Study on process design of partially-balanced, hydraulically lifting vertical ship lift

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Abstract. The hub ship lift in Panjin is the first navigation structure in China for the link between the inland and open seas, which adopts a novel partially-balanced, hydraulically lifting ship lift; it can meet such requirements as fast and sharp water level change in open sea, large draft of a yacht, and launching of a ship reception chamber; its balancing weight system can effectively reduce the load of the primary lifting cylinder, and optimize the force distribution of the ship reception chamber. The paper provides an introduction to main equipment, basic principles, main features and system composition of a ship lift. The unique power system and balancing system of the completed ship lift has offered some experience for the construction of the tourism-type ship lifts with a lower lifting height.

1. Introduction
Panjin Inland and Open Seas Hub Control Project is a comprehensive hydro-Hub project with the main function of tide blocking, as well as those functions such as flood drainage and navigation. The main structure is composed of a tide gate, a navigation structure and traffic roads. Among them, the vertical ship lift is in the left bank of the Hub, allowing the passage of a 150t yacht; the representative ship can have a dimension of 35m×7.4m×2.41m (length × width × draft), which can enable the lockage running with water. The ship lift has the maximum lifting height of 3.82 m, a lifting in one stage; it is the first navigation structure in China for the communication between the inland and open seas, as well as the largest ship lift for tourism in China.

2. Selection of a vertical ship lift
Based on the movement manner of a vertical ship lift, the lifting height, ship reception chamber carrying water or not, as well as the forms of the supporting structure[1,2], the lifting mechanism and the safety mechanism, the vertical ship lifts are of multiple different types, including gear-rack lifting, wire ropes winding, hydraulically lifting, hydraulically jacking, etc. [3]. Considering the overall arrangement of the project, and small scale and lifting height of the ship lift, a partially-balanced, winding vertical ship lift with wire ropes and a partially-balanced hydraulically lifting vertical ship lift[4,5]are selected in design for scheme argumentation.

2.1 Hydraulically lifting vertical ship lift
The hydraulically lifting ship lift (referred to as HL ship lift) adopts suspension cylinders on both sides of the ship reception chamber to lift or put down the ship reception chamber; a part of the weight is balanced through the balancing weights, so that the ship reception chamber can go up and down vertically along the guide rails for transporting the ship.
2.2 Winding-type, vertical ship lift

The winding-typed ship lift is powered by a winder to vertically move the ship reception chamber up and down, with part of the weight balanced by the balancing weights.

(1) In terms of the project investment of the ship lift, the HL ship lift is simple in hydraulic structure and equipment composition; the winding-typed, ship lift has complex equipment. The cost of a winding-typed ship lift is 2 to 5 times as that of a HL ship lift.

(2) In terms of the lifting height of the ship lift, a HL generally has 7m or lower lifting height due to the stroke limit of the cylinder, but the lifting height of a winding-typed ship lift is unconstrained, and can be up to 100m.

(3) In terms of the construction difficulty, the simple structure of the HL ship lift makes the installation easier, while the winding-typed ship lift has a difficult construction and a long period due to the installation of wire ropes, balancing weight system, etc.

(4) In terms of structure, the HL ship lift has a simple structure, with the mechanical part composed of a metal structure and the hydraulic systems. The winding-typed ship lift is rather complex in structure, comprising motors, winding drums, a brake, a reducer, wire ropes, balancing weights, etc.

(5) In terms of the aesthetic property, the HL ship lift has simple hydraulic structure, without the requirement for a lifting machine room, so it enjoys more aesthetic feature and is simpler than the winding-type, ship lift, able to be easily integrated with the surrounding landscapes.

Based on the analysis above, if the lifting height permits, the HL ship lift with mature and reliable technology is preferable for the ship lift for tourism. Considering low lifting height and the main purpose for tourism, a HL ship lift is recommended for the project.

