Research on the Testing Device and Method of Ship's Automatic Berthing and Unberthing

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Abstract. This research analyzes the test device and test method of the ship's automatic berthing and unberthing test, and creates an automatic berthing and unberthing test device. The device includes a test working condition setting module, a shore-based data communication module, a test data recording module, and a shipboard data communication module. The automatic berthing and unberthing test device can generate the traffic environment perception information of the area where the berth to be tested is located, and interact with the real ship berthing and unberthing system to obtain the berthing and unberthing commands. According to different test scenarios, this research is divided into testing and comparison of unberthing and berthing operations. The created test method can reduce the risk of actual ship testing, improve the safety of automatic berthing and unberthing. At the same time, it can completely realize the whole ship test process of berthing and unberthing functions.

1. Introduction
In recent years, with the breakthrough and continuous development of computer technology, communication technology, sensor technology, and material technology, unmanned ship technology involves multiple disciplines and fields, the autonomous ship berthing and unberthing technology is an important research direction in the research of unmanned ship technology[1-2]. The autonomous berthing and unberthing technology not only controls the course and speed of the ship, but also includes berth stabilization, trajectory tracking, path planning and many other contents. The technology of autonomous ship berthing and berthing is a key technology to realize unmanned ships[3]. Research on autonomous berthing and berthing technology can improve the technology system of unmanned ships, which is of great significance to promote the development of unmanned ship technology.

As the tonnage of ships increases, the autonomous berthing and unberthing operations of ships have become more and more complicated, especially for large ships[4]. Most transport ships are under-driven ships, unable to achieve translational motion, and their own maneuverability is relatively poor, which brings difficulties to autonomous berthing and unberthing operations. Due to the relatively shallow water depth of the berth, the rudder efficiency and maneuvering performance of the ship is lower than that in the deep waters, resulting in a decline in the overall maneuverability of the ship and increasing the difficulty for the ship to berth and leave the berth autonomously.

Automatic berthing and unberthing technology can get rid of the dangerous factors caused by man-made berthing and unberthing, so that the ship can complete the entire berthing and unberthing process more safely. Automatic berthing and unberthing technology can improve the intelligence level of ships,
which is indispensable in the development of smart ships[5-6]. If the automatic berthing and unberthing technology is to be applied in practice, it must be fully tested and verified. The test and verification methods include simulation test and real ship test. Real ship test can make up for the simulation environment caused by the simulation test to be not realistic enough. The errors caused by the actual ship test process are many uncertain factors and the degree of danger is high. At this stage, there is no test system and method for the automatic berthing and unberthing function of smart ships. Therefore, it is very necessary to propose a test device and test method for the automatic berthing and unberthing function of smart ships.

2. Research on Automatic Berthing and Departure Technology

Automatic berthing and unberthing technology is a relatively complicated and difficult maneuvering control movement in ship maneuvering. In the actual ship berthing process, the ship is affected by factors such as quay wall effect, shallow water, and weak rudder effect at low speeds, and usually requires tugboats to assist in providing lateral force and moment to reach the designated berth. With the significant improvement of ship automation, the automatic berthing of unmanned surface ships can be realized under certain conditions. The research on the automatic berthing of unmanned surface ships is of great significance to truly realize the full autonomous, intelligent and unmanned transportation of unmanned surface ships.

At present, due to the large inertia of ships, even with the presence of side thrusters, maneuvering in the port is mainly done with the assistance of tugboats. The main control tasks of ships in the process of autonomously berthing and unberthing are divided into: course keeping control, path tracking, and stabilization control. The maneuvering of the ship includes: deceleration control, parking control, reversing control, parallel berthing control, approaching track keeping control, steering control control, U-turn control control, etc. Through the research, three types of berthing and departure are summarized: outside berth stabilization, direct approaching, first outside berth stabilization and then parallel approaching. Three autonomous berthing modes: stable outside the location, parallel entry into the berth, and direct entry. Considering external disturbances such as wind, waves and currents during autonomous berthing and unberthing, researchers used various algorithms such as artificial neural networks, sliding mode control, expert systems, and feedback control to design autonomous berthing and unberthing controllers. In this study, a test device and test method for the automatic berthing and unberthing test of the ship have been established, which can reduce the risk of the actual ship test and improve the efficiency of the test process.

