the Invention

[0001] The present invention relates to the crane domain, in particular to a lifting structure of tower crane, a hydraulic system for the lifting structure, and a lifting method of tower crane. A crane having such a structure is disclosed in EP 0516938 A1.

Background of the Invention

[0002] At present, most self-lifting tower cranes employ a single-cylinder lifting hydraulic system, but some large-tonnage self-lifting tower cranes employ a double-cylinder lifting hydraulic system, in which balancing valves or hydraulic locks are rigidly connected to the cylinder bodies to attain the explosion-proof purpose and ensure safety. However, if such an arrangement is employed on super-large-tonnage self-lifting tower cranes, the lifting cylinders will be huge and be difficult to install and service.

[0003] For multi-cylinder large-tonnage self-lifting tower cranes which employ two or more cylinders, there will be the following problems if balancing valves or hydraulic locks still are rigidly connected to the cylinder bodies simply:

1. The cylinders may not operate synchronously, because the balancing valves or the hydraulic locks for the cylinders may not be opened synchronously during the cylinder startup process, even synchronous control arrangement (e.g., synchronizing valves) are taken. The accuracy of synchronization depends on the control accuracy of the synchronizing valves when the cylinders ascend or the piston rods extend; whereas, the accuracy of synchronization not only depends on the control accuracy of the synchronizing valves but also is subjected to the control of the balancing valves when the cylinders descend or the piston rods retract; that problem is seen in double-cylinder lifting tower cranes of the prior art.

2. As for lifting cylinders that employ hydraulic locks, since the rodless cavities of the cylinders are locked by the respective hydraulic locks, in case one of hydraulic lock is not opened timely, the weight of the entire climbing frame and the back-tension force of other cylinders will act on this cylinder, and thereby may cause over-pressure on said cylinder, resulting in severe damage to said cylinder and severe safety hazard.

Summary of the Invention

[0004] The object of the present invention is to provide a lifting structure of tower crane, a hydraulic system of the lifting structure, and a lifting method of tower crane,

so as to solve the problem of out-of-sync lifting of tower cranes that employs two or more cylinders in the prior art.

[0005] To attain the object described above, in an aspect, the present invention provides a hydraulic system for lifting structure of tower crane, used to drive a climbing frame of the tower crane to ascend or descend on the tower body of tower crane, comprising a plurality of cylinders that are connected to lifting beams and upper beams of the tower crane respectively; wherein, each of the cylinders has a forward branch working oil circuit and a reversed branch working oil circuit; the forward branch working oil circuit of each cylinder has a forward speed regulator valve used to regulate the flow rate of hydraulic oil in the forward direction, and the reversed branch working oil circuit of each cylinder has a reversed speed regulator valve used to regulate the flow rate of hydraulic oil in the reversed direction.

[0006] Moreover, the hydraulic system for lifting structure further comprises balancing valves arranged in each of the forward branch working oil circuits.

[0007] Moreover, each of the balancing valves comprises an oil inlet, an oil outlet, and a control port, wherein, the oil inlet communicates with the forward branch working oil circuit, the oil outlet communicates with one of the rodless cavity and rod cavity of the cylinder, and the control port communicates with the reversed branch working oil circuit and another one of the rodless cavity and rod cavity of the cylinder.

[0008] Moreover, the hydraulic system further comprises a main working oil circuit communicating with the forward branch working oil circuits and reversed branch working oil circuits respectively, and which has a pilot check valve communicating with the forward branch working oil circuits of the cylinders respectively, the pilot check valve has an opening ratio smaller than the opening ratio of each balancing valve.

[0009] Moreover, the forward branch working oil circuit and reversed branch working oil circuit of each cylinder have a stop valve respectively.

[0010] Moreover, the plurality of cylinders are connected in parallel to an oil tank, and the hydraulic system further comprises a main working oil circuit connected between the oil tank and the cylinders, which communicates with the forward branch working oil circuits and reversed branch working oil circuits, and the main working oil circuit has a combined valve comprising a combined reversing valve and a combined overflow valve, which communicate with each other.

[0011] Moreover, the main working oil circuit has a back pressure valve connected in series to the oil tank, and which communicates with the reversed branch working oil circuits.

[0012] Moreover, the main working oil circuit has an overflow valve, which communicates with the reversed branch working oil circuits.

[0013] Moreover, the quantities of cylinders are six, the tower body has two sides, and one front and one back connected to the two sides, and two cylinders connected

between the climbing frame and the lifting beams are arranged on each of the sides and the back of the tower body respectively.

[0014] The present invention further provides a lifting structure of tower crane, which comprises a tower body and a climbing frame arranged on the top of the tower body, wherein, the tower body has a step, the lifting beams are connected at the bottom to the upper beams, and the step support the lifting beams; the lifting structure further comprises a hydraulic system for lifting structure described above.

[0015] The present invention further provides a lifting method of tower crane, which is characterized in: arranging a plurality of cylinders connected between the upper beams and the lifting beams of the tower crane, controlling the forward and reversed flow rates of hydraulic oil in the branch working oil circuits of each cylinder and the accuracy of synchronization among the cylinders by means of a forward speed regulator valve and a reversed speed regulator valve on each of the cylinders, and controlling the cylinders to lift synchronously by maintaining the forward and reversed flow rates of hydraulic oil in the branch working oil circuits at the same value among the cylinders and controlling the cylinders to act synchronously.

[0016] Moreover, two cylinders are arranged on two sides and a back of the climbing frame of tower crane, and each of the cylinders is connected between the upper beams and the lifting beams; the forward and reversed flow rates of hydraulic oil in the branch working oil circuits are maintained at the same value among the cylinders and the cylinders are controlled to act synchronously with the forward speed regulator valve and reversed speed regulator valve on each of the cylinders.

[0017] Furthermore, the weight of the lifting beams is balanced by means of a back pressure valve connected in series to an oil tank.

[0018] Moreover, the climbing frame is prevented from falling in case of pressure loss in the cylinder by arranging a balancing valve on each of the cylinders to control the rodless cavity of the cylinder.

[0019] Moreover, arranging a pilot check valve in the main working oil circuit of the hydraulic system, and the opening ratio of the pilot check valve is smaller than the opening ratio of each of the balancing valves.

[0020] In the solution of the present invention, the forward and reversed flow rates of hydraulic oil in the branch working oil circuits of each cylinder and the accuracy of synchronization among the cylinders are controlled by means of the forward speed regulator valve and reversed speed regulator valve on each cylinder, and the cylinders are controlled to lift synchronously by maintaining the flow rates in the branch working oil circuits at the same value among the cylinders; in that way, the problem of out-of-sync lifting of cylinders on tower cranes in the prior art is solved, and the poor efficacy of synchronizing valves on tower cranes in the prior art can be solved.

Brief Description of the Drawings

[0021] As a part of the patent application, the accompanying drawings are provided to further illustrate the present invention; the embodiments and the description thereof in the present invention are provided to illustrate the present invention, but not be deemed as any undue limitation to the present invention. Among the drawings:

Figure 1 shows the working principle of the lifting structure of tower crane in the embodiments of the present invention;

Figure 2 shows the structure of the hydraulic system for lifting structure of tower crane in the embodiments of the present invention;

Figure 3 shows the structure on the back of the lifting structure of tower crane in the embodiments of the present invention;

Figure 4 shows the structure on the side of the lifting structure of tower crane in the embodiments of the present invention;

Figure 5 shows the structure on the front of the lifting structure of tower crane in the embodiments of the present invention; and

Figure 6 shows the structure of the lifting beams of tower crane in the embodiments of the present invention.

Detailed Description of Embodiments

[0022] It is noted that the embodiments and the features in the embodiments can be combined freely, in the case of there is no confliction between them. Hereunder the present invention will be detailed in the embodiments, with reference to the accompanying drawings.