3. Overall equipment arrangement of the ship lift

Based on the representative ship in the design and the design specification of the ship lift, the ship reception chamber has a boundary dimension of 50.0m × 11.0m × 8.2m, the effective water area being 38.0m × 8.6m × 3.1m (length × width × water depth), and the dimension of the ship chamber room being 50.35m × 11.2m. The ship reception chamber structure is composed of primary longitudinal box beams, a bottom board, secondary longitudinal beams, transverse box beams and other members.

The ship reception chamber has the weight of 550t and water carrying capacity of 1,500t, and it is moved up and down with four 4 × 300t primary lifting cylinders; 6 sets of balancing weights are arranged respectively on both sides of the ship reception chamber for its weight balance; the total weight of the balancing weights is 1,200t, and the driving force of the primary lifting cylinders have the surplus driving force of 350t.

The change amplitude of water level in the inland sea is 1.24m, and the service gate for the inland sea lock head adopts a horizontal steel gate; the large gate has fixed gate frame and the small horizontal gate is synchronously driven with the cylinders; the change amplitude of water level in the open sea is 4.83m, and the service gate for the inland sea lock head adopts a horizontal steel one, the large gate is lifted with a hydraulic hoist to be adapted to the water level change of the open sea, and the horizontal small gate is synchronously driven with the cylinders.

Stoplog gates are adopted for the bulkhead gates for both the inland and open seas. The gate for the inland sea has a sill elevation of -2.34m and a top elevation of 2.56m, which is composed of 2 stoplog gate leaves with the same boundary dimension; the gate for the open sea has a sill elevation of -4.91m and a top elevation of 6.09m, which is composed of 5 stoplog gate leaves with the same boundary dimension. A stoplog gate is composed of the gate leaf structure, positive supports, reverse slide blocks, side wheels, water seals, etc. The gate has the structure of emersed bulkhead slide gate with double primary beams, and the lifting lugs of the gate are arranged on the top of the bulkhead on the top, the positioning sleeves above and below the upper and lower main girder, and the gate panel and the waterstop on the side of the room of the ship chamber. A single-plate one with the same section is adopted for the main girder, the side columns being of an H-shaped structure and H-bars for the joist; slide blocks for the positive and reverse supports of the gate, and cantilever wheels for the side guided.
The balancing weight system is mainly composed of a pulley block, the balancing weights, the wire ropes, the wire-rope connection components, a balancing weight rail and the embedded parts. One end of the wire rope is connected with the lifting lugs of the ship chamber through the wire rope connection components, rounding the pulley block, while the other end is connected with the balancing weights through the wire rope connection components. The system has totally 12 pulley blocks, eight of them balancing 120t of balancing weights each, and the other 4 of them balancing 60t of balancing weights each; the pulley blocks balances 1,200t weight of the ship chamber in total.

The spherical hinges are used to connect the piston rod for the primary lifting hydraulic cylinder and the supporting beam of the ship reception chamber; the cylinder body is supported on the lock walls on both side of the ship chamber room, with double-cross-hinge universal joint type supports, and the supports are arranged in a central symmetry along the horizontal and longitudinal directions of the pool of the ship chamber.

There are two hydraulic systems, each of which is composed of a hydraulic pump station, a control valve set, a pipeline system, special tools, and other equipment. The systems are arranged on the left and right banks respectively (with the orientation to the open sea, the left bank being on the left hand side and the right bank on the right side), symmetrically in the equipment platforms in the corridors on both sides of the ship chamber room, and the control valve sets of the actuators are arranged near the actuators.

