Mechanical oil spill recovery in ice; Finnish approach
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ABSTRACT

Finland, being one of the Baltic Sea States, is strongly dependent of marine transport. About 80 % of Finnish exports and imports are carried by maritime transport. Since one of the main routes of Russian oil export goes along the southern coastline of Finland (155 million metric ton year 2010) (SYKE 2010) and Finland is the only country in the world, where all harbors can freeze in the winter, it has been essential to develop adequate ability to respond oil spills also in ice.

The national oil spill response authority, Finnish Environment Institute (SYKE) has, for over 20 years worked with together with private companies and research institutes both in Finland and abroad to develop mechanical recovery methods to combat oil in icy conditions. Mechanical recovery is preferred due to recommendations of the Baltic Marine Environment Protection Commission (HELCOM), where chemical agents and in situ burning can be used only in special, restricted circumstances. (HELCOM recommendations)
The methods and techniques developed are based mainly on brush skimmer technology and separation of oil from ice in the water thus avoiding the energy needed to lift oily ice blocks from surface water for cleaning operations. Several devices have been developed and tested in laboratory scale and in real conditions. Most of the equipment is designed to be used in connection with specialized response vessels, but some can be used from a vessel of opportunity thus enlarging the available response vessel fleet. SYKE has used the above methods in cases of oil accidents and releases in the ice season both in Finnish waters and to helping neighboring Baltic States. Most operations have been cleaning operations of small releases. Fortunately there have not been any major oil spills in the Baltic Sea in ice since 1987.

This paper gives an overview of developed response methods, their working principles and their characteristics. The results of laboratory and field tests are also presented.

INTRODUCTION

Baltic Sea

The Baltic Sea situated in northern Europe is one of the biggest brackish water basins. Its water area is 400 000 km2 and it is divided between nine Baltic Sea States. The Sea is shallow the mean depth being only 53 meters. There is significant fresh water input from many big rivers and the Sea is nearly non-tidal. Unfortunately, the Baltic Sea is heavily polluted and due to the shallow and narrow Danish straits, which are the only connection to the Atlantic Ocean, it takes 25 to 30 years to change out the water from the whole basin.
Baltic Sea Co-operation

The co-operation within oil spill response among the Baltic States is regulated by several agreements. HELCOM, Helsinki Commission (Baltic Marine Environmental Protection Commission) is the main body, and all Baltic countries including the European Commission are contracting parties to the Commission. Decisions taken by the Helsinki Commission are regarded as recommendations to the governments concerned. These HELCOM Recommendations are to be incorporated into the national legislation of the member countries.

The main recommendations which deal with oil combating are as follows:

- **RECOMMENDATION 1/8**: Recommendation on Minimization of the Use of Dispersants, Sinking Agents and Absorbents in Oil Combating Operations in the Baltic Sea
- **RECOMMENDATION 11/13**: Development of national ability to respond to spillages of oil and other harmful substances.

Due to these HELCOM recommendations, development of oil response methods in Baltic Sea States has almost exclusively concentrated on the ability to mechanically collect oil from sea, even in winter conditions.

**Reasons for the need of Finnish oil spill response capacity also in winter**

The sea area of Finland covers a significant part of Baltic Sea, the northern side of the Gulf of Finland, the northern part of the Baltic Sea Proper and the eastern side of the Gulf of Bothnia. The total length of the Finnish coastline without taking into account islands, capes and bays, is about 1 200 km. Due to the thousands of islands and broken shoreline, the total length of shoreline which could be affected in case of oil spills is about 16 000 km. Also significant to
Finnish waters are the narrow fairways, which make navigation difficult especially in winter time and high sea conditions. About 80% of Finnish exports and imports are carried by marine transport and all Finnish harbors can freeze in winter.

The Gulf of Finland is also a major oil route since the Russian oil harbors in the eastern part of the Gulf are the biggest export harbors of Russian crude oil. The total amount of transported oil via the Gulf of Finland in 2010 was about 155 million tons and is expected to increase to 235 million tons by 2015 (SYKE 2010). Therefore, as safe as possible navigation in ice conditions and an adequate capability to combat oil in connection of marine accidents in winter time is a necessity for Finnish authorities.

In a normal winter, the northern part of the Gulf of Bothnia gets ice cover in November which lasts about 5 months. The Gulf of Finland is normally covered with ice for a 3 months period and in the eastern part of the Gulf ice conditions can be very difficult even in spring due to pack ice caused by prevalent westerly winds. The maximum solid ice thickness is normally from 0.4 to 1.0 m, but the main navigational difficulties are caused by pack ice, which can be several meters thick.

**RESPONSE POLICY ESPECIALLY IN ICE CONDITIONS**

Finland's northern geographical location places special requirements on spilled oil recovery and cleanup methods to improve operational efficiency at low temperatures and in icy conditions. In practice, the ability to recover high viscosity oil is a basic requirement. Cleanup
operations often take place in temperatures below the point at which oil becomes solid when conventional surface skimming equipment designed for the recovery of light oil is inadequate.