3. Research on the test device for the automatic berthing and unberthing test of the smart ship

The test device for the automatic berthing and unberthing test of an intelligent ship includes a test working condition setting module, a shore-based data communication module, a test data recording module, and a shipboard data communication module.

The test condition setting module is used to receive the traffic environment setting information input by the user, and generate traffic environment perception information of the area where the berth to be tested is located. The shore-based data communication module sends the traffic environment perception information of the berth to be tested to the ship under test according to the traffic environment perception information set by the test condition setting module. The onboard data communication module is used to use the received traffic environment perception information as the environment perception information perceived by the ship to be tested, and send the information to the off-berth system on the real ship. The data communication module is used to receive the berthing and unberthing commands of the unberthing system, so that the ship under test can perform corresponding operations based on the berthing and unberthing commands. The shore-based data communication module is used to receive the berthing and unberthing commands, hydrological environment information and the status information returned by the shipborne data communication module. The test data recording module is used to record the traffic environment information generated by the test condition setting module. The structure of the test device is shown in the figure 1 below:
4. Research on the Testing Method of Ship's Automatic Berthing and Unberthing

The test method of ship berthing and unberthing is shown in the following flowchart. The test device receives the traffic environment setting information input by the user, and generates the traffic environment perception information around the berth. The testing device sends the traffic environment perception information to the ship to be tested. The ship to be tested sends the traffic environment perception information and the ship's hydrological environment information and status information to the unberthing system mounted on the real ship, and receives the berthing and unberthing commands returned by the unberthing system. The testing device receives the berthing and unberthing commands returned by the ship to be tested, and the traffic environment perception information and the hydrological environment information of the ship corresponding to the berthing and unberthing commands. The test device collects and stores the image information of various angles during the berthing and unberthing process of the ship under test in real time. The testing device receives the ship navigation information of the ship under test input by the user, and the testing device sends the information to the ship under test so that the ship under test can travel according to the navigation information. The above-mentioned test method can reduce the risk of the actual ship test, and at the same time can completely realize the entire actual ship test process of the berthing and unberthing function, save the test cost, and improve the efficiency of the test process.
The test device receives the traffic environment setting information input by the user, and generates the traffic environment perception information around the berth area.

The test device sends the traffic environment perception information to the test ship.

The test ship sends the perceived traffic environment information, the real hydrological information and the status of the ship to the unberthing system, so that the berthing and unberthing system generates corresponding operating instructions.

The test device receives the berthing and unberthing commands from the test ship, and the corresponding traffic environment perception information, the real hydrological information and the status of the ship.

The test device stores the berthing and unberthing operation commands, and the corresponding traffic environment perception information, the real hydrological information and status of the ship.

Figure 2 The test method of ship berthing and unberthing

4.1. Mooring toilets

4.1.1. Test scenario 1
There are no other ships docking near the scheduled berth, the berthing area is open, there are no other obstacles, and the weather meets the requirements of the berthing test. The test ship is driven into the wharf area from outside the water area of the wharf at the predetermined speed and heading, and the information of the berth to be berthed is sent to the ship to observe the operation commands executed by the ship under test. The test requires that the residual speed of inertia cannot exceed the required standard value when arriving at the front of the berth, and the speed and direction of the ship should be adjusted in time during the berthing process, so that the speed and angle during the berthing process meet the performance requirements.