![Figure 1. Three-dimension general assembly drawing of the ship lift for Inland and Open Seas Hub in Panjin](image)

4. Mechanical equipment design of the ship lift

The vertical ship lift in Panjin is of a partially-balanced, hydraulically lifting type, a novel one ever adopted in China and even in the world; its ship reception chamber can move up and down without the entry into the water. The ship reception chamber of the ship lift is driven by four primary lifting cylinders and powered by a hydraulic pump station; four primary lifting cylinders are arranged on both sides of the ship reception chamber symmetrically, and the lifting speed of the cylinder is controlled by the hydraulic system and the electric control system. Six sets of balancing weights are arranged on each side of the ship reception chamber, for the purpose of balancing some weight, reducing the load of the primary lifting cylinder and optimizing the force distribution of the ship reception chamber. When navigation is needed, a ship firstly enters the water-carrying, steel ship reception chamber, and is carried by the ship reception chamber vertically moving up and down along the guide rails on the tower columns with the primary lifting cylinders.

The mechanical equipment of the ship lift mainly includes the primary lifting equipment, the balancing weight device, the jacking guiding device for the ship reception chamber, a gap sealing mechanism, water filling and discharging devices, ship lift two-way operation program, the anti-collision device for the ship reception chamber, etc.
4.1 Primary lifting equipment
The primary lifting equipment includes two hydraulic systems, each being composed of the hydraulic pump station, the control valve set, the pipeline system, the special tools, and other equipment. The systems are arranged on the left and right banks respectively, symmetrically in the equipment platforms in the corridors on both sides of the ship chamber room, and the control valve sets of the actuators are arranged near the actuators. The electric control system is arranged in the control building. Spherical hinges are used to connect the piston rod for the primary lifting hydraulic cylinder and the supporting beam of the ship reception chamber; the cylinder body is supported on the lock walls on both side of the ship chamber room with double-cross-hinge universal joint type supports, which are arranged in a central symmetry along the horizontal and longitudinal directions of the pool of the ship chamber.

The ship reception chamber is arranged in the ship chamber room which is composed of the service gates for the inland and open seas, and the tower columns; the ship chamber room has a length (along the water flow direction) of 50.35m, and a width (vertical to water flow direction) of 11.2 m. The distance from an end surface of the ship reception chamber to a sealing waterstop surface of the lock heads for the inland and open seas is 100mm. The ship reception chamber is hung with 72 wire ropes and driven by the primary lifting cylinder to move up and down along the four sets of guide rails arranged on the tower columns. A groove-shape steel thin-wall structure is adopted, and a horizontal gate is arranged on each of the ends; when the gates are closed, an enclosed water area is formed in the ship chamber, providing the condition for ship transportation over the dam running with water. The ship reception chamber has a weight of 550t and a water carrying capacity of 1,500t, moving up and down with four 4 × 300t primary lifting cylinders; six sets of balancing weights are arranged respectively on both sides of the ship reception chamber to balance its weight; the total weight of the balancing weights amounts to 1,200t, while the driving force of the primary lifting cylinders possess the surplus driving force of 350t.

The ship reception chamber structure is mainly composed of primary longitudinal box beams, a bottom board, secondary longitudinal beams, single-plate transverse beams, transverse box beams, small longitudinal beams, the equipment supporting structure and other members. The internal plates of the two primary longitudinal box beams, together with the bottom board and the gate of the ship reception chamber, forms the water containing structure of the ship reception chamber. The head of the ship reception chamber is provided with service gate recesses, guide grooves of anti-collision beams and U-shaped sealing surfaces. The jacking guiding device and other equipment on the ship reception chamber are installed on corresponding racks which are welded with the ship reception chamber structure. For the lifting lug plates for the ship reception chamber, thickened boards are employed, which are butt-welded with the external plates of the primary longitudinal box beams. The locking device of the ship reception chamber is integrated to the structure of ship reception chamber via the bearing box beam construction. Fenders are arranged in the internal sides of the ship reception chamber.

