International Journal of Offshore and Polar Engineering
Vol. 3, No. 4, December 1993 (ISSN 1053-5381)

Laboratory Experiments of Oil Spreading in Brash Ice

Mohamed Sayed*
National Research Council, Ottawa, Ontario, Canada

Sveinung Løset
SINTEF Norwegian Hydrotechnical Laboratory, Trondheim, Norway

ABSTRACT

Experiments were conducted in an ice basin to examine the behaviour and spreading rates of oil in brash ice. Sea water was used to grow ice sheets which were broken to produce the required ice cover. Two types of North Sea crude oils (Gullfaks and Oseberg) as well as Bunker fuel were used. Oil samples were spilled on the broken ice/slush covers at an approximately constant flow rate. Analysis of the video records gives maximum spill dimensions, spreading rates, and ratio of the oil-covered area to the total area of the spill. The results show that oil always flowed over the brash ice, and that surface tension plays a more significant role than viscosity in decreasing oil spreading. Measured slick dimensions were used to develop empirical expressions for the balance of gravity, surface tension and viscous forces.

INTRODUCTION

Broken ice fields in areas such as the marginal ice zone of the Barents Sea consist of distinct ice floes that can be from a few metres to several hundred metres in diameter (Wadhams, 1980; Korsnes, 1991). Brash ice often forms between the ice floes. The brash ice consists of frazil ice that grows during freeze-up as well as rudiments of fracturing and colliding floes. Oil spilled in such areas is expected to spread primarily in the brash ice and open water between the floes, since the freeboard of the floes is usually too large compared to oil thicknesses during most phases of a spill. Therefore, estimating oil spreading rates and maximum extent of a spill in brash ice is necessary for planning cleanup operations and assessing the environmental impact.

The behaviour of oil spills in brash ice, however, is poorly understood. The processes of oil interaction with brash ice are complex, and relevant data are very limited. The early laboratory tests of Metge and Telford (1979) consisted of releasing crude oils under broken ice in a small tank. The results were qualitative and showed that oil moves to the surface of the slush and that slush reduces spreading. A field test was also conducted by Ross and Dickens (1987), which included two spills in brash ice. They observed that spreading rates and maximum slick areas were much less than the values predicted by the formulas often used for open water spills. Recently, Belaskas and Yapa (1991) conducted laboratory experiments of oil spreading in broken ice. They monitored the spreading of a number of oils in a rectangular 1.2-m x 1.2-m tank. The ice covers consisted of fresh-water ice blocks as well as floating plastic blocks. In addition to the above references, the literature contains studies that do not directly address the present problem but deal with some aspects of oil interaction with ice. For example, oil spreading in leads was examined by Buist et al. (1987), and under ice by Yapa and Chowdhury (1991).

*ISOPE Member.
Received March 9, 1993: revised manuscript received by the editors September 1, 1993. The original version (prior to the final revised manuscript) was presented at the Third International Offshore and Polar Engineering Conference (ISOPE-93), Singapore, June 6-11, 1993.
KEY WORDS: Oil spills, oil-ice interaction, oil spreading, brash ice.

The present experiments examine spreading rates and maximum extent of oil spills in brash ice. Sea water and North Sea crudes as well as Bunker fuel were used in order to produce the correct values of surface tension and viscosity, which were expected to control spill behaviour. A relatively large basin was used, which made it possible to study the behaviour of oil slicks as they approach their maximum extent.

EXPERIMENTAL SETUP AND PROCEDURES

The experiments were conducted in an ice basin at SINTEF NHL in Trondheim. The basin is 7.7 m long, 4.7 m wide and 1.2 m deep. Sea water, approximately 24 m^3, was transported from a nearby fjord to the basin. Water depth in the basin was 0.65 m. Water salinity was 12 ppt. Ice was grown without seeding the water at temperatures of approximately −10°C. Room temperature was raised to 0°C when the required ice thickness was reached. Ice strength then gradually decreased because of the raised temperatures. The ice sheet was manually broken in order to prepare the required brash ice cover. In the case of small ice thicknesses (up to 20 mm), the ice was usually very weak and broke into slush with no distinct ice blocks. For thicker ice sheets (>25 mm), the brash ice cover consisted of distinct ice blocks with slush between them. All of the ice covers used in the experiments had no open water areas within the brash ice.

After preparing the ice cover, a grid of markers was placed a few centimetres above the ice surface for a scale. The grid consisted of strings attached to two steel bars at 0.5-m spacings. The steel bars were in turn mounted on the side walls of the basin. Small tape markers were then attached to the strings at 0.5-m spacings. Thus, a 0.5-m x 0.5-m grid was constructed. This type of grid was used for all oil spills of 4-litre volumes. Three types of oil were used in the experiments: two North Sea crudes (Gullfaks and Oseberg) and Bunker fuel IF-30. Properties of these oils are listed in Table 1. Oil samples were kept in an ice bath for several hours prior to testing.

Temperatures of the oil samples were measured immediately before spilling and were always between −2°C and +1°C. These