"State of the art review on Baltic Sea oil recovery practices and development of mechanical response in ice"

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ABSTRACT

Mechanical oil recovery concept is one of the main principles used by the Finnish oil combating authority. The concept is well known among the Baltic Sea countries, and currently there are a lot of commercially available applications based on the oil recovery bucket with stiff rotating brushes and screw pump to transfer oil to the recovery tanks. The basic system has proofed to be operational also in cold environment and in the presence in ice. During the years of development the basic system has been developed to suit for a variety of oils to be collected, tests have also been performed with viscous oils, and there exists test versions also capable for the Arctic conditions.
This paper first gives a brief introduction to the mechanical oil recovery systems available for the oil-in-ice operations. Then the development of the brush-type of recovery unit will be highlighted with selected case studies and test results. The latest system developments for large scale ice-going vessels will be demonstrated via prototype systems supported by meso-scale tests and full scale demonstrations. Finally, the adaptation of the brush system to the more generic ice-going ship types will be illustrated by draft engineering design drawings.

INTRODUCTION

The northern geographical location of Baltic Sea States 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, and the challenge. 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. (Lampela, K. & Rytkönen, J. 2012)

There is not a universal method of responding to oil releases in cold and icy conditions. Several skimmer types and techniques exist, but, because of variations in circumstances and climate conditions, ice coverage varies case-specifically and conditions may change even during response to a single incident, necessitating a toolbox of several response tools.

Most of the equipments are 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. Brush technology is the most common response method in ice condition in the Baltic Sea states: mechanically separating oil from water and from ice, provided that the oil is floating on the water's surface or is stuck to the ice.

When skimmers are used in ice and in cold conditions, the skimmer must be modified for these special circumstances. Heating of the skimmer and recovered oil with steam, hot water, etc. is often needed, and the pumps used must be able to pump heavy, viscous oil. The Nordic nations have studied how the skimmers and pumps used in these countries behave in cold conditions.

Typical mechanical recovery units for ice conditions are for example:

- Rope Mop skimmers,
- Arctic skimmer (LAMOR LtD)
- Polar Bear skimmer
- Polaris Ice skimmer
- Lori Ice Cleaner
- Oil Ice Separator, LOIS
- Oil recovery bucket.

More detailed description of these devices is given in (Lampela K.& Rytkönen, J. 2012).

Oil recovery bucket has been under R&D development activities in Finland already during more than two decades. The 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 sizes of oil recovery bucket exist. The smallest device has a sweeping width of 60 cm, the medium size's sweeping width is 1.6 m, and the largest has a sweeping width of 3 m. The diameter of the brush wheel has been 800 mm. The two largest oil recovery buckets can be connected to and operated by a hydraulic crane or hydraulic excavator, see Figures 1 and 2. The largest bucket has been developed to be operated by a large oil recovery vessel's crane. The oil recovery bucket has been the standard equipment in Finland for cases of small spills in ice, and it is also used in some other Baltic Sea States.

Figure 1. Previous tests of oil recovery bucket under LORI and LAMOR trade mark.

Figure 2. Oil recovery bucket connected to hydraulic excavator. Tests in 2009 in ice.(Photo: J. Pirttijärvi)

The co-operation within oil spill response among the Baltic States is regulated by several agreements. There are bilateral and trilateral agreements between different states on co-operation in oil and chemical spill response. One of the basic agreements is the Copenhagen Agreement between all Nordic States including Norway and Iceland. The main body in Baltic Sea area is the Helsinki Commission - Baltic Marine Environment Protection Commission - also known as HELCOM. The present Contracting Parties to HELCOM are Denmark, Estonia, European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. Decisions taken by the Helsinki Commission are regarded as recommendations to the governments concerned (Lampela K. & Rytkönen J. 2012).

HELCOM also arranges every year combating exercises where response vessels and teams from different Baltic States can practice cooperation in oil spill response. Last year the largest full-scale exercise ever in the Baltic Sea area, Balex Delta 2012, was arranged by Finland offshore Helsinki Capitol area under the coordination of HELCOM and EU's Civil Protection Unit DG ECHO (Rytkönen, J. & Haapasaari, H. 2013).