[0023] As shown in Figure 1, in the tower crane in the embodiments of the present invention, hydraulic system of lifting structure drives a climbing frame 31 of tower crane to ascend and descend on the tower body 39 of the tower crane, for example, the climbing frame 31 is supported and driven by the hydraulic system to ascend and descend on the tower body 39 via guide pulleys 32 arranged on the tower body 39. The hydraulic system comprises a plurality of cylinders 15; for example, two, three, four, six, or eight cylinders can be used, the cylinders 15 in such a quantity can be arranged more easily. For example, if the hydraulic system comprises two cylinders 15, the two cylinders 15 can be arranged on one side or both sides of the climbing frame 31. The piston rod and cylinder body of each cylinder 15 are connected to lifting beams 35 and upper beams 34 of the tower crane respectively, wherein, the upper beams 34 are fixed to the climbing frame 31, and the lifting beams 35

are fixed to the standard mast sections in a detachable manner, i.e., when the climbing frame 31 climbs, the lifting beams 35 are connected to the topmost standard mast section; when new standard mast section is added, the lifting beams 35 can be disconnected from the original standard mast section and then connected to the added standard mast section. In the process the climbing frame 31 climbs, a clevis 33 can be utilized to support and locate the climbing frame 31, and thereby the position of the lifting beams 35 can be adjusted. A step 37 are arranged on the tower body 39 of the tower crane. At the end of the lifting process, the step 37 will support and stop the lifting beams 35 to prevent the lifting beams 35 from moving again, and thereby ensure the safety of the tower crane.

[0024] As shown in Figure 2, in one embodiment of the present invention, the hydraulic system comprises six cylinders 15, which can have the same model and same structure. Among the cylinders 15, each cylinder has a forward branch working oil circuit and a reversed branch working oil circuit, which are used to control the movement of rodless cavity and rod cavity of the cylinder 15 respectively. The hydraulic system further comprises a main working oil circuit 21 that communicates with the forward branch working oil circuits and the reversed branch working oil circuits respectively. In this embodiment, the main working oil circuit 21 comprises a first main working oil circuit communicating with the forward branch working oil circuits and a second main working oil circuit communicating with the reversed branch working oil circuits. Wherein, one end of each forward branch working oil circuit communicates with the rodless cavity of cylinder 15, and another one end of the forward branch working oil circuit communicates with an oil tank 1 of the hydraulic system via the first main working oil circuit; one end of each reversed branch working oil circuit communicates with the rod cavity of cylinder 15, and another one end of the reversed branch working oil circuit communicates with the oil tank 1 of the hydraulic system via the second main working oil circuit. A speed regulator valve 14 is arranged in the forward branch working oil circuit and reversed branch working oil circuit of each cylinder 15 respectively, wherein, the speed regulator valve 14 arranged in the forward branch working oil circuit is a forward speed regulator valve used to regulate the flow rate in the forward branch working oil circuit; the speed regulator valve 14 arranged in the reversed branch working oil circuit is a reversed speed regulator valve used to regulate the flow rate in the reversed branch working oil circuit. The speed regulator valve 14 has precise scale, so as to control the flow rate of hydraulic oil in the working oil circuits accurately. It is understood that the forward branch working oil circuit will communicate with the rod cavity and the reversed branch working oil circuit will communicate with the rodless cavity when the piston rod of cylinder 15 is connected to the head beam 34 and the cylinder body is connected to the lifting beam 35.

[0025] Please see Figure 2 again. The hydraulic system further comprises an oil pump 6 and a motor 7 driving the oil pump 6, wherein, the oil pump 6 is arranged in the main working oil circuit 21, one end of the oil pump 6 communicates with the oil tank 1, and another end of the oil pump 6 communicates with both the forward branch working oil circuit and the reversed branch working oil circuit simultaneously.

[0026] Specifically, as shown in Figure 2, the forward speed regulator valves on the six cylinders 15 are A11, A12, A13, A14, A15, and A16 respectively; the reversed speed regulator valves on the six cylinders 15 are B11, B12, B13, B14, B15, and B16 respectively. The extending and retracting speeds of each cylinder and the synchronization accuracy of the cylinders can be controlled respectively by controlling the opening of the speed regulator valve 14 in each branch to the same scale. The forward branch working oil circuit of each cylinder 15 meets the first main working oil circuit of the main working oil circuit 21 at point A, and the reversed branch working oil circuit of each cylinder 15 meets the second main working oil circuit of the main working oil circuit 21 at point B. Owing to the fact that the speed regulator valve 14 has high speed rigidity, i.e., the flow rate is essentially immune to the impact of the load and the pressure fluctuation in the pump station once it is regulated to a specified value, the controlled flow rate will have no fluctuation essentially, and thereby the accuracy of synchronization among the cylinders 15 will be increased highly.

[0027] In the hydraulic system provided in the present invention, the forward and reversed flow rates of hydraulic oil in the branch working oil circuits of each cylinder 15 and the accuracy of synchronization among the cylinders 15 are controlled by means of the forward speed regulator valve and reversed speed regulator valve on each cylinder 15, and the cylinders 15 are controlled to lift synchronously by maintaining the synchronization of the working oil in each branch working oil circuits. In this way, the problem of out-of-sync lifting of cylinders on tower cranes in the prior art is solved, and the poor efficacy of utilization of synchronizing valves in the prior art can be solved. Owing to the fact that the ascending speed of the cylinders is different to the descending speed of the cylinders, a bridge rectifier synchronization circuit composed of a speed regulator valve and four check valves is not used; instead, each cylinder 15 employs two speed regulator valves to control the ascending speed and descending speed thereof respectively, so as to achieve the synchronization, i.e., six cylinders 15 employ 12 speed regulator valves altogether to achieve speed regulation and synchronization control. The accumulative synchronous error during synchronous operation of the cylinders 15 can be eliminated by that the piston rods of the cylinders reach to the target positions.

[0028] Preferably, as shown in Figure 2, the hydraulic system further comprises balancing valves 13 arranged in the forward branch working oil circuits. Each of the balancing valves 13 comprises an oil inlet, an oil outlet,

and a control port, wherein, the oil inlet communicates with the forward branch working oil circuit, the oil outlet communicates with one of the rodless cavity and rod cavity of the cylinder, and the control port communicates with the reversed branch working oil circuit and another one of the rodless cavity and rod cavity of the cylinder.

[0029] In an embodiment of the present invention, the oil inlet communicates with the forward branch working oil circuit, the oil outlet communicates with the rodless cavity of the cylinder, and the control port communicates with the reversed branch working oil circuit and a rod control port in the rod cavity correspondingly. Wherein, the rod control port is arranged in the rod cavity of cylinder, and controls the pressure in the rodless cavity by means of the communication with the balancing valve 13, so as to reduce the idle work. In a hydraulic system with six cylinders 15, the six balancing valves 13 are arranged. In case that a rubber tube connected to the rodless cavity of a cylinder ruptures in the mast section addition process for lifting of the tower crane, and therefore the cylinders tend to drop rapidly with the climbing frame on the upper part of the tower crane due to sudden pressure loss in the rodless cavity, the balancing valve 13 will be closed, and thereby keep the cylinders at its position, so as to ensure safe operation of the tower crane. In addition, as shown in Figure 2, the control port of balancing valve 13 communicates with the rod control port in the rod cavity, so as to regulate the working pressure in the rod cavity and reduce energy consumption.

[0030] Preferably, as shown in Figure 2, a plurality of cylinders 15 are connection in parallel to one oil tank 1; in that way, the space can be save, and the weight of the tower crane can be reduced. A back pressure valve 11 connected in series to the cylinders 15 is arranged in the second main working oil circuit of the main working oil circuit 21 of the hydraulic system, and the back pressure valve 11 communicates with each of the reversed branch working oil circuits and an oil pump 6 as well.

[0031] The back pressure valve 11 is mainly used to balance the weight of the lifting beams 35 on the end of the piston rods of the cylinders. Since the lifting beams 35 are connected on the piston rods of the cylinders 15, the heavy lifting beams 35 will tend to drive the piston rods to descend further due to inertia effect, and therefore have impact on the position accuracy of the pistons when the piston rods descend to a position and try to stop thereon. In this case, the system weight can be balanced, owing to the existence of the back pressure valve 11.

[0032] Preferably, as shown in Figure 2, the hydraulic system further comprises a main working oil circuit 21, which communicates with the forward branch working oil circuits and the reversed branch working oil circuits respectively, and the main working oil circuit 21 has a combined valve 9 comprising a combined reversing valve and a combined overflow valve which communicate with each other. The oil inlet of the combined valve 9 communicates with the oil pump 6, and the oil outlet of the combined valve 9 communicates with the forward branch working

oil circuits and the reversed branch working oil circuits. The hydraulic system further comprises an oil return circuit, through which the oil outlet of the combined valve 9, the forward branch working oil circuits and the reversed branch working oil circuits may communicate with the oil tank 1 directly.

[0033] The combined valve 9 is a group valve that integrates a plurality of valves. In this embodiment, the combined valve 9 is used to control the flow, reversal, and overflow of hydraulic oil in the main working oil circuit 21. Wherein, the combined reversing valve comprises check valves and reversing valves, while the combined overflow valve comprises overflow valves. The combined valve can be an off-the-shelf product, or can be assembled from check valves, reversing valves and overflow valves or other valves in the field. An off-the-shelf combined valve is preferred, so as to save installation time, furthermore, it is widely available in the market.

