Research on Transportation Technology and Disposal Plan of Oil Storage in Deepwater Sunken Ship

Yunfei Zou 1, 2, Panpan Zhang 1, 2 and Weiting Ning 1, 2, *

1 China Waterborne Transportation Research Institute, Beijing, China
2 Key laboratory of port logistics equipment and control engineering, Beijing, China

*Corresponding author e-mail: ningwt@wti.ac.cn

Abstract. Due to the complex hydrological conditions, large water depth, complex operation technology, and large construction difficulties, the disposal of oil storage in the sunken ship is very difficult. Taking the oil storage in the sunken ship as the object, the technologies of rapid extraction, shuttle transportation and transfer of the oil are mainly studied. The disposal plan of the oil storage in the sunken ship is put forward. The plan can meet the requirement that the oil is directly pumped from the cabin to the working ship. The plan also provides decision and technical support for oil spill emergency disposal of the deepwater sunken ship accident.

1. Introduction

Oil tankers are the most important mean of the oil transportation in the world. However, under severe sea conditions, the sinking accidents caused by collision, striking rocks and damage of oil tankers are on the rise [1]. If no treatment is taken for the sunken ships, the risk of oil leakage from the oil tanks will increase with time [2-3]. There will be a large-scale oil spill pollution accident. On January 6, 2018, “SANCHI” ship carrying 111300 tons of condensate oil collided with “CF CRYSTAL” ship in waters about 160 nautical miles east of the Yangtze River Estuary [4-5]. On January 14, “SANCHI” ship exploded and sank more than 100 meters underwater [6]. Three people died and 29 people were missing in the accident. There were a certain amount of condensate oil and about 1900t of marine fuel oil in the sunken “SANCHI” ship, which is likely to pollute the marine environment. According to “Nairobi International Convention on the Removal of Wrecks” issued in 2007, it is necessary to dispose the sunken “SANCHI” ship.

“SANCHI” ship has sunk in the open sea area with the strong wind and waves. Moreover, the marine hydrological conditions are complex and the submergence depth is relatively large, which has exceeded the requirements of conventional diving (conventional diving depth is 60m). For the high viscosity oil in deep water under the condition of low temperature and high pressure, the lift of the existing oil pump is low, which can’t meet the requirement of pumping oil directly from the cabin to the working ship. Therefore, it is very difficult to dispose of oil stored in the deepwater sunken ship.

2. Fast extraction of stored oil

Fast extraction is pumping the oil from the cabin to the oil storage device at a certain height and direction outside the sunken ship by the oil pump. The core equipment of extraction operation is oil pump.
2.1. Archimedes screw pump

Nowadays, the capacity of the typical Archimedes screw pump ranges from 20m³/h to 140m³/h. The pump is mainly used for oil skimmer and marine unloading. It can transport high viscosity substances, such as emulsified oil, crude oil, high viscosity oil, asphalt, etc. Its pumping head can reach 100m and its overall performance is good. Due to the good internal sealing of the pump, it can also transport low viscosity substances under high pressure without leakage, such as diesel, water, etc.

In order to facilitate the suction and pumping of substances with extremely high viscosity, the GTA series pump of Lamor are equipped with hot steam/water injection device at the suction, which can instantly heat the substances and reduce the viscosity. The heating of the hot steam/water can also reduce the friction with the pump wall and pipeline in the process of material transportation, which improve the substances patency and enhance the pumping capacity. In order to prevent large solid from blocking the substances delivery, a cutter is designed at the suction of the pump. The cutter can cut large oil blocks and garbage into pieces with a diameter of less than 30mm. The GTA series pump of Lamor is shown in Figure 1.

![GTA series pump of Lamor](image1)

**Figure 1. GTA series pump of Lamor**

2.2. Cam rotor pump

Nowadays, the capacity of the typical cam rotor pump ranges from 10m³/h to 200m³/h. It can transport some corrosive substances from low viscosity to high viscosity and the substances of low shear rate, such as waste oil, slurry water, mining wastewater, waste fuel oil, emulsion, etc. Its pumping head can reach 40m.

![Cam rotor pump](image2)

**Figure 2. Cam rotor pump**

The body of the pump adopts the meshing rotation of two cam rotors. The substances are squeezed from one side to the other side along the pump shell by two cam rotors, resulting in the movement of substances. The pump flow increases with the increase of pump rotation speed and the outlet pressure increases with the increase of load. For the substances with large particle diameter, the cam rotor pump has good traffic ability, up to 20~50mm. Because the surface of the cam rotor is wrapped with elastic material, the cam rotor has good sealing performance and strong self-priming ability.

The comparison of the two types of oil pumps is as follows:
(1) The transportation principle is different. The viscosity of the substances transported by Archimedes screw pump is higher than that of the cam rotor pump.