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. Furthermore, mechanical recovery systems may also be suitable for Arctic areas, thus Finnish environment Institute (SYKE) has recently concentrated to develop more robust and remote controlled systems for Arctic operations: the good performance and lessons learned in laboratory and field operations confirmed the SYKE staff to continue the R&D efforts with the oil recovery bucket development and the new goals were defined: larger units with the better performance in ice conditions, suitable also for Arctic conditions. The base line ideas for the development were agreed after the Runner-4 accident in the Gulf of Finland waters in 2006

MT Runner-4 accident

Runner-4 was the Dominican registered cargo ships carrying aluminum, travelling together with the Malta-registered cargo ship Svjatoi Apostol Andrey in the eastern Gulf of Finland, piloted by a Russian ice breaker. There were 102 ton of heavy fuel oil, 35 ton of light fuel oil, and 600 liters of lubricant oil on the Runner-4 onboard. At site 26°19.84′E and 59°52.92′N, the Runner 4 was collided by the Svjatoi Apostol Andrey, and sank into the Gulf of Finland on the night of 5 March.(Wang et al 2008).

Collision also initiated an oil spill, and oil spill was very difficult to detect in the first week due to severe ice conditions. Combating Operations started when the wind pushed the ice floes away and the spill was observed in open sea areas. Two efforts were made to collect and control the oil spill, one during 15-19 March and the other on 9 April.

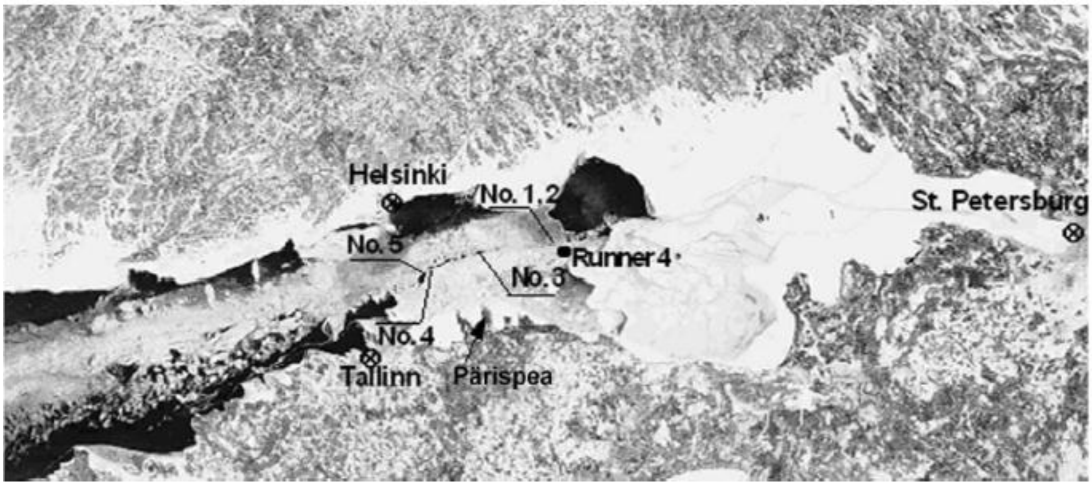

Figure 3. Oil spill observations on 15 March 2006 in the Gulf of Finland, with the ice conditions on 13 March. Image courtesy of MODIS Rapid Response Project at NASA/GSFC, modified by Keguang Wang. Patches No. 1 and No. 2 were very close to the wreckage site of the Runner 4. Patches No. 4 and No. 5 were in ship channels and No. 3 tells of much oil around in ship channels and in brash ice (Wang et al 2008).

Three Finnish vessels, the Seili, Halli, and Hylje participated in the combating of the oil spill in the first period of recovery in March. Finnish vessels were able to collect some 15 tons of oil after they were forced to stop to operations after wind pushed the oil to too shallow water for large recovery vessels. Later, after the oiled ice floes changed again their drifting direction two Finnish vessels, Merikarhu and Hylje, started the oil spill collection operation at the Runner 4 site after mid-day on 9 April. This second attempt was performed with the Estonian oil combating vessel Kati. Operations, however, were soon stopped due to the very this oil slicks and rather small coverage of the oiled area among ice. Figure 4 shows the Finnish oil combating vessel Halli during Runner-4 operation.

Figure 4. Finnish Oil Combating Vessel Halli in operation during Runner-4 case.