[0034] Preferably, as shown in Figure 2, the hydraulic system further comprises a main working oil circuit 21, which communicates with the forward branch working oil circuits and the reversed branch working oil circuits respectively, and the main working oil has a pilot check valve 12 communicating with the forward branch working oil circuit of each cylinder 15 respectively, and which has an opening ratio smaller than the opening ratio of each balancing valve 13. The pilot check valve 12 arranged in the first main working oil circuit communicating with the forward branch working oil circuit of each cylinder 15, thus, the hydraulic oil can only flow into the forward branch working oil circuits, but can't flow back when the tower crane lifts. The opening ratio of the pilot check valve 12 is smaller than the opening ratio of each balancing valve 13, which is to say, the balancing valves 13 will open prior to the pilot check valve 12; thus, the startup error of the cylinders 15 can be reduced. Moreover, the pilot check valve 12 is arranged between the combined valve 9 and the forward branch working oil circuits.

[0035] In addition, another purpose of the pilot check valve 12 and balancing valves 13 is to force the oil to fill up all the pipelines extending from the pump station to the cylinders 15 (i.e., from the back pressure valve 11, pilot check valve 12, to the cylinders 15), so as to avoid air entrapment in the pipelines and thereby ensure stable and synchronous operation of the cylinders.

[0036] Preferably, as shown in Figure 2, the forward branch working oil circuit and the reversed branch working oil circuit of each cylinder have a stop valve 16 respectively. Altogether 12 stop valves 16 are arranged in the oil circuits of six cylinders 15. Thus, the individual cylinders can be controlled to act separately, or several cylinders among the cylinders can be controlled in any combination to act in a coordinated manner. Furthermore, when the cylinders are to be held at a position for long, the stop valves 16 can be closed, so that there will be no leakage in the working pipelines in that state.

[0037] Preferably, the main working oil circuit 21 has an overflow valve, which communicates with the re-

versed branch working oil circuits and the oil tank 1. The overflow valve 10 communicates with the rod cavity 15 of each cylinder 15 through the reversed branch working oil circuit, so as to reduce the pressure in the rod cavity of each cylinder 15, thus, the idle work and improve the energy efficiency of the entire system can be reduced.

[0038] The quantities of cylinders are six. Preferably, as shown in Figures 3-5, the tower body has two sides, and one front and one back connected with the two sides, i.e., the tower body 39 has left side 391, right side 392, front introduction face 393, and back face 394; two cylinders 15 connected between the climbing frame 31 and the lifting beams 35 are arranged on each sides and the back face, but no cylinder 15 is arranged on the front introduction face 393 of the tower body, so that a preparation work for lifting can be done on the front introduction face 393 of the tower body; for example, some parts required for the lifting work can be introduced through the front introduction face 393.

[0039] Such arrangement is a three-face and six-cylinder lifting structure of tower crane. As shown in Figures 2-6, such lifting structure comprises three lifting beams 35, six lifting cylinders 15, one hydraulic pump station 50, and hydraulic rubber tubes 17, etc. Each two lifting cylinders 15 are connected to one lifting beam 35 and climbing frame 31 via pins, and each lifting cylinder 15 is connected to the hydraulic pump station 50 by hydraulic rubber tubes 17. The three lifting beams 35 are arranged on the opposite face and sides face of the standard mast section introduction face respectively. Under the control of the lifting hydraulic system, the cylinders 15 will operate synchronously and bear the same pressure in the lifting process of the tower crane, and operate stably, safely, and reliably in the mast section addition process for lifting and the mast section subtraction process for descending; moreover, every two cylinders 15 share a lifting beam 35, and the lifting force required in the lifting process is provided by six cylinders 15 respectively, which is to say, each lifting cylinder 15 only has to provide very low lifting force; thus, a common small-size lifting cylinders can be used, and therefore the cost and space can be reduced. Especially, for large-size or extra-large tower cranes, such as D5200-240 self-lifting extra-large tower cranes, which can bear heavy lifting load up to more than 800 tons and whose lifting beams 35 has weight of more than 4 tons, the lifting work can be done easily with said three-face and six-cylinder lifting structure; in contrast, in the prior art, to implement such an efficacy, a complex approach has to be used, and there is a risk of over-pressure on cylinder.

[0040] Moreover, the present invention is not limited to the three-face and six-cylinder arrangement; for example, two cylinders or four cylinders can be arranged on the two sides, or three cylinders can be arranged on three sides.

[0041] With the three-face and six-cylinder lifting structure, the procedures of mast section addition process for lifting or mast section subtraction process for descending

of tower crane are as follows:

1. Start up the hydraulic pump station 50, extend the cylinders 15 and hang the three lifting beams 35 to the nearest set of step, and insert safety pins;

2. Verify the above work, and then start up the hydraulic system to extend the piston rods and lift the climbing frame 31 and the part thereabove.

[0042] In the lifting process, the six cylinders 15 are controlled to ascend synchronously and bear the same pressure under the control of the hydraulic system.

[0043] The main working process with a three-face and six-cylinder lifting structure is described as follows:

For the lifting operation of the tower crane, after the drive motor 7 is started, the hydraulic oil will be filtered by a filter 2 and then transferred by a high pressure pump 6 to the combined valve 9; after the control lever is switched to the left position, the hydraulic oil will flow freely through the pilot check valve 12 and balancing valves 13 into the rodless cavities of the cylinders 15, and firstly, set the lifting beams 35 connected to the top of the piston rods of the cylinders into the step on the tower body, wherein the six cylinders can lift synchronously. The accuracy of synchronization is preset by the speed regulator valves 14.

[0044] When the cylinders lift synchronously to the target position, the reversing lever is switched to the right position of the combined valve 9, the hydraulic oil will flow freely through the back pressure valve 11, and be regulated by the speed regulator valves 14, and then flow into the respective rod cavities; at the same time, the control oil from the second main working oil circuit will open the pilot check valve 12 arranged in the first main working oil circuit; thus, the cylinders will support the climbing frame 31 to descend; in this process, the weight of the upper part of the tower crane is balanced by regulating the balancing valves 13, so that the climbing frame 31 will descend smoothly and steadily; after the clevis 33 are fit, the weight of the upper part of the tower crane will be supported by the clevis 33. Then, the piston rods of cylinders 15 will retract and carry the lifting beams 35 to release from the step on the tower body synchronously; then, the lifting beams 35 will ascend.

[0045] When the lifting process is completed, a vacant position for a standard mast section will occur between the lower support of the tower crane and the top of the standard mast sections, and the upper revolving part will be supported completely by the climbing frame 31. To increase the mast height of the tower crane, a new standard mast section can be added between the top of the standard mast sections and the lower support, with the upper part of the added standard mast section connected to the lower support, and the lower part of the added

standard mast section connected to the existing standard mast sections. The above procedure can be executed in the reversed sequence to reduce the mast height of the tower crane.

[0046] When the piston rods of cylinders carrying the lifting beams 35 is retracted to the position above the step for the upper standard mast section, the reversing lever is switched to the left position, the piston rods of cylinders will extend and carry the lifting beams 35 to descend synchronously into the groove of the step. The weight of the lifting beams 35 is balanced by regulating the back pressure valve 11; then, the lever of the combined valve 9 can be switched to the left position, and the above procedure can be repeated to start another lifting cycle.

[0047] For the mast section subtraction operation for descending of the tower crane, after the drive motor 7 is started, the hydraulic oil will be filtered by filter 2 and then transferred by high pressure pump 6 to the combined valve; after the control lever is switched to the left position, the hydraulic oil will flow freely through the check valve 12 and balancing valves 13 into the rodless cavities of the cylinders 15, and therefore the piston rods of the cylinders will extend and set the lifting beams connected to the top of the piston rods of cylinders synchronously into the step for the lower mast section of tower body; after the cylinders lift synchronously to the target position and the standard mast section subtraction operation is completed, the reversing lever is switched to the right position of the combined valve 9, and the hydraulic oil will flow freely through the back pressure valve 11, and be regulated by the speed regulator valves 14 synchronously, and then flow into the respective rod cavities; at the same time, the control oil from the right oil circuit will open the check valve 12 in the left oil circuit, and the cylinders will carry the climbing frame 31 to descend smoothly and steadily; then, after the clevis are fit, the piston rods will carry the lifting beams to release from the step synchronously. Next, after the reversing lever is switched to left position, the piston rods of the cylinders will extend, and carry the lifting beams 35 to fall into the groove of step for the lower mast section. Then, the lever of the combined valve 9 can be switch to the left position and above procedure can be repeat to start another mast section subtraction cycle.

