Design and Experimental Research of the Inbuilt Oil Collection System for the Oil Spill Recovery Ship

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Abstract. The inbuilt oil collection system of the oil spill recovery ship is based on the principle of downward belt skimmer. The system adopts a composite structure, which is integrated with the downward belt skimmer and the upward belt device. The skimmer is used for oil recovery and the upward conveyor belt device is used for rubbish disposal. In this paper, experiments in the test hull and test pool were carried out to investigate the performance of the inbuilt oil collection system such as the recovery rate, the recovery efficiency and the waste adaptability. The test results show that the oil spill recovery system has the advantages of compact structure, high recovery rate and efficiency, high adaptability of garbage, high safety of operation and so on.

1. Introduction

In recent years, crude oil import volume of China has been increasing by about 15% annually on average. In 2019, crude oil dependence of China on foreign countries has exceeded 70%. There are millions of tons of crude oil imported into China through ports every day. Great risk of oil spill pollution from ships still exists. In addition, there are many large oil terminals, oil refining facilities, oil pipelines and oil storage bases along the coastline and inland river hinterland which brings a major risk source of the offshore oil spill.

Oil spill accidents occurring in China, such as the "7.16" oil spill accident in Dalian, the "11.22" oil pipeline explosion in Qingdao, the ConocoPhillips oil spill accident in Bohai Sea and the oil spill accident caused by the collision of "Sanchi" ship [1] have caused the serious pollution of marine environment and a large number of deaths of marine fish, birds, seaweed and marine mammals, which have brought huge economic losses and severe social impact to China.

The oil spill recovery ship known as a kind of special ships is an important equipment which can effectively control range of the oil spill pollution and can quickly dispose the oil spill. It is an indispensable part of the oil spill emergency system [2]. The inbuilt oil spill recovery system is the most important part of the spill recovery ship. The system is mainly composed of the oil skimmer, the power system, the electrical system, the oil guide device and other components [3]. In this paper, the mechanism of the oil spill collection system was introduced, Experiments of the inbuilt oil collection system were carried out to assess the performance such as the recovery rate, the recovery efficiency and the waste adaptability.
2. Principle of the downward belt skimmer
The principle of the downward belt skimmer is designed based on the phenomenon of the water dragging oil and the upstream effect [4]. The working mechanism is shown in Fig. 1.

![Figure 1. The principle of the downward belt skimmer.](image)

1. the collection belt; 2. the transmission system; 3. the pump; 4. the oil sump

The oil spill on water surface was brought away under high-speed rotating of the collection belt and then oil was collected in the sump because of the density difference between water and oil. The oil gradually accumulates at the top of the oil sump, and water is discharged from the oil sump. When the oil layer reaches a certain thickness, the oil is pumped out and is stored in the oil tank or other storage device by the transmission system.

The three-dimensional simulation results of the mechanism of the downward conveyor belt skimmer show that, the oil accumulates at the inlet of the collection belt under a high flow velocity of water and a low velocity of the collection belt, and the oil surface will curl up under the rotation of the driving roller. On the contrary, under a lower flow velocity of water and a high velocity of the collection belt, a large amount of water is brought into the oil sump by the oil collection belt, which will result in waste of driving energy [5-6]. According to the performance test of the downward belt skimmer by Ohmsett laboratory, the water content in the collected oil is less than 1% when the velocities of the water and the collection belt are matched. Taking the agitation of great waves into account, the water content in the collected oil is not more than 10% [7].

3. The inbuilt oil collection system of the oil spill recovery ship
The system adopts a composite structure, which is integrated with the downward belt skimmer and the upward belt device. The skimmer is used for oil recovery and the upward conveyor belt device is used for rubbish disposal. As shown in Fig. 2, the oil collection system is built in the special tank of oil spill recovery ship. The oil collection system adopts automatic control and it can effectively recover the oil in semi closed water areas and open water areas such as ports, rivers, lakes, open seas and coastal areas. The specific structure of the oil spill recovery system is shown in Fig. 3.
Figure 2. Arrangement of the oil collection system in oil spill recovery ship.