The four primary lifting cylinders are controlled by their control circuits, so the ship reception chamber can move up and down at the adjustable speed of (0.5-1) m/min; the four primary lifting cylinders can be operated synchronously, and the synchronization circuit adopts electro-hydraulic proportional close-loop control, with the synchronization error in any position not exceeding 20 mm, and the synchronization errors can be automatically eliminated at the end of a stroke without accumulation; the circuits are provided with hydraulic locks to reliably lock the ship reception chamber in any position of the whole stroke; the cavity with piston rod in the primary lifting cylinder is provided with lock-up valve sets beside the cylinder, ensuring that the ship chamber can stop reliably in the case of oil circuit fault or pipeline burst; both the cavities with and without piston rod are provided with pressure sensors and pressure gauges; the stroke of the cylinder is detected by the displacement sensor, and the ending point of the stroke is controlled by the stroke switch.

4.2 Balancing weight system
The balancing weight system is mainly composed of a pulley block, the balancing weights, the wire ropes, the wire-rope connection components, a balancing weight rail and the embedded parts. One end of the wire rope is connected with the lifting lugs of the ship chamber through the wire-rope connection components, rounding the pulley block, and the other end is connected with the balancing weights through the same components. The system has totally 12 pulley blocks, eight of which balance 120t of balancing weights each while the remaining four balance 60t of balancing weights each; the pulley blocks balance 1,200t weight of the ship chamber in total.

Each pulley block is composed of pulley sheets, pulley shafts, bearings, bearing blocks, a rack, etc. Double rows are employed, with eight blocks having 14 pulley sheets and 7 lifting points each, and the four blocks having eight pulley sheets and four lifting points. The pulley has the nominal diameter of 1,250mm, and the wrapped wire rope diameter of 44mm.

The balancing weights have a total weight of 1,200t, built with 12 sets of weight boxes, eight of which weight 120t each, which has a boundary dimension of 4.85m × 3.6m × 1.6m (height × width × thickness), and fillers of no less than 4.5t/m³ should be put into the boxes; for the other 4 sets, the weight amounts to 60t each, which has a boundary dimension of 4.85m × 2.4m × 1.6m (height × width × thickness), and fillers of no less than 3.5t/m³ should be put in. Guide wheels should be arranged on both sides of the weight box. Cast iron adjustment blocks with the total weight of 30t should be arranged on the top of the weight box. The weight boxes are connected with the wire rope sockets through the connection components of the wire ropes.

The wire rope should be surface contacted, compacted strand, alternating twisted and galvanized steel wire rope with a nominal diameter of 44mm. The ship lift has a total of 72 pieces of wire rope in right concurrent twists. Each piece of wire rope is 11.38 meters with open sockets at both ends.

There are 72 sets of wire rope connection components in total, including the adjustment screw, nut, pin and anti-rotation device.

Embedded parts for balancing weight rail include rails and their support, fixed parts, etc. Two sets of balancing weight rail are laid on the concrete wall of each balancing weight well to guide lifting of the balancing weight sets. The rail is made of profile steel and steel plate by welding and the embedded parts are made of steel plates and steel bars. The rail top distance of the two rails in the same balancing weight well should not deviate for more than ± 3 mm and the rail centerline should not deviate for more than ± 2 mm.

4.3 Jacking guiding device for a ship reception chamber

There are eight sets of jacking structure in total symmetrically arranged on both sides of the chamber and their main role is to withstand the horizontal load when the ship is docking. The structure is mainly composed by the wheel, riser block, bolts, bracket and other components. The roller block is bolted to the bracket and the bracket is welded to the ship chamber. The horizontal load of the ship chamber is conveyed to the jacking rail on the concrete tower column embedded part via the wheel and passed to the concrete tower column. Both the jacking block and guide block are made of HTN reinforced nylon and the rail is made of stainless steel.

4.4 Gap sealing mechanism

The gap sealing mechanism is arranged in the U-type cabin of the steel lock head service gate embedded part for sealing the gap between the ship chamber and the service gate when the ship and the gate are docked, so as to connect waters the chamber is in with the waters of inland sea after the gap is filled with water, forming ship passage condition.

