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Comment on Ballast Free Ship

Wang Hong, Li Huabin

Abstract— **In order to ensure the balance and stability of the ship without cargo, the ship needs to be loaded with ballast water to achieve the purpose of reducing the center of gravity of the ship. However, the discharge of seawater from ballast tanks will cause marine ecological pollution. In order to completely solve the problem of non-native aquatic species brought by ballast water, in recent years, researchers have proposed the concept of non-ballasted tanks with innovative ideas. This paper introduces the research situation of this technology and hopes to contribute to the research and design development of non-ballasted water tanks.**

Index Terms— **ocean pollution; ballast water treatment; ballast-free ship**

I. INTRODUCTION

Ship transportation is an important part of the global logistics chain, most of the goods are transported by ship. Today's merchant ships generally have ballast tanks at the bottom, filling the tanks with seawater at the starting port where the empty ships sail to maintain the balance of navigation on the way to the ship; When the cargo arrives at the port of destination, the water in the tank is discharged. This traditional concept of ballast water tanks has two major drawbacks: the empty ship sailing increases the weight of the water tank filled with sea water, which increases the fuel consumption of the ship; the seawater loaded in the water tank is discharged, causing marine pollution. There are about 10 billion tons of ballast water in the world each year. The ballast water discharge of ships on international voyages has caused the invasion of alien organisms and has been listed as one of the four major hazards of the ocean by the Global Environmental Protection Fund (GEF). At present, shipowners, business managers, etc. mostly rely on ballast water technology, such as heating, electrolysis and UV treatment [1] 。The United States has adopted a number of measures, such as ballast water replacement and retention of management fees on board. [2] 。However, these ballast water treatment technologies are not only time-consuming and labor-intensive, but also increase the operating cost.

II. II.SHIP DESIGNS FOR SOLVING BALLAST WATER

1. Through Flow System Hull

The traditional method of setting ballast tanks is for the safety of navigation. It is to increase the gravity of the ship at light loads. To change the mind, it can be considered that ballast water reduces the buoyancy of the ship rather than increasing gravity. In this way, the researchers proposed the concept of a ballastless tank. (US patent #6694908, 2004) [3] 。

Dr. Michel Parsons, University of Michigan, USA . He published a paper at the annual meeting of the American Society of Shipbuilding and Marine Engineering in 2004. He specifically talked about the project design of non-ballasted tanks, and specifically discussed the hull technology of the through flow system. [4 - 6] 。

Though Flow System Hull is a traditional type of pressurized water tank used to replace the longitudinal structure below the cargo waterline. Its biggest feature is to change the original closed type to front and rear open type.The water inlet is arranged under the water line of the bow, and there is a water outlet at the stern. The sea water continuously flows from the inlet of the bow and is quickly discharged from the stern drain port, which can function as a pressurized water tank and reduce the load on the ship. This design concept can be seen as reducing the buoyancy of the ship rather than increasing the gravity of the ship. The water flow velocity through the pressurized water tank is controlled by the different pressures of the water flow at the bow and the stern inlet and outlet. The seawater that passes through the flow-through tanks is always the seawater in the local seas and does not take the seawater from one place to another, thus complying with the International Maritime Organization (IMO) regulations on marine environmental protection.

At present, the world's research on non-ballasted water tanks has achieved some results. The University of Michigan successfully developed a model of a ballastless tank cargo ship, as shown in Figures 1 and 2, and conducted related tests in the hydrodynamics laboratory. The design idea is to cancel the ballast tank and replace it with two large open pipes, namely the water flow box. When the empty ship leaves the port, the front and rear covers of the large pipe are opened, and the seawater flows in. After the ship sails, the seawater flows from the pipe back and forth to keep the ship balanced. When the cargo ship is sailing, close the front and rear covers to release the seawater.

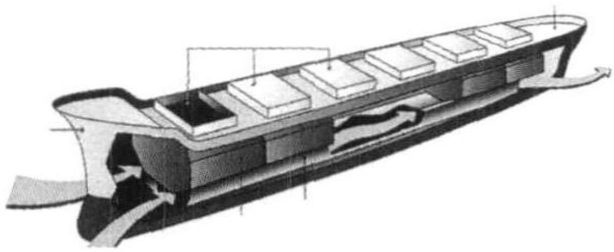

图 1 无压载水舱货船的示意图
Fig. 1 Ballast-free ship sketch map

Wang Hong； College of Naval Architecture and Ocean Engineering, Jiangsu University of Science and Technology, 2nd Road, Mengxi Road, Zhenjiang City, Jiangsu Province ,China .Phone：0511-84407400

Li Huabin: College of Naval Architecture and Ocean Engineering, Jiangsu University of Science and Technology, 2nd Road, Mengxi Road, Zhenjiang City, Jiangsu Province, China. Mobile:18796089295