EVOLUTION OF NEW GENERATION BRUSH BUCKET

The past experiences gained from the Runner-4 case confirmed the need to develop larger and more robust mechanical recovery units for ice conditions, thus SYKE started to develop new concept to be attached onboard a large ice-going multipurpose vessel or an icebreaker. First pilot devices were manufactured in 2005 after several indoor and outdoor tests were performed. Following chapters will describe the evolution phases since 2006's out-door tests up to the recent full-scale recovery tests conducted in April 2013 in heavy ice conditions.

Earlier tests out of Kokkola Port in 2006

For the heavier ice conditions the existing oil recovery bucket concept was modified: the rotating brush system was modified by adding both the length of the drum and the diameter of the brush system. Additional improvements were also made to the oil scraping system by inbuilt heating panels, and to test both functions of the recovery bucket and the pumping device for viscous oils.

The first pilot version had the length of 2000 mm and the diameter of 1800 mm. This system was tested in the special built outdoor basin with oil and ice, see Figure 5 below. The tests performed gave certain confidence for the developers and highlighted also the required bristle materials of the brushes for different oils in ice conditions.

Figure 5. Prototype after oil-in-ice tests.

Later in April 2006 this system was tested in real ice conditions off the coastline without oil. Primary idea was to test the behavior and durability of long bristles in ice conditions.

Full scale recovery trials in Pietarsaari in 2007

The prototype version described above was modified for full-scale tests conducted off the port of Pietarsaari in March 29, 2007. The test site was an broken ice channel in the ice field with average thickness of 30 cm. Primary modifications compared to the earlier version were sticker bristles, heated recovery basin within the bucket system, and heated scraper unit to confirm continuous oil recovery even in colder air. During the tests, however, the air temperature was slightly over the zero degrees, thus the icing did not cause any problems for testing.

Altogether three tests were performed in ice channel using 1300 l of heavy fuel oil (POR 220) by reversing the recovery ship in the oiled test area and collecting oil using the prototype unit. First two trials produced 170 l and 80 l recovery rates, after certain modifications were made to change the propulsion and manoeuvring used of the vessel. Third test with 600 l oil poured to the ice channel resulted oil recovery rate of 250 l, i.e. over 40 % of the total amount. This was understood to represent a very good result due to the small amount of oil encountered during single test run(ILS 2007).

Finally the oil recovery bucket of oil recovery vessel HALLI was used to clean the remaining oil from the test site, and practically all test oil was lifted out of the sea.

The test showed the prototype system works in ice conditions. Primary lessons learned was concerning the proper way to manoeuvre the vessel in reversing mode: test showed the proper manoeuving way will boost recovery rate and prevent ice accumulation against the aft. Test also prodeuced a set of new ideas to improve the concept. Tests also confirmed that if the existing oil recovery bucket will be fixed with the long crane it would offer an excellent tool to clean the oiled area effectively.

Laboratory tests and new concept design

After the earlier full scale tests new ideas were tested both with indoor and outdoor tests. The length of the brush system was added to 4000 mm with the new diameter close to 2000 mm. Several bristle types were tested and a new prototype was made by steel frame. Figure 6 shows the new generation prototype ready for open water tests with two different bristle types.

This new design was selected to represent the "mother" tool for further improvements, and various sub-projects were run to achieve:

- lighter total weight,
- good recovery capacity in various ice conditions,
- robust against demanding environmental conditions,
- suitability within different oil types,
- remote operation and
- simultaneous usage of several units onboard a single recovery vessel.

Figure 6. Design picture (left) and manufactured prototype unit prior the open water tests. L = 4000mm and D= 2000 mm.

Both laboratory and full scale test were performed every year in 2009 – 2012. Indoor and outdoor laboratory tests were performed using oil and different bristle materials. Full-scale tests onboard recovery vessels were performed without oil, but in varying ice conditions. Tests confirmed certain performance criteria and gave valuable information on the operational modes required for different ice conditions.

Test conducted in laboratory scale in 2012 gave the average oil recovery rates on the average 30 – 100 m3/h depending on test ice conditions, oil type and bristle materials. Tests conducted in open water without ice showed smaller recovery rates due to the basic design features of bristles designed for ice conditions: if this unit will be used in open water conditions, the brush bristles need to be similar than those with the standard oil recovery buckets in operational use now.

The theoretical maximum oil recovery rate has not yet tested in open water or in ice conditions thus far. It seems quite likely, however, that in good operational situation the limiting factor for the system would be the pump capacity of the system – the brush module would be able to lift hundreds of tons of oil/hour.

