Sorption Capacity of New Type Oil Absorption Felt for Potential Application to Ocean Oil Spill

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Abstract

A new type of oil absorption felt (NOAF-1) with high adsorption capacity, expected to be applied in ocean oil spill, was designed. The NOAF-1 was fabricated with commercial oil absorption felt (OAF) and expanded graphite (EG). The oil adsorption experiments were carried out under laboratory conditions. Meanwhile, the mechanical properties of oil absorption felt have been determined by burst and tensile test. The results show that the NOAF-1 has better oil adsorption capacity than OAF. The best oil adsorption capacity is achieved when the filling density of EG in NOAF-1 is 0.0087 g/cm³ and the thickness of the OAF around 1 mm. In addition, compared with OAF and EG, it is easier to regenerate the NOAF-1 after adsorption.

Keywords: Oil spill; Oil adsorption felt; Expanded graphite; Oil adsorption capacity

1. Introduction

With more offshore oil-exploitations, the petroleum shipping activities have become increasingly frequent. In recent years, many crude oil spill events have occurred and some caused serious disasters to human being and the world. The oil pouring in January 1991 during the Gulf War and oil spill of “Prestige” in November 2002 [1] brought deep concerns from many governments. Further, in April 2010, the explosion of offshore drilling platform in Mexico Gulf resulted in fearful ocean pollution due to large quantities of crude oil pouring, which became the worst environmental disaster in US history [2]. In fact,
these severe incidents not only led to the destruction of many bird habitats and the death of large quantities of sea life, but also badly affected the food chain of marine life. It may take decades or even centuries to restore the ecosystem in the polluted ocean areas [3].

Once oil leaks, necessary measures must be taken to reduce the hazards caused by oil spill. The methods of oil-spill processing are mainly classified as chemical method and physical method [4-6]. As a new environmentally friendly physical adsorption material, expanded graphite (EG) has attracted much attention of researchers in recent years [7,8]. The EG has an excellent oil adsorption capability due to its osteoporosis porous structure, high specific surface area, hydrophobic and oleophylic, which enable EG to carry out the selective adsorption in water. The absorption capacity of EG for crude oil can be 80 g/g, which is significantly higher than that of the oil absorption felt whose absorption capacity was around 10g/g [9]. However, the EG has poor structural strength and low density which make it difficult to be thrown and recovered because it can be easily blowed away by wind. As one of the solutions, packing the exfoliated graphite in a bag of proper material has been used to solve the problem [10].

In this paper, a new oil absorption felt material combined with EG has been presented. The oil adsorption experiment proved that this modified oil absorption felt could significantly enhance the adsorption efficiency compared with ordinary oil absorption felt and EG.

2. Experimental details

3.1. Experimental materials

In these experiment, the crude oil with a viscosity of 93 mPa·s and a density of 0.92 g/cm³ was used. The EG samples were prepared by microwave irradiation method, with the expanded volume above 260 ml/g. To study the adsorption effect of NOAF-1, the seawater from Qinhuangdao sea area was used in these experiments. The representative SEM micrograph of EG was shown in Fig. 1. Fig. 1a shows the EG with worm-like structure and Fig. 1b shows the section feature of EG. It can be seen that the large amount of microporous provide huge storage room for oil.

![Fig. 1 SEM image of expanded graphite (a) worm-like structure of EG; (b) microporous structure of the cross-section of EG](image)

3.2. Experimental method

The size of the bag with the commercial oil absorption felt was 300×500 mm and the thickness is 1mm, 2mm, 4mm and 6mm, respectively. The EG was filled in the bags in different filling density of 0.006g/cm³, 0.0087 g/cm³, 0.012 g/cm³, 0.018 g/cm³ and 0.039g/cm³. In this way, the modified oil
absorption felt sample so called NOAF-1 was made. The NOAF-1 was then dipped into an oil layer floating on seawater to adsorb oil. The saturating sorption process was completed until the transparent oil on the top surface of NOAF-1 appeared. After that, the bag was recovered from the crude oil by metallic mesh and hanged it up until the excess oil dripping off (Michio, 2000). Sorption capacity of NOAF-1, e.g. weight of sorbed oil per 1 g of EG (g/g), was determined from the weight changes after recovering the bag from the test cell.