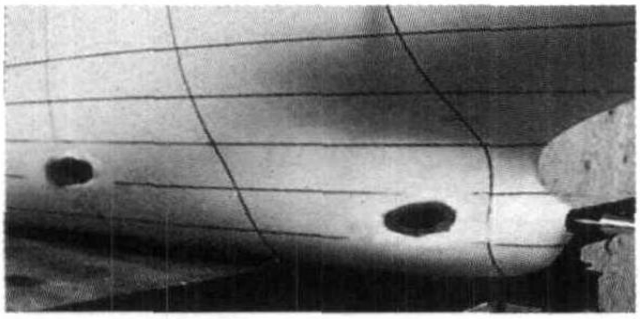

图 2 无压载水舱货船模型试验

Fig. 2 Ballast-free ship model test

Researchers at the University of Michigan have tested the new type of vessel in large tanks. The results show that the ship not only maintains good stability, but also because the seawater flows from front to back due to the two large pipes installed at the bottom of the ship. The propeller can play a role in accelerating the rotation, increasing the speed and saving fuel and reducing emissions. Test results show that up to 7.3% of ship power can be saved.

2. Single Structure Hull

Single Structure Hull Design: Design Scheme Figure 3 is to provide a rearwardly open recess at the bottom of the ship. The bottom of the ship is shaped like an inverted front and rear flapper. This type of ship allows the ship to produce a larger water gauge at light or no load. However, the disadvantage of this scheme is that the area of the hull contacting seawater is greatly expanded compared with the conventional ship type, and the length of the ship's side is increased.

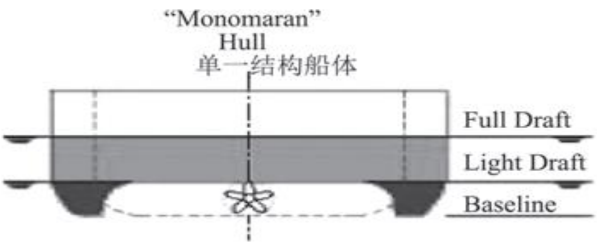

Fig. 3 Monomaran hull

However, Dr. Parsons believes that these deficiencies can be minimized by the effect of air lubrication generated by the downward flaps on both sides of the bottom of the ship. At present, this single-hull hull type ship has been successfully tested at Delft University in the Netherlands. It has a deadweight of 4 000 t and a ship speed of 14 kn. There is no pressurized water tank. From the perspective of sea trials, it basically meets the standards for so-called ballastless water vessels.

3. V-hull

The idea of a non-ballasted tank super large tanker hull project was originally proposed by Anders Ulvarson at the University of Golmers in Gothenburg, Sweden. The Japan Shipbuilding Research Institute has been working hard to develop non-ballasted water tank ships since 2001 with the government's strong funding and promotion. In 2003, the Japan Ship Technology Research Association decided to upgrade the non-pressure tank tanker to the Japanese national engineering project. The shipyard and shipbuilding research unit participating in the project jointly established the NOBS Design and Construction Research Institute in Japan.

V-Shaped Hull proposed by Japanese research institute. The biggest feature of the non-ballasted tank super large tanker (VLCC) design is the hull of the lower part of the ship is more slender, and the bottom of the ship presents a V-shaped shape that protrudes downwards, which makes the draught of the non-ballasted tanks sufficient to support the weight of the ship when it is empty. Shipbuilding experts initially selected two designs for non-ballasted tanks. The main purpose of the first non-ballasted tank hull design codenamed "Best" is to design a non-ballasted tank vessel that is built on a waterless deep restricted waterway, such as the Persian Gulf. Its hull type is 35 m deep, with a maximum width of 56 m, full load of 27 m, and cargo capacity exceeding 300,000 t. Experts said that the development of the second non-ballasted water hull design codenamed "Malacca" is to build ships suitable for sailing from the Persian Gulf through the Straits of Malacca to China, Japan and South Korea in the Far East. Its hull has a maximum width of 79 m, a depth of 30 m, a full load of 21 m and a cargo capacity of 280,000 t.

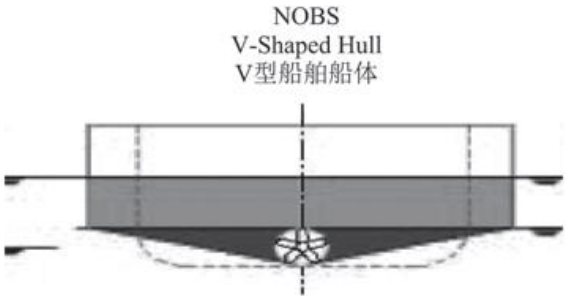

Fig. 4 V-Shaped hull

Japan NOBS Design and Construction Institute believes that the airworthiness and operation of the innovative V-hull non-ballast water tanker have now reached the IMO legal and regulatory standards. It has been confirmed through computer simulation tests that the "optimal" non-ballasted tanker can sail smoothly on a sea with little wind and waves; The "Malacca" non-ballast water tanker (Malaca-max) has a poor sailing situation because the hull is widened and the bottom of the ship is not deep enough in the water. The two non-ballast water tankers are equipped with ballast water tanks. If there is bad weather, they must enter 15,000 tons and 35,000 tons of ballast water respectively to increase their navigation stability and ensure the safety of the ship. In the same environment, the traditional VLCC must carry at least 80,000 tons of ballast water to meet the standards of the ship draft of not less than 8. 4 m as stipulated by the International Ship Pollution Prevention Convention. It can be seen that the advantage of the so-called non-ballast water tanker is still very obvious. In particular, the design concept is not constrained by the so-called "no ballast water tank". In the hull, there is still a spare pressurized water tank, which can flexibly and flexibly decide how much ballast water to be pumped in the spare water tank according to the weather of the sea and the wind and waves in the sea, and enhance the safety and stability of the hull.