4.1.2. Test scenario 2
There are other ships or other obstacles blocking the berth before and after the scheduled berth, and the weather conditions can meet the berthing test requirements. The speed is the design speed, and the course is toward the dock area. The ship is equipped with bow thrusters and azimuth propellers. The test ship is driven into the wharf area from outside the wharf water area at the predetermined speed and heading, and the scheduled berth information is sent to the ship to observe the operation commands executed by the ship under test. The test requires that the speed and direction be adjusted when approaching the front of the berth, and when arriving at the berth, the ship moves to be basically parallel to the berth by inertia, and remains basically still, and uses lateral thrust and azimuth propellers to safely drive the ship into the predetermined berth.
4.1.3. Test scenario 3
There are other ships or other obstacles blocking the berth before and after the scheduled berth, and the weather conditions can meet the berthing test requirements. The test ship is driven into the wharf area from outside the wharf water area at the predetermined speed and heading, and the scheduled berth information is sent to the ship to observe the operation commands executed by the ship under test. When approaching the berth, adjust the speed and heading and turn the middle or head of the berth with a larger heading angle to form a proper approach angle between the ship and the berth. Use the rudder to adjust the ship's position so that the ship can safely enter the scheduled berth.

4.1.4. Test scenario 4
The test ship is driven into the wharf area from outside the wharf water area at the predetermined speed and heading, and the scheduled berth information is sent to the ship to observe the operation commands executed by the ship under test. It is required that the residual speed of inertia cannot exceed the required standard value when arriving at the front of the berth, and the speed and direction of the ship should be adjusted in time during the berthing process, so that the speed and angle during the berthing process meet the performance requirements, so that the ship can safely enter the predetermined berth.

4.2. Departure test

4.2.1. Test scenario 1
There are no other ships docking near the berth, the mooring water area is open, there are no other obstacles, the weather meets the requirements of the mooring test, and the ship's mooring direction is opposite to the direction of leaving the dock. Send a command to leave the berth to the test ship, and observe the operation command performed by the ship to be tested. According to the requirements, the correct operation sequence of rewinding shall be realized, and the correct heading and departure command shall be adopted to enable the ship to safely leave the predetermined berth, and realize a U-turn in the revolving water area and leave the pier.

4.2.2. Test scenario 2
There are other ships or other obstacles at the front of the berth where the ship is berthed. The weather meets the requirements of the berthing test, and the berthing direction of the ship is opposite to the direction of leaving the wharf. Send a command to leave the berth to the test ship, and observe the operation command performed by the ship to be tested. According to the requirements, the correct operation sequence of rewinding shall be realized, and the correct stern command shall be adopted to enable the ship to safely leave the predetermined berth, and realize a U-turn in the revolving water area and leave the wharf.

4.2.3. Test scenario 3
There are other ships or other obstacles at the front and rear ends of the berth where the ship is berthed. The weather meets the requirements of the berthing test, and the berthing direction of the ship is opposite to the direction of leaving the wharf. Send a command to leave the berth to the test ship, and observe the operation command performed by the ship to be tested. According to the requirements, the correct operation sequence of the rewinding shall be realized, and the correct parallel departure command shall be adopted to make the ship safely sail out of the predetermined berth, and realize a U-turn in the revolving water area and sail out of the dock.

4.2.4. Test scenario 4
There are other ships or other obstacles blocking the scheduled berth. The weather conditions can meet the berthing test requirements. The berthing time is night. There are red signal lights at the front and rear ends of the berth, and green signal lights on the bank in the middle of the berth. Others
required acousto-optic signals also meet the berthing requirements. Send a command to leave the berth to the test ship, and observe the operation command performed by the ship to be tested. According to the requirements, the correct operation sequence of the rewinding shall be realized, and the correct parallel departure command shall be adopted to make the ship safely sail out of the predetermined berth, and realize a U-turn in the revolving water area and sail out of the dock.

5. Conclusion
In this research, an automatic berthing and unberthing test device was created. The test device combines the actual hydrological environment and the virtual traffic environment. The simulation of the surrounding environment of the berth is achieved by setting relevant parameters such as the position of the ship around the berth, avoiding the use of real ships to build the complexity of the test environment. The automatic berthing and unberthing device uses the real hydrological environment, which avoids the problem that the hydrological simulation is not real enough at this stage, and can make the actual ship test results have better authenticity. The application of the test method in this study can reduce the test preparation time, reduce the cost of traffic environment setup, and improve the safety of the test, and avoid the safety problems caused by the instability of the berthing and unberthing system.

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