There is a set of gap sealing mechanism each for the inland and open seas, each mechanism is composed by the U-shaped frame structure, sealing rubber, butterfly spring set, cylinder and support and other components. The cylinder acts on the U-shaped frame via the butterfly spring set and the U-shaped frame moves along the guide slider in the U-shaped groove of the service gate. There are a total of 11 cylinders; the cylinder piston rod and butterfly spring set are thread connected with a hinge support provided in the central part of the cylinder. The cylinder bracket and the steel lock head
baseplate are connected by welding. The main role of the cylinder is to drive the frame movement in the service gate U-shaped groove, exert pressure on the U-shaped frame, while providing preload to the butterfly spring set. There are a total of 11 butterfly spring sets, each set consists of six butterfly springs, guide rod and pad, etc., the butterfly spring set is fixed on the U-shaped frame by bolts, each piece of butterfly spring \( DE = 200 \text{mm}, Di=102\text{mm}, T=8.6\text{mm} \), the butterfly spring set releases energy in the event of a leak in the cylinder, allowing the u-shaped frame to maintain a certain pressure on the water stop between the ship chamber and the lock head to ensure the sealing effect between them. At the end of a U-shaped frame are set with two pieces of sealing rubber, one is C-shaped and one \( \Omega \)-shaped, the water stop width is 10.8 meters and height 6.6 meters.

4.5 Water filling and discharging device
There are two sets of water filling and discharging systems in the gap of lock head service gate for the inland and open seas symmetrically arranged in the steel lock head cabin to the steel lock head longitudinal centre line, the two sets work at the same time in normal operation, and can also be backed up for each other. The main equipment includes electric disc valve (manual), manual gate valve, gulp/vent valve, disassembly joints, and pipes, racks and so on. The valves and pipelines should not leak at the joints; the pipe should be supported firmly with no great vibration or abnormal noise caused to the system; the gap water filling and discharging system should be pre-assembled with the service gate in the factory.

4.6 Two-way operation procedure of the ship lift
(1) The ship to leave the port arrives at the designated location in the channel;
(2) The ship reception chamber rises or lowers to the docking position for navigation in the inland sea;
(3) The docking sealing frame cylinder for the inland sea is pushed out to tightly press against the sealing frame water seal rubber;
(4) The water filling and discharging system for the inland sea is operated to make the gap water level reach a specified height, and the service tumble gate of the lock head for the inland sea is opened, the small horizontal gate of the ship chamber on the side of the inland sea is opened;
(5) The anti-collision beam on the side of the inland sea lowers to the bottom of the ship reception chamber;
(6) Entry order is given (via sound or light signal), the ship to leave the port comes to the designated position of the ship reception chamber at a specified speed, fasten the cable and issue a signal for ship arrival;
(7) The anti-collision beam on the side of the inland sea rises to the designated position;
(8) The horizontal gate of the ship reception chamber on the side of the inland sea is closed and the service tumble gate of the lock head for the inland sea is closed;
(9) The water filling and discharging system on the side of the inland sea is operated and the docking sealing frame cylinder on the inland sea side retracts;
(10) The ship reception chamber is operated at the design speed so that the water level inside the chamber is flush with that in the open sea;
(11) The sealing frame cylinder on the side of the open sea is pushed out to tightly press against the sealing frame water seal rubber;
(12) The water filling and discharging system for the open sea is operated to make the gap water level reach a specified height, the service tumble gate of the lock head for the open sea is opened and the small horizontal gate on the open sea of the chamber is opened;
(13) The anti-collision beam on the side of the open sea lowers to the bottom of the ship reception chamber;
(14) Leaving order is issued (via sound or light signal), the ship to leave the port leaves the ship reception chamber at a specified speed;
(15) The anti-collision beam on the side of the open sea rises to the designated location;
(16) The horizontal gate of the ship reception chamber on the side of the open sea is closed and the service tumble gate of the lock head for the open sea is closed;

(17) The water filling and discharging system on the side of the open sea is operated and the docking sealing frame cylinder on the side of the open sea retracts;

4.7 Ship reception chamber anti-collision device
There are two sets of anti-collision device, arranged on the inner side of service gates at both ends of the ship chamber respectively to protect the stalling ship from hitting the chamber service gate. Each set includes one steel structure anti-collision beam and two sets of drive devices. The drive device is composed by the pulley blocks, wire ropes, hydraulic cylinders and other components to act in collaboration with the service gate.