[0048] In the mast section addition process for lifting of the tower crane, in case a rubber tube connecting the rodless cavity of a cylinder 15 ruptures, the cylinder 15 will tend to carry the climbing frame 31 to fall rapidly due to sudden loss of pressure in the rodless cavity; in this case, the balancing valve 13 will be closed so as to keep the cylinder 15 at its position, so that the safe operation of the tower crane can be ensure.

[0049] In the hydraulic system, the outlet pressure of the oil pump 50 is regulated by the combined valve 9, and is usually set to 1.15 times of the actual lifting pressure. The working pressure of rod cavities of the cylinders is regulated by the overflow valve 10, which is lower than

the set value of outlet pressure of the pump, so as to reduce energy consumption.

[0050] It is seen from the above description that the embodiments of the present invention can attain the following technical efficacies:

For a tower crane with two or more cylinders for lifting operation, the present invention can achieve stable, safe, and reliable during the mast section addition operation for lifting and the mast section subtraction operation for descending, and the over-pressured of cylinder can be avoided.

[0051] The present invention can maintain synchronization for multi-cylinders essentially. The accuracy of synchronization for multi-cylinders mainly depends on the control accuracy of the speed regulator valves, and which is essentially immune to the impact of the balancing valves.

[0052] While the present invention has been illustrated and described with reference to some preferred embodiments, the present invention is not limited to these. Those skilled in the art should recognize that various variations and modifications can be made.

Claims

1. A hydraulic system for lifting structure of tower crane, used to drive a climbing frame of the tower crane to ascend or descend on a tower body of the tower crane, **characterized in that:**

the hydraulic system comprises a plurality of cylinders, which are connected to lifting beams and upper beams of the tower crane respectively; wherein, each of the cylinders has a forward branch working oil circuit and a reversed branch working oil circuit, the forward branch working oil circuit of each cylinder has a forward speed regulator valve used to regulate the flow rate of hydraulic oil in the forward direction, and the reversed branch working oil circuit of each cylinder has a reversed speed regulator valve used to regulate the flow rate of hydraulic oil in the reversed direction.

2. The hydraulic system for lifting structure according to claim 1, **characterized in that**, the hydraulic system further comprises balancing valves arranged in each of the forward branch working oil circuits.
3. The hydraulic system for lifting structure according to claim 2, **characterized in that**, the balancing valves comprises an oil inlet, an oil outlet, and a control port, wherein, the oil inlet communicates with the forward branch working oil circuit, the oil outlet communicates with one of the rodless cavity and rod cav-

ity of the cylinder, and the control port communicates with the reversed branch working oil circuit and another one of the rodless cavity and rod cavity of the cylinder.

4. The hydraulic system for lifting structure according to claim 3, **characterized in that**, the hydraulic system further comprises a main working oil circuit communicating with the forward branch working oil circuits and the reversed branch working oil circuits respectively, and which has a pilot check valve communicating with the forward branch working oil circuit of each cylinder respectively, the pilot check valve has an opening ratio smaller than the opening ratio of each balancing valve.
5. The hydraulic system for lifting structure according to claim 4, **characterized in that**, the forward branch working oil circuit and reversed branch working oil circuit of each cylinder have a stop valve respectively.
6. The hydraulic system for lifting structure according to claim 1, **characterized in that**, the plurality of cylinders are connected in parallel to an oil tank, and the hydraulic system further comprises a main working oil circuit connected between the oil tank and the cylinders, which communicates with the forward branch working oil circuits and the reversed branch working oil circuits respectively, and the main working oil circuit has a combined valve comprising a combined reversing valve and a combined overflow valve, which communicate with each other.
7. The hydraulic system for lifting structure according to claim 6, **characterized in that**, the main working oil circuit has a back pressure valve connected in series to the oil tank, and which communicates with the reversed branch working oil circuits.
8. The hydraulic system for lifting structure according to claim 6, **characterized in that**, the main working oil circuit has an overflow valve, which communicates with the reversed branch working oil circuits.
9. The hydraulic system for lifting structure according to any of claims 1-8, **characterized in that**, the quantities of cylinders are six, the tower body has two sides, and one front and one back connected to the two sides, and two cylinders connected between the climbing frame and the lifting beams are arranged on each of the sides and the back of the tower body respectively.
10. A lifting structure of tower crane, comprising a tower body and a climbing frame arranged on the top of the tower body, the tower body has a step, the lifting beams are connected at the bottom to upper beams,

and the step support the lifting beams, **characterized in that**, the lifting structure further comprises the hydraulic system for lifting structure as described in any of claims 1-9.

11. A lifting method of tower crane, **characterized in that**, the method comprises:

arranging a plurality of cylinders connected between upper beams and lifting beams of the tower crane, controlling the forward and reversed flow rates of hydraulic oil in the branch working oil circuits of each of the cylinders and the accuracy of synchronization among the cylinders by means of a forward speed regulator valve and a reversed speed regulator valve on each of the cylinders, and controlling the cylinders to lift synchronously by maintaining the forward and reversed flow rates of hydraulic oil in the branch working oil circuits at the same value among the cylinders and controlling the cylinders to act synchronously.

12. The lifting method according to claim 11, **characterized in that**, two cylinders are arranged on two sides and a back of the climbing frame of tower crane, and each of the cylinders is connected between the upper beams and the lifting beams; the forward and reversed flow rates of hydraulic oil in the branch working oil circuits are maintained at the same value among the cylinders and the cylinders are controlled to act synchronously with the forward speed regulator valve and reversed speed regulator valve on each of the cylinders.
13. The lifting method according to claim 12, **characterized in that**, the weight of the lifting beams is balanced by arranging a back pressure valve connected in series to the oil tank.
14. The lifting method according to claim 11, **characterized in that**, the climbing frame is prevented to fall due to pressure loss in the cylinders by arranging a balancing valve on each of the cylinders to control the rodless cavity of the cylinder.
15. The lifting method according to claim 14, **characterized in that**, arranging a pilot check valve in the main working oil circuit of the hydraulic system, and the pilot check valve has an opening ratio smaller than the opening ratio of each of the balancing valves.

Patentansprüche

1. Hydrauliksystem für eine Hebestruktur eines Turmkranes, das verwendet wird, um einen Kletterrahmen des Turmkranes anzutreiben, um an einem Turmkörper

per des Turmkrans hinauf- oder hinabzufahren, **dadurch gekennzeichnet, dass**

das Hydrauliksystem eine Mehrzahl von Zylindern aufweist, die mit Hebebalken bzw. Oberbalken des Turmkrans verbunden sind;

wobei jeder der Zylinder einen Vorwärtszweig-Betriebsölkreislauf und einen Rückwärtszweig-Betriebsölkreislauf aufweist, wobei der Vorwärtszweig-Betriebsölkreislauf jedes Zylinders ein Vorwärtsgeschwindigkeits-Regelventil hat, das verwendet wird, um die Fließrate von Hydrauliköl in Vorwärtsrichtung zu regeln, und wobei der Rückwärtszweig-Betriebsölkreislauf jedes Zylinders ein Rückwärtsgeschwindigkeits-Regelventil hat, das verwendet wird, um die Fließrate von Hydrauliköl in Rückwärtsrichtung zu regeln.

