Oil Containment Fence and Method for Polar Ice Water Environment

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Abstract. The polar regions are covered with ice and snow all the year round, and the environmental conditions are special. Many times of oil spill accidents in the polar regions have brought great pollution to the marine environment. According to the environmental characteristics of the polar ice area, a kind of polar oil fence and its method are designed. When the oil spill accident occurs, the tugboat can quickly enclose the oil to slow down the diffusion of oil spill, so as to reduce environmental pollution and economic loss. With the prosperity of shipping in high latitude area, the possibility of oil spill accident is increasing. This method will have a broad application prospect. It has certain guiding significance for the oil spills in the northern sea area and the Arctic in cold winter.

1. Introduction
The polar region is the coldest region on the earth. It is quiet because of the ice and snow cover and bad climate. After the trial run of China's commercial vessel Yongsheng, the Arctic route is 40% shorter than the traditional Asia Europe and Asia America routes, and its shipping interests are remarkable [1]. At the same time, the Arctic is rich in oil, gas and mineral resources, of which the proven oil reserves account for 13% of the world's reserves, and the natural gas reserves account for 30% of the world's reserves [2]. The Arctic is ushering in the era of natural resource development. In the Antarctic region, except for scientific research purposes, Antarctic tourism activities increase rapidly at the rate of 10% - 15% every year. China's "Xuelong" scientific research ship has been sailing in polar regions for many times, which fully proves that China has the technical ability of polar navigation, and the development of the polar regions is also of strategic significance to China [3].

With the increasing expectation of people to explore the polar oil and gas resources and develop the two poles, the threat of the polar oil spill accident is growing [4]. Marine ecological environment crisis has been listed as one of the top ten environmental crises in the 21st century. Oil spill pollution control is becoming one of the most important issues of marine environmental protection, especially the fragile ecological environment in polar areas [5].

The oil spill accidents of ships sailing in polar regions have seriously polluted the marine environment [6]. Large areas of oil spill floating on the sea surface will not only cause hidden dangers to the navigation safety of ships passing by, but also cause devastating impact on the polar biological chain, bringing a lot of pollution to the original fragile polar ecological environment [7].

2. Oil Fence and Containment Design
According to the principle of "containment first, recovery later" in the emergency disposal of oil spill at sea, it is necessary to use the containment fence to control the oil spill in view of the drift and diffusion...
of oil spill after the oil spill accident. Oil spill containment can effectively reduce the diffusion of oil products, prevent the expansion of pollution area, cooperate with the oil spill recovery ship to enter the work area to carry out operations, and carry out polar oil spill recovery.

2.1 Oil Fence Design
At present, the commonly used oil fences are solid floating oil fences, inflatable oil fences, folding oil fences and separation tension oil fences. The performance comparison of several oil fences is shown in Table 1 below:

| Oil Fence Type                  | Advantage                                          | Disadvantage                                               |
|--------------------------------|----------------------------------------------------|------------------------------------------------------------|
| Solid floating oil fence       | Large buoyancy, good stability and good oil containment performance | Too large for transportation and storage                   |
| Inflatable oil fence           | Small volume, convenient for storage and transportation | It is difficult to adapt to the polar ice environment, and the air chamber is easy to be damaged |
| Folding oil fence              | Foldable, small size, easy to store and transport  | Small contact area with water surface, poor stability      |
| Separation tension oil fence   | Protect skirt, good wave riding and stability      | The structure of tension rope and tension rope is difficult to work with recovery ship |

By comparing the characteristics of the above-mentioned oil fences, combined with the fact that there are many ice floes and low temperature in the polar ice water environment, and the current, ice floes and wind will also produce certain stress on the oil fences, the oil fences designed by the work are shown in Figure 1:

![Figure 1. Structural diagram of oil fence](image)

The oil retaining function of the oil fence is mainly realized by the skirt body, so the selection of skirt material is very important. Table 2 shows the comparison of mechanical properties of commonly used fiber materials of the skirt body.

| Fiber name | Polyamide fiber (nylon) | Polyester (polyester) | Polyvinyl alcohol fiber (Wei Guan) | Polypropylene fiber (Bing Guan) |
|------------|-------------------------|-----------------------|-----------------------------------|---------------------------------|
| Fracture strength | Staple fiber | Filament | Staple fiber | Filament | Staple fiber | Filament | Staple fiber | Filament |
| Fracture strength | 4.8-6.5 | 4.3-6.0 | 3.6-6.3 | 4.2-5.9 | 3.2-5.2 | 2.1-3.2 | 3.0-6.5 | 3.0-8.0 |
| Relative wet strength /% | 83-90 | 84-92 | 100 | 100 | 72-85 | 70-80 | 100 | 100 |
When the elastic recovery rate is extended by 3% /


table: 3. Specification parameters of oil fence

| Specifications | Water part / M | Underwater part / M | Standard length / M | Weight kg/m | Total tension /kg |
|----------------|---------------|---------------------|---------------------|-------------|-------------------|
| Small model    | 0.15          | 0.30                | 12.19               | 2.23        | 4989.51           |
| Standard model | 0.30          | 0.61                | 12.19               | 4.46        | 9071.85           |

2.2 Oil Containment Strategy Design

After the parameters of oil spill boundary and oil film thickness are extracted by full polarization synthetic aperture radar, combined with the field current and wind speed, the oil containment strategy can be formulated to arrange the oil fence, and the oil spill at the accident site can be controlled and recovered. The specific steps are as follows:

Step 1: before the arrangement of the oil boom, the icebreaker will open a flowing ice belt around the pollution area to facilitate the arrangement of the oil boom. (Fig. 2)

Step 2: two oil spill recovery ships are divided into two ways to arrange the oil boom. According to the sensor information of the sensing module, combined with the data of wind speed, current direction, etc., the oil boom shall be arranged first on the side with fast oil spill diffusion speed (Fig. 3). At the same time of arranging the oil fence, the icebreaker continues to break the ice in a circle around the periphery, gradually treating the polluted area into a state of broken ice, so as to reach the design condition of the oil receiver.

Figure 2. Icebreaker out of the ice belt

Figure 3. Arrangement of oil fence

Step 3: the oil spill recovery ship starts to work. Along the ice breaking area completed by the icebreaker, the two oil spill recovery ships work symmetrically at the same time, pushing the oil...
collection inward layer by layer. At the same time of receiving oil, the spill recovery ship recovers the oil boom on the right side and arranges a new oil boom on the left side (Figure 4-5), so as to ensure that the untreated oil spill will not continue to spread out when the oil is collected, which is equivalent to gradually reducing the oil receiving work area until the oil is collected.

Figure 4. Arrangement of oil fence completed Figure 5. Oil receiving process

3. Conclusion and Prospect
In this paper, a new method of oil containment in polar oil spill environment is proposed. In the later stage, it can be used in combination with the high-efficiency oil spill recovery device in polar ice water environment to realize the high-efficiency oil spill recovery in ice water oil mixed environment. At the same time, there may be a certain amount of garbage at the oil spill accident site, which will have a certain impact on the oil containment effect of the oil boom.

In the later stage, the structure and function of the oil boom should be optimized and improved, so that the oil boom can eliminate the impact of the site garbage on the oil containment work, and improve the oil containment method to achieve the optimal oil containment effect.

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