5. Design of ship lift metal structure

5.1 Flood control bulkhead gate
The flood control bulkhead gate is used to repair the lock head hydraulic structures, service gates and their gate slots, hydraulic hoist, etc. The bulkhead gates for the inland sea are arranged on the inland sea side of the ship chamber and consist of two stoplog gate leaves of the same boundary dimensions, with the sill elevation of -2.34m and the top elevation of 2.56m, can accommodate 2.0m maximum water level, opened and closed in still water, a single gate is 22t and requires an opening and closing force of 45t; the bulkhead gates for the open sea are arranged on the open sea side of the ship chamber and consist of four stoplog gate leaves of the same size, with the sill elevation of -4.91m and the top elevation of 3.89m, can withhold 3.27m once-in-a-century flood level, opened and closed in still water with an opening and closing force of 41t. When the ship lift navigates, the bulkhead gate is placed in the gate chamber.

The stoplog gate is composed of the gate leaf structure, positive supports, reverse slide blocks, side wheels, water seals, etc. The gate has the structure of emerged bulkhead slide gate with double primary beams, the lifting lugs of the gate are arranged on the top of the bulkhead on the top, the positioning sleeves above and below the upper and lower main girder, and the gate panel and the waterstop on the side of the room of the ship chamber. A single-plate one with the same section is adopted for the main girder, the side columns being of an H-shaped construction and H-bars for the joist; slide blocks for the positive and reverse supports of the gate, and cantilever wheels for the side guided.

5.2 The lock head service gate and hoist for the inland sea
The lock head service gate for the inland sea is arranged at the inland sea channel end to block water of the navigable open channel. When the ship reception chamber is docked with the inland sea lock head, waters in the ship reception chamber and inland sea will be connected through the docking sealing rubber on the embedded part of the inland sea lock head service gate and the water stop seal on the inland sea side of the ship reception chamber, so that the ship can be made accessible.

The lock head service gate for the inland sea is composed of horizontal steel gate, U-shaped gate slot structure, gap sealing mechanism and water filling and discharging system, etc. The size of the hole is 11.2m (width) × 9.4m (height), the gate type is horizontal steel gate, support span being 6.6m, able to open and close in still water; the maximum waterhead when opening is 0.4m, with the pressure adjusted by the water filling and discharging system.

The water retaining panel, waterstop and support of lock head service gate for the inland sea are arranged on the outer side with two support hinges located on the inland sea side of the gate. The gate rotates around the hinge axis when opened or closed; when opened, the lock head service gate for the inland sea is horizontal in the gate recess at the head part of lock head and the gate panel is flush with the bottom deck of the ship chamber; when closed, the gate top is flush with the service gate embedded part.
Each service gate of lock head for the inland sea is operated by two sets of hydraulic hoist whose cylinder is arranged on both sides of the gate, piston rod lifting lug is connected with the cantilever shaft installed on the main girder of the gate through the knuckle bearing and the tail part of the cylinder is connected with the support installed on the embedded part of lock head service gate through the knuckle bearing. The gate is generally closed. When the ship reception chamber and the embedded part of the service gate are docked tight, water pressure is adjusted with the water filling and discharging system, after the water level difference in front of and behind the tumble gate leaf of the lock head for the inland sea is less than 0.4m, the horizontal gate can be opened to connect waters in the open channel and ship chamber so that the ship can come into and go out of the ship reception chamber.