2. Hydrauliksystem für eine Hebestruktur nach Anspruch 1, **dadurch gekennzeichnet, dass** das Hydrauliksystem des Weiteren in jedem der Vorwärtszweig-Betriebsölkreisläufe angeordnete Ausgleichsventile aufweist.
3. Hydrauliksystem für eine Hebestruktur nach Anspruch 2, **dadurch gekennzeichnet, dass** die Ausgleichsventile einen Öleinlass, einen Ölauslass und eine Steueröffnung aufweisen, wobei der Öleinlass mit dem Vorwärtszweig-Betriebsölkreislauf in Verbindung steht, der Ölauslass mit einem Hohlraum von stangenlosem Hohlraum und Stangenhohlraum des Zylinders in Verbindung steht, und die Steueröffnung mit dem Rückwärtszweig-Betriebsölkreislauf und dem anderen Hohlraum von stangenlosem Hohlraum und tangenhohlraum in Verbindung steht.
4. Hydrauliksystem für eine Hebestruktur nach Anspruch 3, **dadurch gekennzeichnet, dass** das Hydrauliksystem des Weiteren einen Haupt-Betriebsölkreislauf aufweist, der mit den Vorwärtszweig-Betriebsölkreisläufen bzw. Rückwärtszweig-Betriebsölkreisläufen in Verbindung steht, und der ein Pilotrückschlagventil hat, das mit dem Vorwärtszweig-Betriebsölkreislauf jedes Zylinders in Verbindung steht, wobei das Pilotrückschlagventil ein Öffnungsverhältnis hat, das kleiner ist als das Öffnungsverhältnis jedes Ausgleichsventils.
5. Hydrauliksystem für eine Hebestruktur nach Anspruch 4, **dadurch gekennzeichnet, dass** der Vorwärtszweig-Betriebsölkreislauf und der Rückwärtszweig-Betriebsölkreislauf jedes Zylinders jeweils ein Sperrventil haben.
6. Hydrauliksystem für eine Hebestruktur nach Anspruch 1, **dadurch gekennzeichnet, dass** die Mehrzahl von Zylindern parallel zu einem Ölbehälter geschaltet sind, und das Hydrauliksystem des Weiteren einen Haupt-Betriebsölkreislauf aufweist, der

zwischen den Ölbehälter und die Zylinder geschaltet ist, und der mit den Vorwärtszweig-Betriebsölkreisläufen bzw. den Rückwärtszweig-Betriebsölkreisläufen in Verbindung steht, und dass der Haupt-Betriebsölkreislauf ein Kombinationsventil hat, das ein kombiniertes Umschaltventil und ein kombiniertes Überlaufventil aufweist, die miteinander in Verbindung stehen.

7. Hydrauliksystem für eine Hebestruktur nach Anspruch 6, **dadurch gekennzeichnet, dass** der Haupt-Betriebsölkreislauf ein Rückschlagventil hat, das zum Ölbehälter in Reihe geschaltet ist, und das mit den Rückwärtszweig-Betriebsölkreisläufen in Verbindung steht.
8. Hydrauliksystem für eine Hebestruktur nach Anspruch 6, **dadurch gekennzeichnet, dass** der Haupt-Betriebsölkreislauf ein Überlaufventil hat, das mit den Rückwärtszweig-Betriebsölkreisläufen in Verbindung steht.
9. Hydrauliksystem für eine Hebestruktur nach einem der Ansprüche 1 bis 8, **dadurch gekennzeichnet, dass** die Anzahl der Zylinder sechs beträgt, der Turmkörper zwei Seiten hat, und eine Vorderseite und eine Rückseite, die mit den beiden Seiten verbunden sind, und dass zwei Zylinder, die zwischen den Kletterrahmen und die Hebebalken geschaltet sind, an jeder der Seiten und der Rückseite des Turmkörpers angeordnet sind.
10. Hebestruktur eines Turmkrans, mit einem Turmkörper und einem Kletterrahmen, der oben auf dem Turmkörper angeordnet ist, wobei der Turmkörper eine Stufe hat, die Hebebalken an der Unterseite mit Oberbalken verbunden sind, und die Stufe die Hebebalken stützt, **dadurch gekennzeichnet, dass** die Hebestruktur des Weiteren das Hydrauliksystem für eine Hebestruktur nach einem der Ansprüche 1 bis 9 aufweist.
11. Hubverfahren eines Turmkrans, das **dadurch gekennzeichnet ist, dass** das Verfahren umfasst: Anordnen einer Mehrzahl von Zylindern, die zwischen Oberbalken und Hebebalken des Turmkrans geschaltet sind, Steuern der Vorwärts- und Rückwärts-Fließraten von Hydrauliköl in den Zweig-Betriebsölkreisläufen jedes der Zylinder und der Genauigkeit der Synchronisation zwischen den Zylindern mittels eines Vorwärtsgeschwindigkeits-Regelventils und eines Rückwärtsgeschwindigkeits-Regelventils an jedem der Zylinder, und Steuern der Zylinder, um synchron zu heben, durch Halten der Vorwärts- und Rückwärts-Fließraten von Hydrauliköl in den Zweig-Betriebsölkreisläufen unter den Zylindern auf demselben Wert, und Steuern der Zylinder, um synchron zu arbeiten.

12. Hubverfahren nach Anspruch 11, **dadurch gekennzeichnet, dass** zwei Zylinder an zwei Seiten und der Rückseite des Kletterrahmens des Turmkranes angeordnet sind und jeder der Zylinder zwischen die Oberbalken und die Hebebalken geschaltet ist; die Vorwärts- und Rückwärts-Fließraten von Hydrauliköl in den Zweig-Betriebsölkreisläufen unter den Zylindern auf demselben Wert gehalten werden, und die Zylinder gesteuert werden, um mit dem Vorwärtsgeschwindigkeits-Regelventil und dem Rückwärtsgeschwindigkeits-Regelventil an jedem der Zylinder synchron zu arbeiten.
13. Hubverfahren nach Anspruch 12, **dadurch gekennzeichnet, dass** das Gewicht der Hebebalken durch Anordnen eines Rückschlagventils, das mit dem Ölbehälter in Reihe geschaltet ist, ausgeglichen wird.
14. Hubverfahren nach Anspruch 11, **dadurch gekennzeichnet, dass** verhindert wird, dass der Kletterrahmen aufgrund von Druckverlust in den Zylindern fällt, indem ein Ausgleichsventil an jedem der Zylinder angeordnet wird, um den stangenlosen Hohlraum des Zylinders zu steuern.
15. Hubverfahren nach Anspruch 14, **dadurch gekennzeichnet, dass** ein Pilotrückschlagventil in dem Haupt-Betriebsölkreislauf des Hydrauliksystems angeordnet wird und das Pilotrückschlagventil ein Öffnungsverhältnis hat, das kleiner ist als das Öffnungsverhältnis jedes der Ausgleichsventile.

Revendications

1. Système hydraulique pour structure de levage de grue à tour, utilisée pour entraîner un portique de la grue à tour pour monter ou descendre sur un corps de tour de la grue à tour, **caractérisé en ce que** :
- le système hydraulique comprend une pluralité de vérins, qui sont respectivement reliés à des poutrelles de levage et à des poutrelles supérieures de la grue à tour ;
- dans lequel, chacun des vérins a un circuit d'huile de travail ramifié vers l'avant et un circuit d'huile de travail ramifié en sens inverse, le circuit d'huile de travail ramifié vers l'avant de chaque vérin a une vanne régulatrice de vitesse avant utilisée pour réguler le débit d'huile hydraulique dans le sens avant et le circuit d'huile de travail ramifié en sens inverse de chaque vérin a une vanne régulatrice de vitesse en sens inverse utilisée pour réguler le débit d'huile hydraulique en sens inverse.
2. Système hydraulique pour structure de levage selon la revendication 1, **caractérisé en ce que** le système

hydraulique comprend en outre des vannes d'équilibrage agencées dans chacun des circuits d'huile de travail ramifiés vers l'avant.

3. Système hydraulique pour structure de levage selon la revendication 2, **caractérisé en ce que** les vannes d'équilibrage comprennent une entrée d'huile, une sortie d'huile, et un orifice de commande, dans lequel, l'entrée d'huile communique avec le circuit d'huile de travail ramifié vers l'avant, la sortie d'huile communique avec une de la cavité sans tige et de la cavité avec tige du vérin et l'orifice de commande communique avec le circuit d'huile de travail ramifié en sens inverse et une autre de la cavité sans tige et de la cavité avec tige du vérin.
4. Système hydraulique pour structure de levage selon la revendication 3, **caractérisé en ce que** le système hydraulique comprend en outre un circuit d'huile de travail principal communiquant respectivement avec les circuits d'huile de travail ramifiés vers l'avant et les circuits d'huile de travail ramifiés en sens inverse, et qui a une vanne pilote de non-retour communiquant respectivement avec le circuit d'huile de travail ramifié vers l'avant de chaque vérin, la vanne pilote de non-retour a un rapport d'ouverture plus petit que le rapport d'ouverture de chaque vanne d'équilibrage.
5. Système hydraulique pour structure de levage selon la revendication 4, **caractérisé en ce que** le circuit d'huile de travail ramifié vers l'avant et le circuit d'huile de travail ramifié en sens inverse de chaque vérin ont respectivement une vanne d'arrêt.
6. Système hydraulique pour structure de levage selon la revendication 1, **caractérisé en ce que** la pluralité de vérins est reliée en parallèle à un réservoir d'huile, et le système hydraulique comprend en outre un circuit d'huile de travail principal relié entre le réservoir d'huile et les vérins, qui communique respectivement avec les circuits d'huile de travail ramifiés vers l'avant et les circuits d'huile de travail ramifiés en sens inverse, et le circuit d'huile de travail principal a une vanne combinée comprenant une vanne de réversion combinée et une vanne de débordement combinée, qui communiquent l'une avec l'autre.
7. Système hydraulique pour structure de levage selon la revendication 6, **caractérisé en ce que** le circuit d'huile de travail principal a une vanne de contrepression reliée en série au réservoir d'huile, et qui communique avec les circuits d'huile de travail ramifiés en sens inverse.
8. Système hydraulique pour structure de levage selon la revendication 6, **caractérisé en ce que** le circuit d'huile de travail principal a une vanne de débordement, qui communique avec les circuits d'huile de

travail ramifiés en sens inverse.