(2) The Archimedes screw pump is equipped with hot steam/water injection device to heat the substances in the pump body.

(3) The cam rotor pump can't deal with the large solid with diameter over 50 mm. But the Archimedes screw pump is equipped with a cutter to cut the large solid and prevent the pump from blocking.

(4) Because there is no large solid in the oil tank of the sunken ship, the pump does not need to have the function of cutting large solid.

According to the above comparative analysis, the overall performance of the Archimedes screw pump is better than that of the cam rotor pump. Considering the high viscosity oil under the condition of low temperature and high pressure in deepwater sunken ship, the Archimedes screw pump is recommended for efficient and rapid extraction of stored oil.

3. Shuttle transportation of stored oil

Due to the large sinking depth of “SANCHI” ship, the existing pump can not meet the direct transportation from the sunken point to the working ship. The shuttle transportation technology is to pump the oil stored in the sunken ship to the underwater oil storage device near the sunken ship or at a specific position in the water. The position of the underwater oil storage device meets the pumping head requirement of the pump. After the underwater oil storage device is stored, its own water gas displacement equipment to generate buoyancy to push itself up to or near to the water surface, so as to realize the shuttle transportation of oil storage between the sunken ship and the working ship.

The underwater oil storage device is mainly composed of an oil capsule, an oil hose, a pendant, a cable and a water air displacement device, as shown in Figure 3. The bottom of the oil capsule is fixed with a pendant by a cable, which is used to keep the position and posture of the underwater oil storage device. The oil capsule is equipped with an outlet and an inlet. The two ends of the oil hose are respectively connected with the pump and the oil capsule. The pump takes out the oil from the sunken ship directly into the oil capsule.

![Figure 3. Components of underwater oil storage device](image)

1. Pump; 2. Oil hose; 3. Oil capsule; 4. Cable; 5. Pendant; 6. Water air displacement device

After the oil storage reaches the limit value, the water air displacement device inputs the compressed gas and discharges the ballast water to make the oil capsule obtain buoyancy and float to the water surface. The compressed gas is supplied by the working ship through ROV. The working principle is shown in Figure 4.
Figure 4. Working principle of water air displacement device

Features of underwater oil storage device:
(1) The oil capsule is a soft structure, which is light and miniaturized for underwater operation. It is especially easy to store, transport and lay out. It has outstanding advantages in timeliness of oil spill emergency disposal.
(2) The underwater oil storage device realizes the oil recovery, the oil temporary storage and the oil floating. It avoids the transportation of the oil from deep water to the surface through long pipelines. It overcomes the difficulties of large wind and wave force on long pipelines, large resistance of fluid transportation along the way, and large influence of sea conditions on the working ship.
(3) Shuttle transportation technology does not need large engineering ship and high-performance riser. The technical difficulty and operation cost will be greatly reduced.

According to the storage capacity, disposal time limit and disposal difficulty, multiple oil capsules in series can be considered for the transportation of the oil storage in the sunken ship.

4. Transfer of pumping and auxiliary suction
After the underwater oil storage device floats to or near the water surface, the working ship navigates to the floating position of the oil storage device. The transfer device on the oil storage device is connected with the suction device on the working ship through the oil hose. The oil stored in the oil storage device is transported quickly under the dual action of pumping and suction.

Due to the short distance of transportation and the low requirement of pumping head, the domestic cam rotor type oil pump is recommended for the transfer device and the suction device.

5. Disposal plan of oil storage
In order to prevent the oil leakage of the sunken ship from polluting the marine environment, the disposal of the oil storage should be carried out before salvaging sunken ship, so as to completely eliminate the pollution sources of sunken ship. The disposal plan of the oil storage is as follows:

(1) Working ships in place
The disposal of the oil storage needs two working ships to carry out operation at the same time. In principle, the working ships and the sunken ship should be arranged in a "T" shape, but the heading of the working ship can be adjusted according to the swell direction of the operation site.

(2) Determination of opening position
Through underwater scanning or saturated diver observation, three easy opening positions (Figure 5 shows the pumping hole, steam hole and injection hole) are determined and marked on the oil tank shell. The ship attachment around the opening position is removed.

(3) Underwater placement of drilling equipment
The drilling equipment is hoisted into the vicinity of the sunken ship by using the working ship's lifting equipment, and then the ROV is launched near the drilling equipment. The ROV can fully observe the disposal operation of the oil storage. At the same time, it can also directly operate the connection and separation of drilling, pumping equipment and the oil tank shell.

(4) Drilling of oil tank shell
The saturated diver or ROV controls the drilling equipment to the designated opening position. The drilling equipment is fixed on the oil tank shell by the combination of magnet and nail shooter [8]. Three drilling operations are completed. The Archimedes screw pump is fixed on the pumping hole and the drilling equipment is separated.