5.3 Service gate and hoist of lock head for the open sea

The service gate of lock head for the open sea is arranged at the open sea channel end of the ship lift, opened and closed in flowing water by the service gate hoist arranged at both ends of the gate; the small horizontal gate on the service gate of lock head for the open sea is opened and closed in still water, and the maximum water level difference in the opened state is 0.4m. When the ship reception chamber is docked with the open sea lock head, waters in the ship reception chamber and open sea will be connected through the gap sealing mechanism on the lock head service gate for the open sea and the water stop seal on the open sea side of the ship reception chamber, so that the ship can come and go.

The service gate of lock head for the open sea is composed by U-type gate structure, gate hoist, positive supports, reverse supports, the gate side waterstop, the gate lock mechanism, small horizontal gate and its hoist, gap sealing mechanism, water filling and discharging system and other components. Boundary dimensions for gate body (width × height × thickness): 18.7m × 12.6m × 3.2m, side waterstop spacing: 11,740mm. The small horizontal gate is plate steel gate with the gate lifting lug located on the partitions on both sides of the service gate, the lock is located on outer sides of the columns on both sides, and the panel and the waterstop are arranged on the open sea side with the waterstop on the outer side of the gate. A single-plate one with the varied section is adopted for the main girder, the side columns having H-shaped sections, H-bars for the joist and with positive and reverse supports for the gate.

The service gate of lock head for the open sea has two sets of 4,000KN hydraulic hoist on both sides of the slot and hinged with the gate lifting lugs. The gate is generally in the locked state, the small horizontal gate can be adapted to 1.022m water level changes, when the water level amplitude exceeds 1.022m, the hydraulic hoist of the service gate works with pressure to adapt the service gate to changes in the navigable water level. The hydraulic hoist is composed by the cylinder, cross hinged support, stroke detection device and other components which synchronously operate.

The small horizontal gate of the lock head for the open sea has two set of 600KN hydraulic hoist on both sides of the slot with the piston rod head hanged with the gate lifting lugs and the cylinder end hinged with the support. The gate is generally closed. When the ship reception chamber and the service gate are docked tight, water pressure is adjusted with the water filling and discharging system, after the water level difference in front of and behind the tumble gate leaf of the lock head for the open sea is less than 0.4 m, the horizontal gate can be opened to connect waters in the open channel and ship chamber so that the ship can come into and go out of the ship reception chamber. The hydraulic hoist is composed by the cylinder, cantilever shaft, support, stroke detection device and other components which synchronously operate.

6. Conclusion

The design of the vertical ship lift of the project, by taking into account the actual situation of the overall layout of the project, the scale of the ship lift and shipping operation requirements in the inland and open seas, selected the new partially-balanced, hydraulically lifting ship lift, first of its type ever used in China. The ship reception chamber vertically rises and falls, without an entry into water to
adapt to the characteristics of low lift height and great changes in water levels of the open sea. So far it has been successfully operated and debugged, which provide useful reference for design and construction of vertical ship lifts of small scale, low height difference and great water level amplitude, which requires the lockage running with water.

References:
[1] Liu Jintang. Research on design of hydraulic ship lift in Jinghong [A]. Design and Research, 2008,34 (4): 43-45.
[2] Huang Suxin. Overall design of 1 × 250 t vertical ship lift in Yantan Hydropower Station [B]. Hongshui River, 1999, 18 (4): 5-12.
[3] Sun Jingshi,Zhou Huaxing,Zhao Dezhi, Li Jinhe. An Investigation on Shiplift [J]. Journal of Waterway and Harbour, 2001, 22 (3): 141-145.
[4] Hu Ya-an, Li Zhonghua, Li Yun, Xuan Guoxiang. Research developments in the field of major ship lift in China [J]. Port & Waterway Engineering, 2016, 12: 10-19.
[5] Yang Linjiang, Lu Weibing. Introduction of the Three Gorges Ship Lift [J]. Hydropower and new energy, 2016, 12: 10-19.