9. Système hydraulique pour structure de levage selon n'importe laquelle des revendications 1 à 8, **caractérisé en ce que** le nombre de vérins est six, le corps de tour a deux côtés et un avant et un arrière reliés aux deux côtés, et deux vérins reliés entre le portique et les poutrelles de levage sont respectivement agencés sur chacun des côtés et du dos du corps de tour. 5
10. Structure de levage de grue à tour, comprenant un corps de tour et un portique agencé sur le sommet du corps de tour, le corps de tour a un échelon, les poutrelles de levage sont reliées au niveau du bas à des poutrelles supérieures, et l'échelon supporte les poutrelles de levage, **caractérisée en ce que** la structure de levage comprend en outre le système hydraulique pour structure de levage tel que décrit dans n'importe laquelle des revendications 1 à 9. 10 15 20
11. Procédé de levage pour grue à tour, **caractérisé en ce que** le procédé comprend :

l'agencement d'une pluralité de vérins reliés entre des poutrelles supérieures et des poutrelles de levage de la grue à tour, la commande des débits vers l'avant et en sens inverse d'huile hydraulique dans les circuits d'huile de travail ramifiés de chacun des vérins et de la précision de synchronisation entre les vérins au moyen d'une vanne régulatrice de vitesse avant et d'une vanne régulatrice de vitesse en sens inverse sur chacun des vérins, et la commande des vérins pour lever de manière synchrone en maintenant les débits vers l'avant et en sens inverse d'huile hydraulique dans les circuits d'huile de travail ramifiés à la même valeur entre les vérins et la commande des vérins pour agir de manière synchrone. 25 30 35 40
12. Procédé de levage selon la revendication 11, **caractérisé en ce que** deux vérins sont agencés sur deux côtés et un dos du portique de grue à tour, et chacun des vérins est relié entre les poutrelles supérieures et les poutrelles de levage ; les débits vers l'avant et en sens inverse d'huile hydraulique dans les circuits d'huile de travail ramifiés sont maintenus à la même valeur entre les vérins et les vérins sont commandés pour agir de manière synchrone avec la vanne régulatrice de vitesse avant et la vanne régulatrice de vitesse en sens inverse sur chacun des vérins. 45 50
13. Procédé de levage selon la revendication 12, **caractérisé en ce que** le poids des poutrelles de levage est équilibré en agencant une vanne de contre-pression reliée en série au réservoir d'huile. 55

14. Procédé de levage selon la revendication 11, **caractérisé en ce que** le portique est empêché de tomber à cause d'une perte de pression dans les vérins en agencant une vanne d'équilibrage sur chacun des vérins pour commander la cavité sans tige du vérin.

15. Procédé de levage selon la revendication 14, **caractérisé par** l'agencement d'une vanne pilote de non-retour dans le circuit d'huile de travail principal du système hydraulique, et la vanne pilote de non-retour a un rapport d'ouverture plus petit que le rapport d'ouverture de chacune des vannes d'équilibrage.