Figure 3. Overall structure of the oil spill collection system.

The downward belt skimmer is composed of the body, the collection belt, a pump, a transmission system and other components. The collection belt is a continuous flat belt, which is inclined in the middle of the skimmer. The upper end of the collection belt is above the water surface and the back end of the belt is located under the water at a certain depth. The pump is equipped with a cutter set, which can cut rubbish into small pieces in order to prevent rubbish from blocking the pump body and from causing the failure of the oil spill collection system.

The upward belt device adopts a net belt structure, which can continuously lift and filter large rubbish floating on the water surface. If there is no rubbish on the water surface, the inclination angle of the net belt can be adjusted by the hydraulic cylinder till the belt is above the water surface. Thus, the recovery rate of the oil collection system will increase as the speed of the oil into the skimmer increases.

4. The test hull
The test hull was designed to simulate the working process of the inbuilt oil collection system. The test hull is consisted of two floating tanks, rubbish storage tank, gangway and other structures. The hull was equipped with the inbuilt oil collection system along with the power system, the height adjustment system and the surveillance, as shown in Fig. 4.
The height adjustment system is used to set the vertical position between the oil collection system and the test hull. In order to effectively recover the oil, the underwater depth of the collection belt is within 600 mm.

The surveillance system is used to monitor the operation state of the oil collection and rubbish salvage for improving work safety.

![Scheme of the test hull.](image)

1. the downward belt skimmer, 2. The dustbin, 3. The upward belt device of rubbish salvage, 4. the power system, 5. The gangway, 6. The floating tank, 7. The Height adjustment system, 8. The surveillance system

**Figure 4.** Scheme of the test hull.

### 5. Experimental research

#### 5.1. experiment conditions

The experiment environment temperature shall not be lower than 10°C.

- The velocity of water flow shall not be greater than 3 kn.
- The velocity of the recovery belt and the velocity of water flow should be matched.
- The pump shall run at the rated speed.
- The viscosity of test oil shall be in accordance with the relevant requirements of ISO 21072-1-2009 and GB/T 37447-2019[8].

#### 5.2. experiment design

The test hull is fixed stable in the test pool which is 22 meters in length, 13 meters in width and 1.75 meters in height and the gangway is open. A certain velocity of water flow is generated through the current generation system. The current flows from the gangway to the end of the test hull to simulate the operation condition of the oil spill recovery ship during oil collection process.

The current generation system can be controlled at different velocities of water flow for the test requirements, as shown in Fig. 5.
5.3. **Recovery rate and recovery efficiency test**

The test oil with different viscosity and flow rate was put into the transitional tank by the test oil injection device. The oil enters from the gangway and passes through the oil spill collection system in the test hull. The collected material is a mixture of oil and water and was transported from the pump and the transmission system to the oil tank.

The collection rate ($\nu$) can be obtained according to the test method described in GB/T 37447-2019. In order to accurately detect the recovery efficiency of the oil spill collection system, a special detection device was designed. The device includes an oil-water separation tank and a water storage tank, volume of which can be easily measured as shown in Fig. 6.

![Figure 6. Detection device of recovery rate and recovery efficiency.](image)

5.4. **Rubbish adaptability test**

Polypropylene ropes, softwood, packaging foam, straw, leaves and cartons are used to simulate different kinds of rubbish on the water surface. The test result shown in Fig. 7 reveals that the upward belt device of salvaging rubbish can effectively collect large pieces of rubbish and the cutter set in the pump can cut large ones into small pieces of rubbish to facilitate the process (Fig. 8).
6. Conclusion
In this paper, an inbuilt oil spill collection system was designed. The test hull and test tank have been developed to investigate the performance of the collection system. The recovery rate, the recovery efficiency and the waste adaptability of the collection system have been tested. The test results show that the oil spill collection system has the advantages of compact structure, high recovery rate and efficiency, high adaptability of garbage, high safety of operation, and so on. In the future, the inbuilt spill collection system will provide direct support for the water environment protection.

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