According to the Finnish response policy all development starts from the idea that prevention of environmental accidents at sea is successful when no harmful materials enters the sea. Success is regarded as halfway when such material is collected from the sea. If material remains at sea or if it is collected from a shore, then an operation can be considered nearly as a failure.

MECHANICAL METHODS AND SKIMMERS DEVELOPED AND USED IN FINLAND

Due to the low salinity of the Baltic Sea, the Baltic sea ice is rather solid and without significant brine channels. Therefore, spilled oil attaches rather slightly to sea ice blocks, and oil can mostly be removed (loosened) using just a small amount of energy which eases the cleaning process (Leppävuori, E. 1988) (Liukkonen, S. 1996). On the other hand, due to this low salinity, heavier oils can sometimes have a tendency to sink, which makes oil difficult to recover, especially if the oil is under ice.

There are two main principles for mechanical recovery:

- Lift the oily ice block from surface water and clean them with a specially developed cleaning device.
- To separate the oil from ice in water.
It is possible, and at least in principle, rather simple to lift oily ice blocks from the water and then loosen any oil with water (cold or warm) flushing, for example. These methods have been tested in many countries and also in Finland. The main drawbacks are the great amount of energy needed in lifting the often heavy ice blocks, the need for warming when cleaning occurs in open air and in freezing temperatures, and the need for robust specialized recovery units.

SYKE and those Finnish companies which are the manufactures of oil combating equipment, have conducted numerous laboratory and field test to develop new and improve existing response methods and equipments. The methods and techniques developed in Finland are based mainly on brush skimmer technology and the separation of oil from sea ice in water. Most of the equipment is designed to be used in connection with specialized response vessels, but some can be used also from a vessel of opportunity thus enlarging the usable response vessel fleet.

Many Nordic manufacturers of response equipments have developed special skimmers for response in ice conditions, such as self floating ice skimmers and hanging rope mop skimmers. These are usable, when the ice concentration is clearly less than 100 %, but can be rather difficult and ineffective in high ice concentration cases. In very light ice conditions also skimmers, which are designed for open water can be used effectively.

This presentation is concentrated on such techniques, which are primarily for use in heavy sea ice conditions. The most successful Finnish developments are explained below.
Lori Ice Cleaner

The Lori Ice Cleaner, designed and manufactured by LORI Company, a specialized skimmer bow, is designed to operate in broken ice at sea, lakes, rivers and ports. Its recovery process is carried out by a two-stages brushing and water pumping system. First, high pressure water jets loosen oil from ice blocks and the robust brush chains under the bow completes the cleaning of the ice blocks. Then loose oil is separated from water with conventional oil-collecting brush chains. The working principle of the Lori Ice Cleaner is shown in the Figure 1. After two prototypes and field testing operational equipment is now owned by the Finnish Environment Institute. It has following parameters:

- length 14.25 m
- breadth 6.00 m
- operational draft 0.85 m
- displacement 25 tons
- material aluminum

The maximum thickness of ice blocks, where the unit can be used, is about 0.5 meters

The Ice Cleaner is a removable unit and can be attached to the bow of a tugboat, ice breaker, etc.

After the finalization of the bow, it was tested with 1.2 tons of different types of oils, Russian crude oil and two different emulsions. At the conclusion of tests, it was evident, that the bow can collect oil among ice, but the capacity was low (perhaps mainly due to the small amount of oil allowed in the tests). Oil during the test quickly spread to a large area in the broken ice field, making thin oil layers on the ice blocks, where it was difficult to loosen. It was also noticed
that the bow collected many small ice pieces which soon filled the collecting sacks. (Liukkonen, S., Rytkönen, J. 1991)

The first prototype of Ice Cleaner was used in the last stages of the second Antoni Gramsci 1987 spill and the operational equipment is now often used, when there is a threat of oil spill in icy conditions.