The V-hull design concept is to minimize the hull and reduce the resistance of the hull in the ocean. Among them, the “best-in-class” non-ballast tank tanker reduced the resistance by 33%, and the “Malacca” non-ballasted tank vessel reduced the resistance by 25%, which can obviously save the fuel necessary for the navigation power. However, since no ballast tanks need to optimize the ship's structure and use super-strength steel, the cost of a single ship is about $6.5 million higher than the traditional VLCC. Of course, the increased cost can be fully recovered during the operation of the ship.

III. PROSPECTS FOR NON-BALLASTED WATER SHIPS

Graham Green Smith, a senior expert at Lloyd's Register of Shipping, spoke of various non-pressure water tank designs, and so far there is no one that can completely eliminate ballast water. The ship design can be used in practice. But this does not mean that the true non-ballasted watercraft can never be built.

1.From the above three non-ballasted water tank water system ship design concepts and solutions, it seems that people have seen the bright prospects of fundamentally solving the problem of ballast water tanks. The first option, the cross-flow system, is the best and innovative. It is feasible from the technical point of view, it can play a ballast role at no load, and the seawater pollution is also the smallest. However, the research in various countries is still in its infancy, and it is only a few years to propose this innovative ship design concept. Therefore, it will take some time for this new type of ballastless water tank vessel to be put into actual operation. The disadvantage of a hull vessel with a cross-flow system is that despite the conversion to a pipe flow system, it is also necessary to retain a conventional type of pressurized water tank with a partial transverse structure. At present, the researchers are concentrating on overcoming this difficulty, and try to reduce the volume of the horizontal structural pressure tank that cannot be completely eliminated at that time, that is, to minimize the amount of closed ballast water carried by the ship and to maximize the function of the through-flow ballast tank. Dr. Parsons pointed out that by further improving the fluid dynamic design, most of these problems can be solved.

2.Throughout the research status of non-ballasted water tanks in various countries, the V-hull non-ballast tank tanker can be applied to the actual project first. The V-hull design, although it is still necessary to enter the ballast water when it encounters violent winds on the sea to ensure its stability and safety, it still reduces the problems caused by ballast water to a considerable extent. Dr. Parsons pointed out that by expanding the height of the sewers and appropriately increasing the width of the bottom of the ship, it is sure to successfully build a V-hull tanker that can sail safely in high winds and waves. According to the research results of the NOBS Design and Construction Institute, the V-hull tanker is the same as the traditional tanker. The hull is strong, the wind is superior to the wind and the sea, and it can sail in the ocean. The innovative V-hull non-ballast water tanker has more stable sailing performance, and its hull rolling frequency is lower than that of the traditional oil tanker. Therefore, the innovative non-ballast water tanker does not need to be equipped with keel, saving a lot of shipbuilding funds.

1) The design of a ship without ballast water tanks does not mean that there is no problem of marine pollution at all, but it minimizes pollution. For example, when the ballast tank of a cross-flow system is actually used, a small amount of marine life, microorganisms and sediments remain on the inner wall.

2)Some so-called non-ballast water tanks are actually ships with spare ballast tanks. The water in the ballast tanks of these ships may still be discharged elsewhere, thus causing marine pollution and must not relax the vigilance against ballast water pollution.

3)The most effective way to solve the problem of ship ballast water pollution is to avoid the ship's empty load situation, that is, when the cargo ship is empty or lightly loaded, it can carry the goods back in the unified management dispatch of the shipping company.

IV. CONCLUSION

There is no doubt that the so-called through-flow system pressurized water tank is by far the most innovative shipbuilding design concept. Its biggest feature is to retain the traditional pressurized water tank, but to change the stagnant water in the pressurized water tank into the longitudinal running water, thus fundamentally solving the problem of the spread of microorganisms and pollutants in the global ocean.

Experts said that if a ship without ballast water tanks is successfully developed, it can not only completely solve the pollution problem of ballast water, but also bring energy-saving effects and reduce the operating costs brought by ballast water treatment systems. In summary, although ballast water treatment technology must be heavily relied on at present, the non-ballasted tanks sailing in the ocean will become a reality in the near future.

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Wang Hong, Professor, Graduate Instructor, School of Naval Architecture and Ocean Engineering, Jiangsu University of Science and Technology

Li Huabin, Master student, chief mate for ocean-going ships