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Experimental Study on MHD Oil Separation from Oil-contaminated Seawater Using High Field Superconducting Magnet

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A magneto-hydrodynamic (MHD) oil separation and recovery method is presented for the separation and recovery of oil from oil-contaminated seawater, based on the electromagnetic force in an MHD flow train. An experimental facility consists of a 10 Tesla (T) superconducting magnet, an MHD separating cell (MHD channel) with electrodes, a particle mixing tank, a separating tank, and connecting pipes. A series of tests using simulation particles with a density of 1030 kg/m^3 was carried out with various seawater flow rates, electric currents and particle diameters. A high separation ratio, 99.5%, was obtained when the magnetic field was 10-T.

INTRODUCTION

Recently, the leakage and spill of heavy oil and crude oil due to the collision and stranding of oil tankers have become a serious problem. On the open sea, the oil recovery vessels use the Filter-belt method (Blackbourn, 1980) or other methods, and the spill is first controlled with oil containment booms, then oleophilic and hydrophobic ropes or belts to collect the oil-contaminated seawater, and finally a scraper blade or a set of squeeze rollers to scrape and squeeze the contaminated seawater from the belts or ropes. In a narrow space, handy oil-skimmers (Tatsuguchi et al., 2004) and onboard air conveyor oil skimmers (Fujita et al., 2006) are used. However, these oil recovery devices are effective only in the event that high-viscosity oil pollutes the sea environment. Chung (1976) tested a Lockheed disk-drum oil recovery device, and the full-scale test results of the prototype showed very high recovery rates over a wide range of oil properties and thicknesses, including thin slicks. And Chung (1977) also theoretically studied the thickness variation of an oil spill on waves. The oil skimmers and the Lockheed disk-drum oil recovery device for the U.S. Coast Guard all use mechanical methods to separate and recover oil from contaminated seawater, and obviously they need much time and a comparatively large place; in addition, these methods are effective only for high-viscosity oil with thick films or layers. As to low-viscosity oil spills with thin films, such as kerosene, diesel oil and chemical materials, oil dispersant is normally used. The oil spills are emulsified into fine droplets and sink under the sea surface. The magnetic recovery method was also used for light oils (Joseph, 1977). In this method, a thin blanket of so-called ferro-foam pads spans the oil-contaminated seawater with a rotating magnetic drum upon it. With buoyant force and magnetic force, the oily pads attach firmly to the drum surface; the oily pads are removed at the top of the drum. Evidently, this method also uses mechanisms and needs much time and large space.

Since 2002, a new method, that is expected to rapidly separate and recover oil from oil-contaminated seawater, has been developed in China and Japan. It is based on the electromagnetic force in an MHD flow train. In this MHD method, the oil is separated and collected from the contaminated seawater by an electromagnetic force, which is a separation force for the formation of oil droplets, similar to buoyancy, when an electric field and magnetic field are supplied. While the conventional methods use mechanical devices and dispersants, the MHD method has the advantages of being quiet and compact, facilitating the treatment of separated oil and having little negative effect on the environment. Further, it is more effective for light oil with thin films and fine oil droplets suspended in seawater than the conventional methods.

The MHD separation and recovery of oil from oil-contaminated seawater has been investigated since 2002 by researchers in both Japan and China. The oil-contaminated seawater is either stratified flow or dispersed flow, and the MHD method has been studied for both types of flows. Nishigaki and Takeda with Kobe University (FMSKU) carried out experimental investigations for the dispersed oil-contaminated seawater flow with polymer particles instead of oil droplets (Nishigaki, 2002; Takeda, 2005). The flow characteristics of the stratified oil-seawater flow with the presence of the electromagnetic effect were investigated theoretically as well as experimentally at the Chinese Academy of Sciences (IEECAS) Institute of Electrical Engineering (Peng and Sha, 2003). An experimental apparatus of the MHD oil-spill recovery was manufactured. A demonstration test with artificial seawater (NaOH aqueous) and lubricating oil to simulate oil-contaminated seawater in a stratified flow was successfully conducted (Peng and Zhao, 2005).

This joint IEECAS-FMSKU experiment was carried out in the FMSKU in Kobe in October 2006 with a high magnetic field generated by a solenoid superconducting magnet. Polystyrene particles both 0.5 mm and 1.0 mm in diameter were used to simulate oil droplets. This paper presents the experimental facility and test program in detail, followed by some experimental results and discussions.

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