*Figure 1. The working principle of the Lori Ice Cleaner*

**Oil Ice Separator - LOIS**

The LOIS-system, invented by SYKE and designed and manufactured by Lamor Corporation Ab, consists of removable oil in ice separator units, which can be installed on an oil recovery vessel with special fittings when needed. The idea of this specialized ice skimmer is to use a vibrating grid connected to sides of a response vessel to force the ice blocks submerged under the recovery unit to move upside down when the vessel is going forward, and possible rotate ice by moving the grid. By increasing the relative movement between the oil-covered ice blocks and water spilled oil is washed out of the ice blocks. Oil rises through the grates to water surface, which is inside the body of the LOIS. The oily water is then pumped through a conventional brush chain system in the companion response vessel, where the oil is then separated from the water. Any small pieces of ice, which enter the brush system, are transferred back to sea by conveyor. The principle of the LOIS unit is shown in figure 2.
The above system was first tested in laboratory and then in field at about ½-size prototype. (Hellevara, M. 1998), (Koskivaara, R., Rytkönen, J., Sassi, J. 2002), (Koskivaara, R., Rytkönen, J., Sassi, J. 2003), (Riska, K., Eronen, H. 2005). After successful tests these separators have been installed on four response vessels, three in Finland and one in Estonia. There is a strong belief in cases when there is lots of oil with ice, that these LOIS units are effective tools. In certain ice conditions, especially during spring time when ice is soft and fragile, that this equipment collects too many small ice pieces which strongly reduces the response capacity. SYKE together with the Lamor have plans to make needed improvements to all existing units.

The main characteristics of one LOIS unit (there are normally two units, on each side of a vessel) is:

- length 15.52 m
- breath 3.267 m
- weight 24 tones
- material steel

The construction is as heavy as the vessel itself, so it can be used in same ice circumstances as the ice classified vessel.

*Figure 2. Principle of the LOIS unit*

**Oil recovery bucket**

The working principle of the Oil Recovery Bucket is that the oil adheres to stiff, rotating brushes of the equipment. As the drum rotates, oil is swept from the brushes and enters the
bucket. A screw pump transfers the oil to recovery tanks. Three different sizes of the Oil Recovery Bucket exist. The smallest device has sweeping width of 60 cm, the medium size's sweeping width is 1.6 m and the largest has sweeping width of 3 m. The diameter of the brush wheel has been 800 mm. The two larger Oil Recovery Buckets can be connected to and operated by an hydraulic crane or hydraulic excavator. The largest Oil Recovery Bucket is developed to be operated by a large oil recovery vessel's crane. Figure 3 shows the oil recovery bucket during tank tests. This equipment is invented and designed by SYKE and manufactured by Lamor.

In tests, the recovery rates in broken ice conditions were about 50 %. In shore-line cleaning the recovery rate was better. Oil Recovery Bucket has been the standard equipment in Finland for cases of small spills in ice. For example it collected oil successfully among ice in March 2006 in Estonian waters after the sinking of 'Runner 4'.

The smallest Oil Recovery Bucket was originally developed to clean oil from soft soil areas - for example shore line cleaning. For this purpose, the device can be connected to a modified, remotely-controlled forest work vehicle.

*Figure 3. Oil Recovery Bucket collecting oil among ice*

**Ship mounted ice cleaning brush wheels**

During last four years SYKE worked actively to develop oil response units based on brush wheels, which can also be used in case of major oil releases. After field tests (Eronen, H. 2007) the first operational units are now under construction and are to be installed to a new
multipurpose vessel, that will begin operation this spring. The first set of these equipments is designed and also mainly manufactured by SYKE.

The brush unit consists of a large brush wheel with a diameter 1.8 m and length 4.0 m, which is connected to a special crane. The wheel has stiff (steel) brushes among normal collecting brushes and it rotates and cleans the oiled ice block. Normally, a response vessel will be moving backwards and the units are installed on the aft deck with container fastenings. There will be four brush units in the new multipurpose vessel, so the total sweeping width in ice will be about 16 m. The installation of four units to the new multipurpose vessel is shown in the figure 4.

*Figure 4. Principle of the installation of the units to the new multipurpose vessel*

**Field tests**

Different types of equipments and methods have been directly tested in the field in order to obtain an opinion of the usefulness in real situation. For example following methods were tested during HELCOM special oil in ice exercise:

- Use of compressed air to steer and remove oil below an ice field
- Use of propeller stream to direct oil to desired direction
- Use of ice boom to prevent oil drifting to an undesired direction
- Using a remotely operated vehicle (ROV) searching for oil under ice

The response methods mentioned above can be useful in certain small releases, where other options are no available, e.g. in rivers, lakes, etc.
CONCLUSIONS

In spite of severe attempts, laboratory and field tests to find adequately and efficient solutions to combat spilled oil in ice and cold conditions, progress has been slow. We are still waiting for techniques and equipments which can be successfully used in real big oil spill in ice. Finland now has the capacity to combat small spillages in ice conditions, but in case of a big spill, we normally must wait until the ice melts and then recover oil with the aid of open sea techniques. Normally, under operations in ice conditions you need several different response methods because the circumstances can vary often during long operations. Responders need techniques to collect oil in heavy ice conditions and in almost open sea conditions. The main shortcomings and recommendations, looking from the viewpoint of Finnish authorities, are therefore as follows:

- We have techniques and methods for small spills in ice, but much work is still needed to develop real operative response methods for large spills in ice
- To succeed, responders must have many alternative methods
- Locating spilled oil under snow covered ice is a problem
- If the spilled oil sinks, it will be very difficult to find and collect
- Reliable, operational oil/ice drift models do not exist

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