Research on Automatic Positioning Control System of Riprap Barge

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Abstract. Based on the research of ship automatic positioning technology and deviation correction technology, combined with the gravel laying technology of single ridge subgrade bed of immersed tunnel, the control strategy of riprap barge is determined: ship automatic positioning technology based on tension control and rope length control. Combined with the gravel laying technology of single ridge subgrade bed and the control strategy of riprap barge, the algorithm of automatic positioning and moving of riprap barge is studied. Combined with the engineering practice, control strategy and control algorithm, the intelligent anchoring positioning control system is designed to realize the high-precision and fast intelligent displacement of gravel bed laying ship.

1. Introduction

Xiangyang east-west axis road project is a traffic channel connecting Fancheng and Dongjin new city center area. It adopts tunnel to pass through Yuliang Zhou to protect the ecological landscape of Yuliang Zhou "green water green". The total length of Yuliangzhou section tunnel of Xiangyang east-west axis road project is 5400m, and the sinking pipe is adopted to cross Hanjiang twice, with the total length of 1011m. Four standard sections and one short pipe section are arranged in the West Branch with a total length of 351m. Six standard and one short pipe joint are arranged in the East Branch, with a total length of 660m. The tunnel adopts the design standard of two-way six lane urban expressway with design speed of 60km/h, and the clear width of the tunnel construction clearance is 12.25m. Reinforced concrete is adopted for tunnel structure, with integral pipe joint, with cross section width of 31.2m and height of 9.2m. The main distribution of the caisson section in the West Branch is fine sand layer, pebble mixed with round gravel and round gravel layer. The bottom of the tunnel is basically above the pebble mixed round gravel and round gravel layer. The main distribution of the dongcha immersed pipe section is fine sand layer, pebble mixed round gravel and round gravel layer. The bottom of the tunnel is basically above the pebble mixed round gravel and round gravel layer.
In Xiangyang east-west axis road project, gravel laying and leveling of subgrade bed, horizontal positioning accuracy is not more than 20cm, and elevation accuracy is not more than 4cm. Firstly, traditional large construction ships can not enter the narrow operation area of inland river due to the overall size, draft and other factors. Secondly, the immersed tube distance of immersed tunnel in inland river basin is generally short, the total immersed tube distance of the project is 1011m, and the design and procurement cost of traditional operation equipment is high. From the perspective of the cost, construction quality, construction period and feasibility of the foundation cushion of the immersed tunnel, the technical scheme of laying and leveling gravel on the foundation bed of the immersed tunnel is selected.

In view of the problems in traditional construction, such as high dependence on manual operation, low positioning accuracy and low efficiency, it is necessary to develop a floating barge winch automatic displacement and positioning system[1-2]. To make up for the poor positioning accuracy and low efficiency of manual operation, through the real-time monitoring of ship position based on Beidou Positioning and the comparison and analysis of target ship position, the control algorithm strategy is adopted to realize the characteristics of high efficiency, safety and visualization of barge displacement process[3]. For Xiangyang immersed tunnel construction project, an automatic anchoring control system is developed on the premise of ensuring the dynamic displacement accuracy of 10cm. Under the premise of uniform distribution of winch cables, the system can collect the retraction and release strategy of convergence control, and realize fast and accurate positioning[4-5].

2. Structure and principle of automatic shift positioning control system
Four 10t anchor winches have been equipped on the riprap barge used in the project, which are driven by hydraulic winch, which are respectively arranged on the hull deck, as shown in Figure 1. The construction control system is added to the four three speed anchor winches to meet the automatic ship moving function.

![Figure1 Schematic diagram of riprap barge winch](image1)

The location of the riprap barge in the work area is shown in Figure 2.

![Figure2 Riprap barge operation area](image2)
2.1. System composition
The positioning control system of riprap barge is a computer control system based on RTK satellite positioning. It is composed of ship positioning control computer system, PLC winch controller, winch encoder, control box, etc. A positioning control system computer is set, which adopts integrated industrial computer and 19 inch touch screen wireless keyboard and mouse control. It is installed on the workbench. The computer of the positioning control system sets parameters and visualizes the ship moving operation through the software interface. Set up a set of positioning control PLC controller, using Siemens S7-1200 series controller. It is used to collect the signals of RTK, anchor position, winch encoder and wire rope tension sensor, and control the hydraulic winch to automatically retract and release the cable. Set up a set of Gigabit industrial LAN switch, PLC and computer constitute a control network, realize the function of real-time data transmission. The interface module is used to convert serial communication signals from hydraulic control system and winch wire rope tension sensor into network communication signals to realize the integration with LAN.

2.2. Principle of ship shifting
The project adopts the real-time feedback convergence control method based on position information to realize real-time display of hull profile; input command and one key shift; multiple shift and gradual convergence; accuracy control is within 10cm; short distance shift time is not more than 10min.
In order to realize the automatic ship moving function of the riprap barge, the control system needs to output the winch action signal according to the current position coordinate information and target position coordinate information in real time, so as to realize the cable retraction and release action of four winches, so as to realize the automatic ship moving function of the barge and drive the ship to move along the given trajectory. The whole system is a typical closed-loop control system. In the process of automatic control, the system calculates the rope length of four winches according to the GPS signal, and compares the deviation of the rope length of four winches in real time for control (considering the winch tension deviation balance). The block diagram of automatic ship moving system is shown in Figure 5.