3. Results and discussion

3.1. Effects of the thickness of OAF on the sorption capacity

The mechanical properties of oil absorption felt have been determined by burst and tensile test. The burst and tensile tests were done according to GB/T 19976-2005, GB 6529-86 and GB/T 3923.1-1997, GB 6529-86, by using Model YG026B Electronic Fabric Strength Tester whose accuracy of force measurement is less than ±0.2% F.S and the resolution of elongation is less than 0.1mm. The test results are plotted in Fig. 2. From this figure, it can be seen that the burst and tensile strength increase with the increasing of the thickness of OAF. When the thickness of OAF was 0.89mm, the intersection of burst strength and tensile strength was 9.8N. When the thickness of OAF was 0.6mm, burst strength and tensile strength were less than 1N. Given the fact future production and reliable application, the OAF with thickness of 1mm was chosen in the following adsorption tests. The bursting strength and tensile strength of such OAF were above 10N.

Fig. 2 The mechanical property of the oil absorption felt with different thickness

Fig. 3 The maximum sorption capacity of different thickness of the oil absorption felt

In order to obtain the maximum sorption capacity of the NAOF-1, the effect of the thickness of OAF was studied. The OAF used to enwrap EG was made of four different thicknesses: 1mm, 2mm, 4mm, and 6mm. From the Fig. 3, it can be seen that the adsorption capacity of different thickness of the OAF was essentially same, which was about 8 g/g. This indicates that the change of the OAF thickness has no effects on adsorption capacity of NOAF-1 when the thickness of the OAF is from 1mm to 6mm.

Fig. 4 showed the curve of maximum sorption capacity of NAOF-1 with different thickness of OAF. From this figure, at the same EG filling density, it can be seen that the sorption capacity of NOAF-1 increases with the decreasing of OAF thickness. Compared with the commercial OAF, the absorption capacity of the NOAF-1 increased almost 300%. This phenomenon can be explained. When the OAF is thinner, the proportion of OAF in the NOAF-1 is less with the same filling density of EG. Meanwhile, the
sorption capacity of EG is much higher than OAF. As a result, the adsorbed crude oil per unit weight of the NOAF-1 is much higher. Considering the unit sorption capacity and strength, the OAF with thickness of 1mm is a suitable choice. In addition, it was also found that the adsorption capacity of the NOAF-1 reaches the maximum when the packing density of EG is 0.0087g/cm³ no matter how thick the OAF is.

3.2. Adsorption of oil spill simulation experiment

Fig. 5 The adsorption process of the NOAF-1 (a)The oil absorption felt-1; (b)The oil layer floating on water; (c)The left oil layer floating on water after adsorption; (d)The surface and internal appearance of the oil absorption felt-1 after adsorption
In the Fig. 5, the test cell with the size of 500×800mm was used to simulate the ocean oil spilling environment. Before the experiment, the floating oil was spread on the whole water surface, then the NOAF-1 was dipped into the oil layer floating on water to make a good contact between the bag and the oil. When the NOAF-1 reached the saturating sorption amount, it will be then recovered. Fig. 5a shows the NOAF-1 used to adsorb oil and Fig. 5b shows the test cell floating oil layer. Fig. 5c indicates the left oil layer floating on water after adsorption and Fig. 5d shows the surface and internal appearance of the NOAF-1 after adsorption. As shown in Fig. 5b and Fig. 5c, the thickness of the oil layer has apparently become thinner. Fig. 5d shows that the EG inside the OAF appears bright and the volume of NOAF-1 becomes larger compared with Fig. 5a.

4. Conclusions

1. The content of EG in NOAF-1 has a suitable density under the same thickness of OAF. From the experiments, the density should be maintained at 0.0087 g/cm³.
2. Under the same filling density condition, to obtain the best absorption capacity, the thickness of OAF should be as thin as possible. According to the experimental results, the optimum thickness value was around 1 mm.
3. The experimental results indicate that the absorption capacity of NOAF-1 made of OAF and EG remarkable improved compared with ordinary OAF or EG. It is anticipated that the NAOF-1 can resolve the problem that EG is difficult to be thrown and recovered on the sea.

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