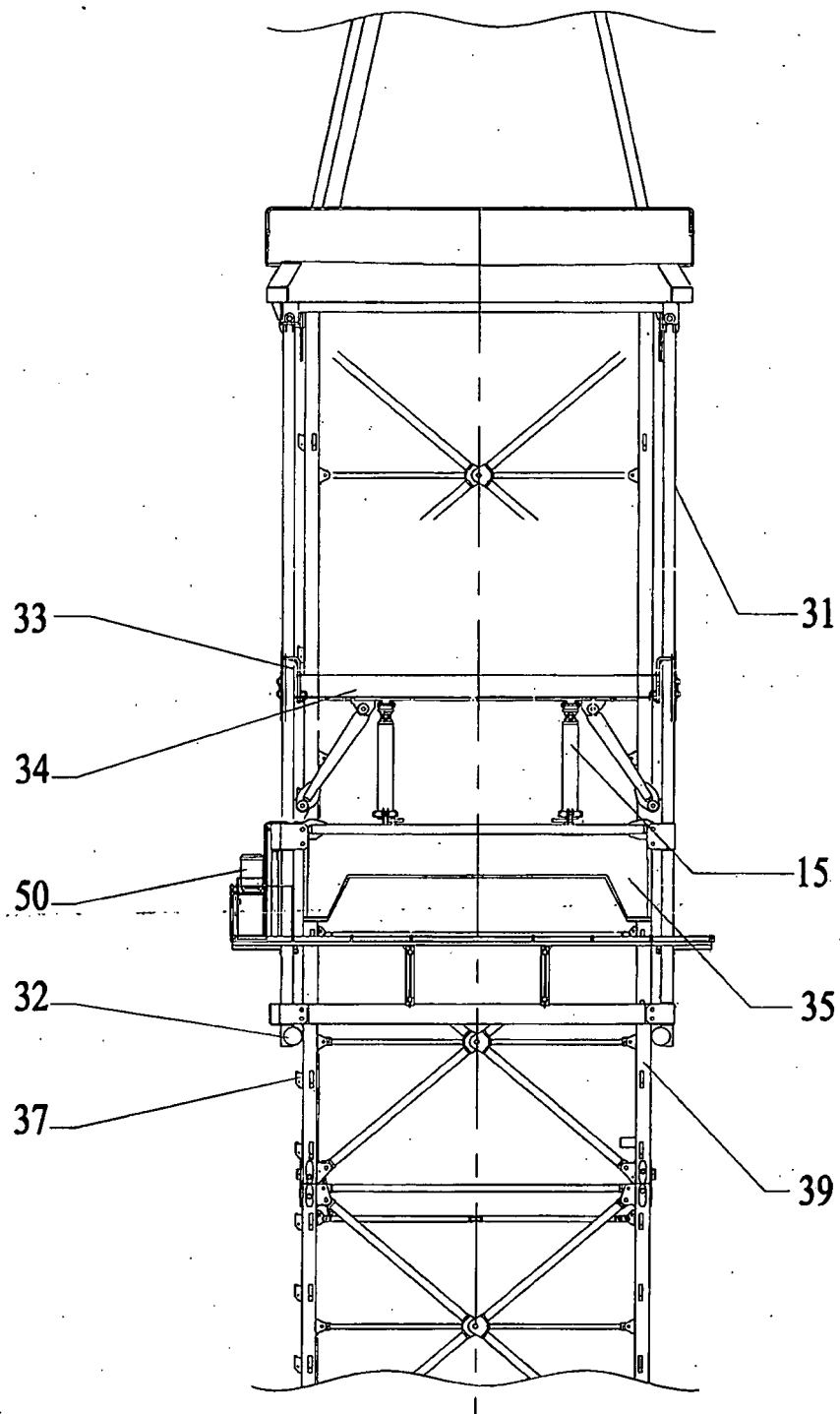


Figure 1

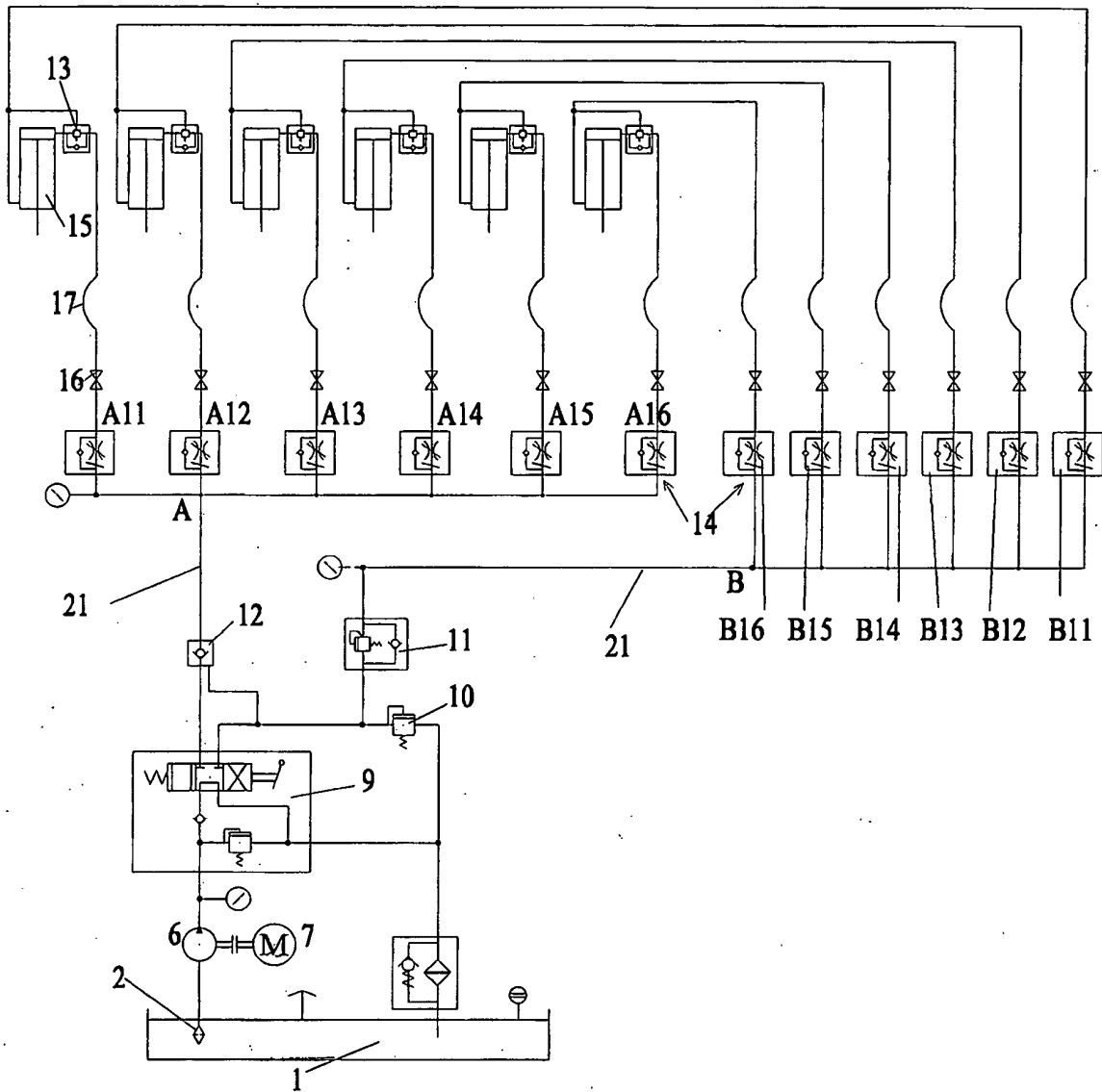


Figure 2

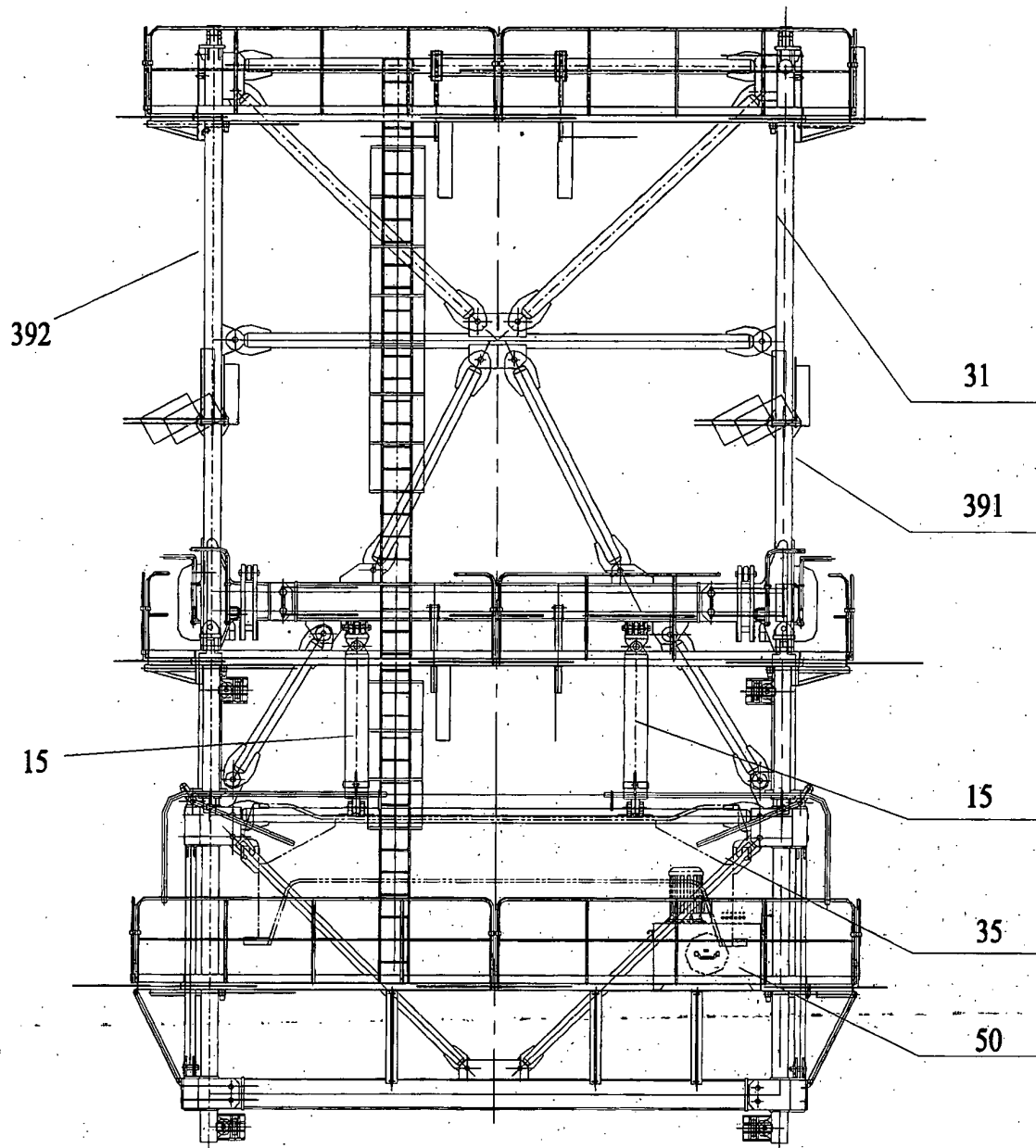


Figure 3

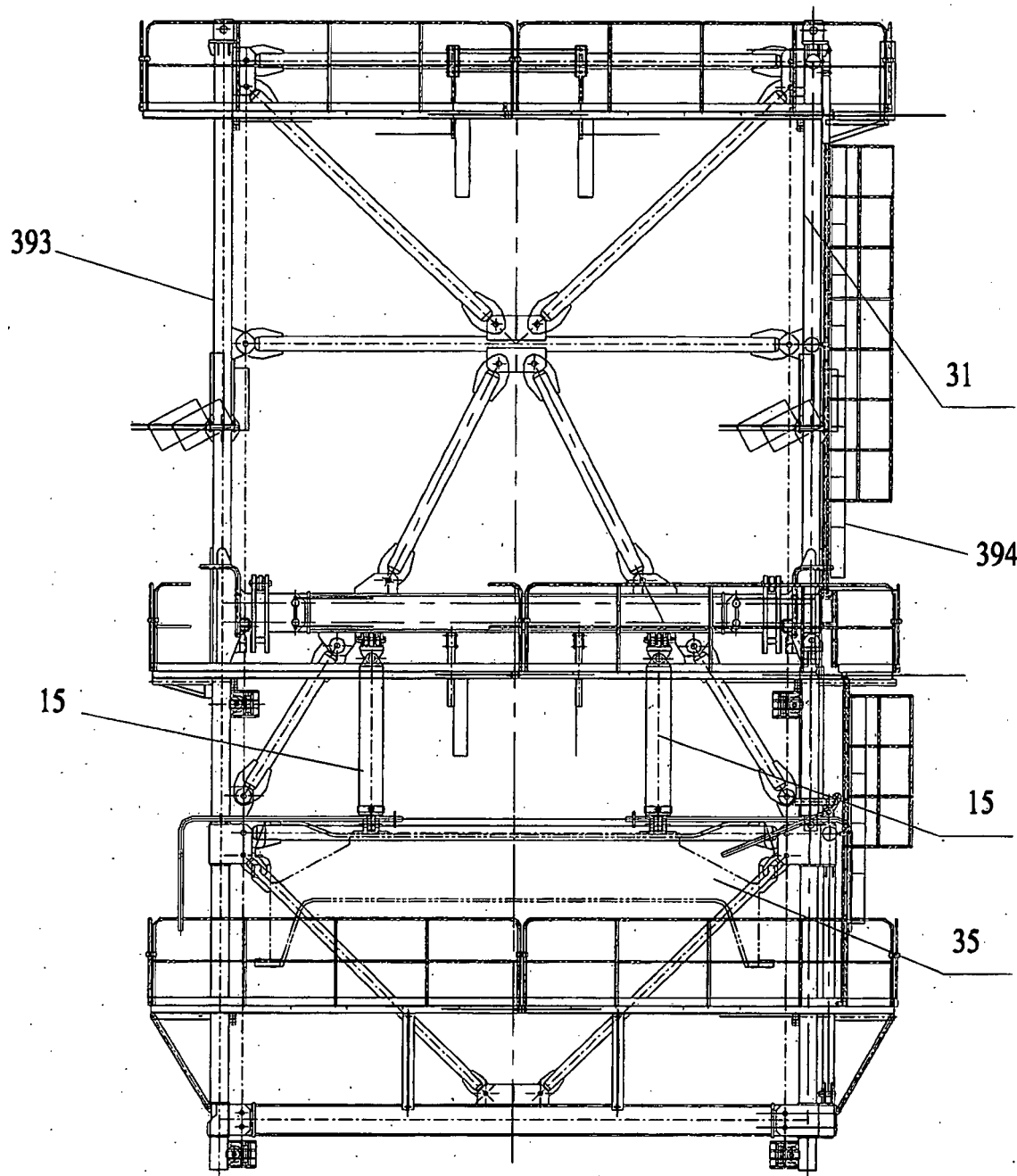