![Figure 5 Block diagram of automatic ship moving system](image)

2.3. Process of ship moving

The automatic ship moving function is realized by PLC controller and positioning computer. By clicking the direction key of ship moving, the ship can be moved to the designated position by one click ship moving. In the process of ship moving, the ship's heading can be continuously modified to maintain the heading. At the same time, the tension of winch wire rope is monitored in real time to keep the tension not more than 100kN. When the ship reaches the designated construction position and has completed the fine positioning, the automatic control system will send the ship position locking command to the winch hydraulic control system. At the same time, the positioning computer system can memorize the current position coordinates and heading angle values, and wait for the next ship moving instruction. The winch hydraulic control system shall transfer the control right to the computer automatic control during the automatic ship transfer operation.

In the process of ship moving, rough positioning shall be carried out first, and four windlass shall be started at the same time. Among them, P1 and P2 shall be used for cable collection, S1 and S2 shall be used for cable laying. Each windlass shall control the L1 value of cable collection or laying (L1 shall be 1.5m-2.0m and other values, which shall be given through on-site debugging) to reach the required rough positioning position. Then, the precise positioning is carried out, and four anchor machines are controlled synchronously, including P1 and P2 cable receiving and S1 and S2 cable releasing. Each anchor controls L2 value of receiving or releasing cables and waits for a few seconds. The system judges the deviation of ship position by GPS. L2 is set to a value close to 0.1M, and the specific value is given by field debugging. When the precise positioning is to control the winch speed at low speed.

The ship position deviation can be divided into three cases, or the three cases appear alone or in combination. Even if the combined deviation occurs, it can be divided into three cases and corresponding measures can be taken. The first kind of deviation occurs, that is, the lateral position does not reach the target position, so there is no need to correct the deviation, and the fine positioning operation can be continued.
In case of the second deviation, the corrective measures shall be started, and four anchors shall be started at the same time. The anchor P1 and S2 shall be taken and P2 and S2 shall be placed. The action range of the anchor machine is L3 (L3 value shall be less than 0.1M, which shall be obtained by site commissioning).

When the third deviation occurs, start the corrective measures, start P1 and S2 windlass at the same time, P1 retracts and S1 releases, P2 and S2 windlass does not act, and the action amplitude of windlass is L4 (L4 value should be less than 0.1M, which is obtained by site commissioning).

Each time after a precise positioning operation or a deviation correction operation, wait a few seconds, and the system will judge the position of the ship and decide whether the next operation is precise positioning or deviation correction operation. Until the system judges that the positioning error of the ship position is within the allowable range of accuracy.
3. **Control effect in the process of actual ship moving**

The project has entered the construction leveling stage. During the construction process, the ship moves horizontally for 2m each time, and remains unchanged vertically after the movement. The automatic ship shifting function is better realized in the process of riprap operation. The specific technical requirements are listed in Table 1.

| Project            | Specifications/Parameters |
|--------------------|---------------------------|
| Positioning Accuracy | Less than 10cm            |
| Preload            | Less than 100kN           |
| Distance Per Move  | 2m                        |
| Time Per Move      | Less than 2min            |

Figure 9 shows the tension changes of four cables during an automatic ship transfer. After rough positioning and fine positioning, the leveling boat moves two meters horizontally to the predetermined position. After reaching the predetermined position, the pulling force of the four cables changes slightly and keeps dynamic balance, offsetting the influence of wind, wave and current in the river and maintaining the position stability of the leveling boat.

![Figure 9 Cable tension variation](image1)

Figure 10 shows the length change of the four winches extending/engaging during the same automatic ship shifting. It can be clearly seen that the curves of the length of the two pairs of cables on the diagonal line with time are basically symmetrical, the ship maintains good stability in the process of moving the ship, and the ship's heading direction basically does not change.

![Figure 10 Length change of four winches in/out](image2)
Figure 11 shows the speed change of four winches extending/drawing in the cable during the same automatic ship transfer. Because the elasticity of the cable cannot be ignored, there is no obvious symmetrical curve in the speed monitoring process. However, it was observed that the tension of the cable was always kept within the safe range, so the movement was not stopped.

4. Conclusion
This paper mainly studies the automatic positioning technology in the operation process of riprap leveling barge. Facing the technical problems of deep water, low underwater visibility and high leveling accuracy in the leveling construction of Xiangyang deepwater channel phase II project, the control strategy of riprap barge is determined: automatic positioning technology based on tension control and rope length control. In the actual operation process, the status information of four winches and cables is monitored and recorded in real time to complete the technical research of automatic moving and positioning of riprap barge. In the process of practice, it is proved that the intelligent anchoring positioning control system designed for this project realizes the high-precision and fast intelligent displacement of gravel bed laying ship, improves the operation efficiency, reduces the construction time and saves the construction cost.

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