(5) Fuel heating
The steam hole is opened. The special heater is inserted into the oil tank from the steam hole. The high-pressure steam pipe is connected with the heater. The high-pressure steam boiler is used to generate the steam, which locally heat the oil tank of the sunken ship.

(6) Hot oil circulation heating

The pump is equipped with a three-way valve, which connects the pumping hole and the injection hole. The pump is started. The hot oil is pumped out from the oil tank and injected again from the injection hole through the circulating pipeline. By repeatedly circulating heating the oil in the oil tank, the fluidity of the oil is improved. It is convenient for the pumping operation.

![Diagram of hot oil circulation heating](image)

**Figure 5.** Diagram of hot oil circulation heating

(7) Arrangement of underwater oil storage device

The lifting equipment of the working ship hoists the underwater oil storage device into the water. The water air displacement device inputs the sea water and discharges the air inside the device, so as to realize the sinking of the underwater oil storage device. Under the auxiliary operation of the diver or ROV, the underwater oil storage device is arranged at a certain distance above the oil pump to ensure that the cable at the bottom of the device is stressed and keep the position and posture of the device in the water. The two ends of the oil hose are respectively connected with the pump and the oil capsule.

(8) Extraction of stored oil

The heating of the oil tank is completed. The connection between the pumping hole and the injection hole is closed. The connection between the oil pump and the oil reservoir is opened. The pump is started to pump the hot oil from the oil tank into the oil capsule.

(9) Shuttle transportation of stored oil

After the oil storage reaches the limit value, the water air displacement device inputs the compressed gas and discharges the ballast water to make the oil capsule obtain buoyancy and float to the water surface.

(10) Transfer of pumping and auxiliary suction

The transfer device on the oil storage device is connected with the suction device on the working ship through the oil hose. The oil stored in the oil storage device is transported quickly under the dual action of pumping and suction.

(11) Oil tank washing

After the oil in the oil tank is extracted, the hot steam is injected into the tank to repeatedly wash the tank. Then the oil sewage is extracted.

(12) Oil tank plugging

After the oil sewage is extracted, the pumping hole, steam hole and injection hole are closed. The pump is recovered. The disposal operation of the oil storage is completed.
6. Conclusion
In view of the large sinking depth of the sunken ship and the low lift of the pump under the condition of low temperature and high pressure, this paper focuses on the technology, which includes fast extraction, shuttle transportation, high efficiency transfer, terminal auxiliary pumping. Disposal plan of oil storage in deepwater sunken ship is put forward. The plan can meet the requirements of the oil directly pumped from the oil tank to the working ship.

Acknowledgments
This work was supported by National high-tech industries development project of China (Project number: 2017YFC0307001).

References
[1] ZOU Yunfei, NING Weiting, ZHOU Jiahai, DING Min. Design of Hydraulic System of Equipment Integrated with Drilling Wreck and Pumping Oil. MACHINE TOOL & HYDRAULICS, 2015, 043(007):113-115, 31.
[2] Albertson P, Pond B, Symons L, et al. IOSC 2005 examines potentially polluting wrecks in marine waters. Marine Technology Society Journal, 2004, 38(3):8.
[3] ZHANG Lei. Design and Experiment of Underwater Opening and Pumping Equipment from Shipwrecks Based on Abrasive Water Jet Technonlogy. Dalian Maritime University, 2019, 6.
[4] Hu Zejiang. Discussion on the capacity building of ship offshore and high sea oil spill emergency disposal on the base of MV "SANCHI" fire and explosion accident. CHINA MARITIME SAFETY, 2019, 166(05):46-52.
[5] KONG Xiangsheng, ZHU Jinshan, XUE Manfu. Cause and responsibility analysis of collision accident between "SANCHI" and "ChangFeng Crystal". WORLD SHIPPING, 2018(6):1-8.
[6] YIN Jie. Analysis and Reflection on Causation and Emergency Disposal of "SANCHI" Crash-Blasting Accident. NAVIGATION OF CHINA, 2019, 42(01):45-49.
[7] Zhang Yinliang, Li Zhigang, Feng Yingbin, Yao Lizhu, Zhang Dewen. Study on ways to deal with oil spill accident of deepwater ship by combination of ROV and diver. ENVIRONMENTAL ENGINEERING, 2013, 31(S):54-57.
[8] NING Weiting, ZHOU Jiahai, ZOU Yunfei, LI Zhigang, ZHANG Yinliang. Study on Ways of Underwater Drilling and Oil Pumping of Oil Tank on Sunken Shipwreck. SHIP ENGINEERING, 2015, 037(010):106-110.