Figure 4

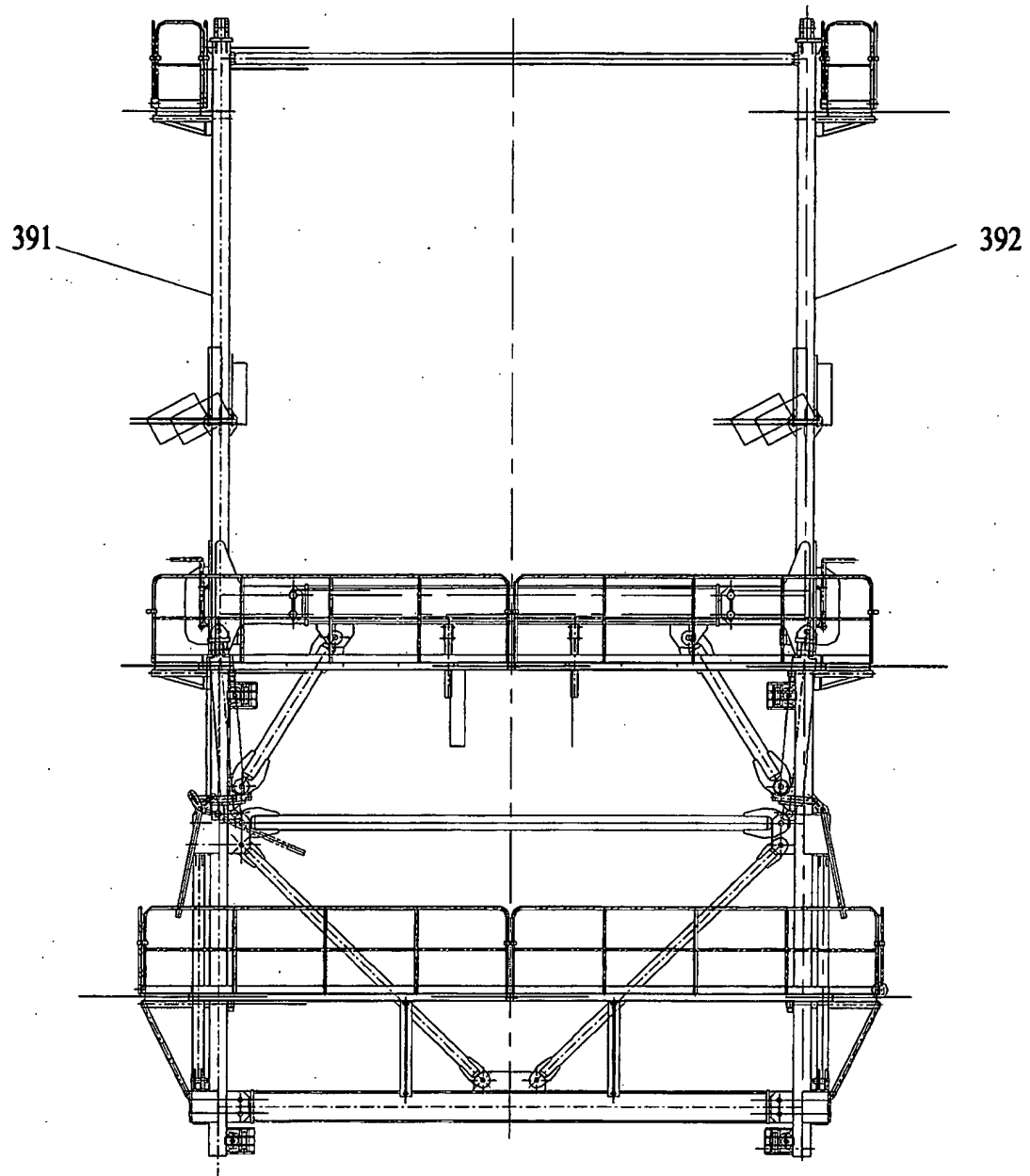


Figure 5

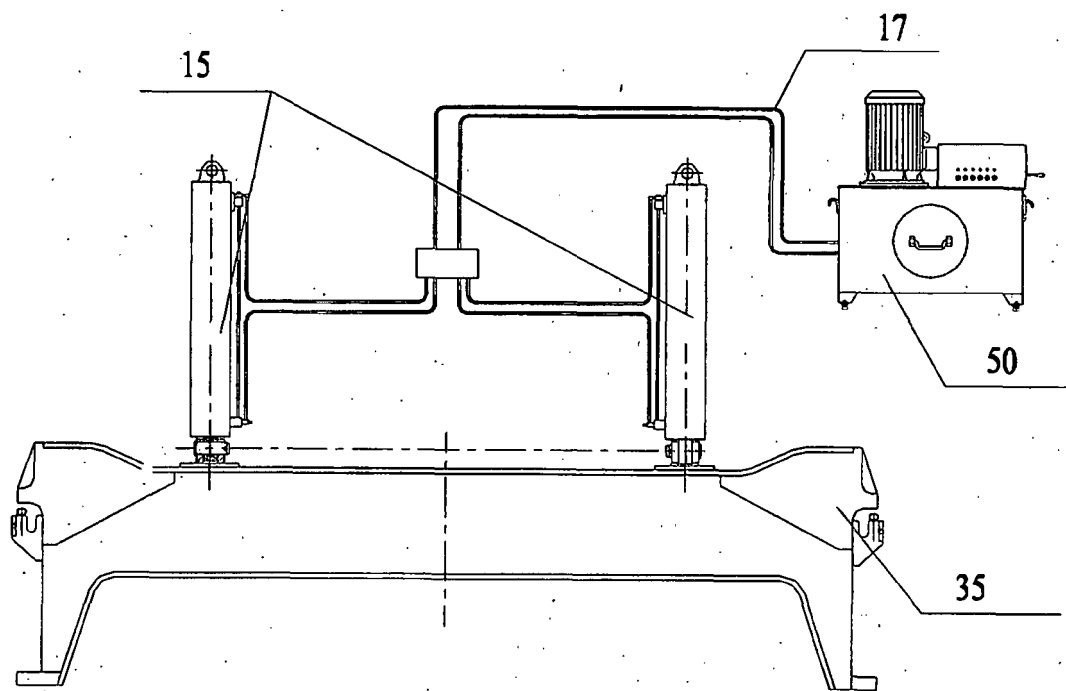


Figure 6

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 0516938 A1 [0001]