International Journal of Offshore and Polar Engineering
Vol. 5, No. 2, June 1995 (ISSN 1053-5381)

Spreading of Crude Petroleum in Brash Ice: Effects of Oil's Physical Properties and Water Current

Mohamed Sayed,* Luba S. Kotlyar and Bryan D. Sparks
National Research Council, Ottawa, Ontario, Canada

ABSTRACT

Experiments were conducted in a refrigerated, circulating current flume to examine crude oil spreading in brash ice. Amauligak, Hibernia and Norman Wells crudes were tested. Measurements of the physical properties of the oils were also conducted, including: surface and interfacial tensions as well as viscosities. Spreading coefficients were calculated from measured surface and interfacial tensions. Results were obtained for original and weathered oils. For the spreading tests, spill volumes up to 3 litres and water currents up to 0.55 m/s were used. Tests were done using both freshwater ice and saline ice. Slick dimensions were measured, and modes of oil spreading were observed. Slick dimensions depended on oil type, but were not influenced by water current. Oils of high spreading coefficient and low viscosity spread over larger areas than those with low spreading coefficient and high viscosity.

INTRODUCTION

Knowledge of oil-spill behaviour in brash ice is important for contingency planning at many locations. This subject, however, is poorly understood. There are no theories or data that can adequately determine, for example, spreading rates, oil thicknesses, oil advection and modes of oil-ice interaction (migration under ice, adhesion, etc.). A review of available literature of oil interaction with ice has been done by Dickins (1992). Some data of oil spreading in brash ice are available from experiments done at Clarkson University (Yapa and Chowdhury, 1990; Yapa and Belaskas, 1993; and Yapa and Weerasuriya, 1993). A field test was conducted by Ross and Dickins (1987) which consisted of two spills in brash ice. They observed that spreading rates and maximum slick areas were much less than the corresponding values for open water. A test series was also conducted by Sayed and Løset (1993) to measure spreading rates of North Sea crude oils in brash ice, in the absence of water current. A few studies have addressed the influence of ice on oil weathering (e.g., Payne et al., 1991). However, the data regarding oil/ice weathering are limited. A linkage between oil weathering and oil-ice interaction has not been established (Dickins, 1992).

Formulas for oil spreading rates and the maximum extent of slicks in brash ice have been proposed by Yapa and Belaskas (1993), Yapa and Weerasuriya (1993), and Sayed and Løset (1993). However, considerable uncertainties remain because of the scarcity of data. Experiments have been conducted to evaluate the effect of the following factors on the behaviour of oil slicks in brash ice: the physical properties of oil, volumes of spilled oils, water current, and ice cover type (block size and salinity). This paper aims at providing an experimental basis for the development of analytical models. Three Canadian crude oils from frontier regions — Amauligak, Norman Wells and Hibernia— were tested. The measurements determined the evolution of slick dimensions. Measurements were also conducted to determine the physical properties as well as spreading coefficients for both original and weathered oil samples.

*ISOPE Member.

Received January 12, 1994: revised manuscript received by the editors January 6, 1995. The original version (prior to the final revised manuscript) was presented at the Fourth International Offshore and Polar Engineering Conference (ISOPE-94), Osaka, Japan, April 10-15, 1994.

KEY WORDS: Oil spills, oil-ice interaction, oil spreading, brash ice, oil's physical properties, oil weathering.

OIL PROPERTIES

A set of experiments was performed in order to measure some of the physical properties of the three types of oil used in the spreading tests. Measurements of oil properties included surface and interfacial tensions, as well as viscosities. Also, since exposure of the oil slicks to air and water was expected to affect oil properties, measurements were done using both original and weathered oil samples.

Weathering

In the spreading tests, oil always flowed over the wet surface of slush and ice. In order to obtain weathered samples for characterization, oil layers were placed on a water surface. Tap water and saline water (prepared by dissolving 3% sea salt) were used. The oil samples were placed on the water in trays and kept in a cold room. Weathering would occur in this case due to evaporation from the oil sample's surface which is exposed to air. It was not clear if the water beneath the oil would play any role. This arrangement, however, was used because it simulates the conditions of oil slicks in the spreading tests. Oil thickness was approximately 10 mm. The surface area of the oil which was exposed to the air was 0.0504 m2 in most tests. In two tests (Norman Wells and Amauligak crudes over saline water), a surface area of 0.042 m2 was used. Specific gravities were not measured, but values given by Whiticar et al. (1992) are : 0.9014 for Amauligak crude, 0.8773 to 0.843 for Hibernia crude, and 0.84 to 0.8581 for Norman Wells crude.

The original weights of the oil samples were between 0.32 kg and 0.43 kg. Weight losses were monitored for 3 h, which is close to the duration of the spreading tests. A few weathering tests were also carried out for 100-h durations. The resulting percentage weight losses are given in Table 1.