Finally after detailed testing and design phases a set of composite material units were manufactured and assembled onboard the oil recovery vessel LOUHI. The new concept was first tested in port ice in early spring 2013 after full scale exercise was arranged in April 2013 in heavy ice conditions, Figure 7.

Figure 7. (Left) 4000 mm long prototype in out-door laboratory tests and (Right) oil recovery brush (L 4000 mm, D 2000 mm) in full scale offshore exercise.

Full scale trials in Kalajoki in 2013

The exercise Kalajoki 2013 "Oil in Ice" was arranged as a yearly international exercise of and in accordance with the Copenhagen agreement of the Nordic Countries. The operational oil spill response exercise was hosted and arranged primarily by Finland and took place in the Bay of Bothnia, that is the Northern part of the Gulf of Bothnia (outside the port of Rahja in Kalajoki) 10 April 2013.

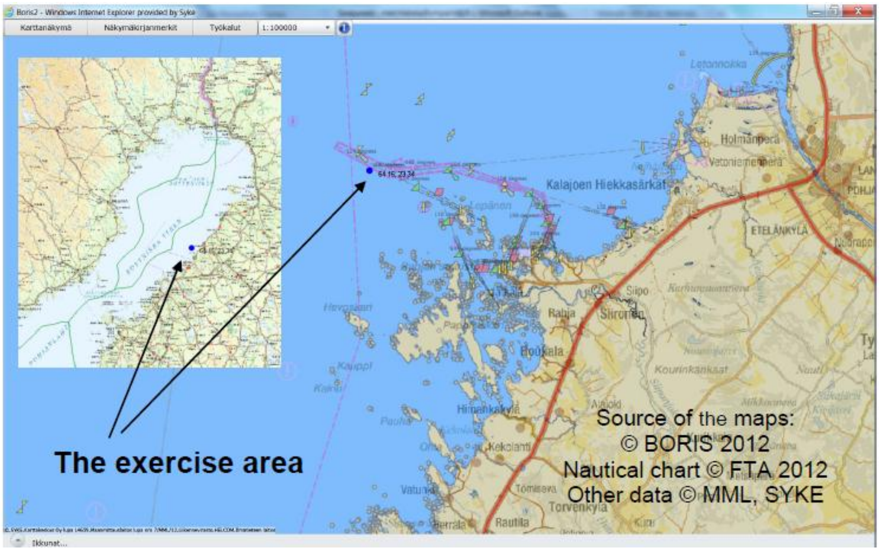

Figure 8. Exercise area in the Gulf of Bothnia sea area.
The host and responsible organization for the exercise was the Finnish Environment Institute SYKE that implemented the exercise in cooperation with the Swedish Coast Guard. The Finnish authorities the Finnish Navy and the ELY Centre South Ostrobothnia (one of the Finnish Centres for Economic Development,Transport and the Environment) as well as the state owned company Meritaito Ltd (SeaHow) assisted. The port of Rahja in Kalajoki offered berthing and other port facilities for the exercise.

The exercise scenario was based on the quite severe grounding of a double hull oil tanker named ‘FART TYG II’ with a cargo of about 5000 tons of heavy fuel oil had occurred 13 March 2013 in the place LAT 64° 20,02' LON 023° 26,52' (Ulkokalla, 18 km North-West from the port of Rahja in Kalajoki, Finland).

As a consequence of the grounding some 500 tons of heavy fuel oil had escaped. Fictively main amount of oil among ice was recovered by two Finnish vessels and one Swedish vessel during few days since 14 March after the incident. Later on April some amount of oil was found among broken ice in the fairway channel from accident place to the port of Rahja and request of assistance of one oil recovery vessel for ice conditions from Sweden was renewed.

Table 1. Participating units in Oil-in-ice exercise in Kalajoki, 10 April 2013.

Nation	**Name of the vessel**	**Type of the vessel**	**Oil Recovery system in ice**	**Oil cargo tank capacity (m^3)**
Finland	LOUHI	Oil recovery/Navy supply vessel	4 Rear Brush 1 Oil recovery bucket /LAMOR	1200
Finland	SEILI	Oil recovery/Fairway maintenance vessel	1 Rear Brush	200
Sweden	KBV 181 GOTLAND	Oil recovery/Coast Guard Patrol vessel	Type of endless rope/FOXTAIL	Portable tanks

LOUHI and SEILI used the new generation oil recovery brushes for ice conditions. SEILI had one brush and LOUHI four units mounted on the stern of the vessel. With the four brush units of LOUHI the total sweeping width in ice was close to 16 m. The exercise took several hours during the exercise the operators estimated the virtual recovery rate over 250 tons.

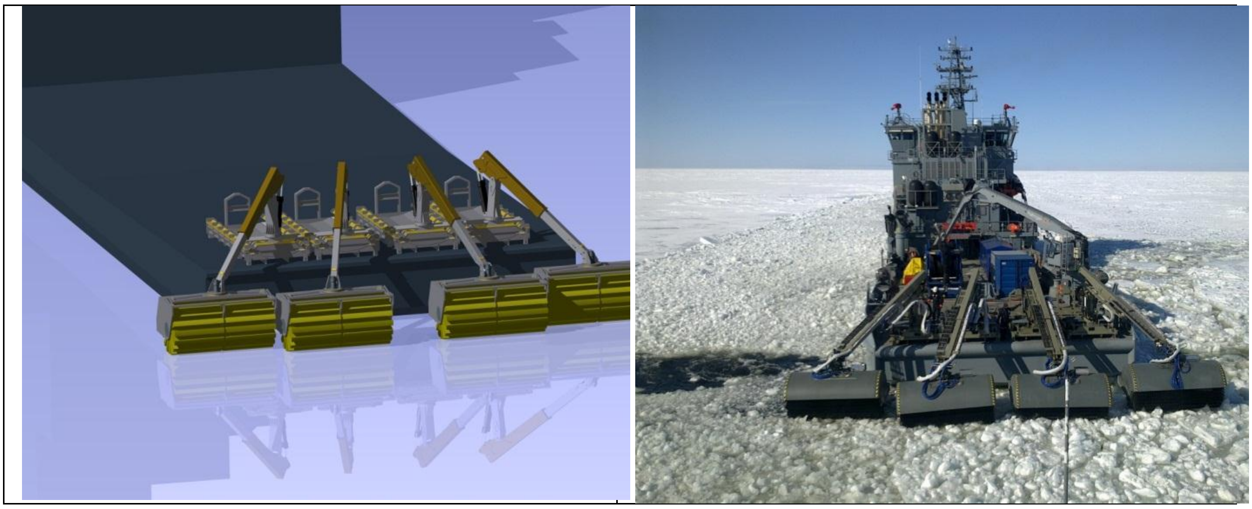

Figure 9. Design (left) and a set of new recovery units mounted onboard Louhi, the newest Finnish oil combating vessel. Each unit L:4000 mm, D: 2000 mm.

LESSONS LEARNED AND FUTURE PLANS

The idea of this paper was to give a brief highlight on the mechanical oil recovery concept development made by SYKE, the Finnish Environmental Institute. The idea of the large diameter recovery bucket for ice conditions is almost as old as the smaller version currently in use within many oil recovery vessels. Oil spills in ice and tests have proofed smaller units have been successful in ice conditions. In many cases the smaller type of oil recovery bucket has been almost the only tool to be used in ice conditions. The disadvantage has been the small size of it and the expected limitations in heavy ice conditions.

The new generation oil recovery bucket in ice is a new tool to be added to the operational tool box. The first performance tests have proved the system works in designed way. Expectations in ice conditions up to 50% ice coverage is high for a good performance. Certain modifications for bristles, drum and control unit will be made to meet even stronger ice conditions, up to 70 % coverage.

Lessons learned from tests and full-scale exercises have showed the importance of correct operational use of the unit with the vessel: vessel's manoeuvring performance during the operations will influence on the recovery rate a lot.

Attention will be paid to:

- development of remote controlled units, to enable autonomous usage of each units,
- testing of new sensors to detect oil among ice, thus to increase the recovery rate during operations,
- testing of robustness of the system in pack ice to confirm its usage in Arctic ice conditions, and confirm the requested types of brush/bristles,
- development of new "generic" system to be attached in different vessels
- testing the system with longer crane; attached it to the A-frame of supply vessels etc..

Figure 10. Oil recovery buckets in transport mode mounted on the aft deck of LOUHI.(photo: J. Rytkönen 2013).

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