Basic ice handling methods in Finnish ports

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Abstract

The economic well being of Finland is depending essentially on the maritime traffic. Finland’s location in the Northern Hemisphere, in the end of the Baltic Sea equals the situation of an island: the shortest and cheapest way to transport goods to the markets is usually the seaway. But due to the northern and sub-arctic location sea areas surrounding the coastline tend to freeze every year. Part of the ports are surrounded by ice six months of the year. The prerequisite for effective transport and the economics is to keep the maritime traffic running year round, thus there must be certain solutions developed for the winter-time. One of the most common examples of these ice control methods is the use of ice breakers, which assist the merchant ships through the ice fields. The use of the government owned icebreakers is usually limited for the heavy ice conditions of the open sea areas only, and ports should have their own harbour tug boats with other options to survive throughout the winter.

The Finnish Ministry of Transport and Telecommunications ordered a study from VTT to evaluate the typical problems caused by ice, and the common ice handling methods in Finnish ports. The development of maritime traffic has turned to more and more quicker transport modes with timetables and frequent traffic. All delays should be minimised. Time is money.

The work was carried out in supervision of the Finnish Port Association and both the seaports and inland ports were included in the study. This paper gives a review of the ice problems, summarising the typical methodologies to maintain the flow of traffic.
1 Introduction

It is a well-known fact in the Nordic countries, that the winter will cause a lot of special problems for harbour activities. Sea areas will be covered by ice, and a lot of ice could be formed into the shipping channels. The most common elements among the local environmental conditions are the layout of the harbour, traffic density together with the manoeuvring and ice breaking characteristics. Due to the manoeuvres of ships a thick layer of round-shaped ice blocks and slush will develop in the harbour basin which slow down the traffic and berthing. The thick ice layer increases the resistance of the ship, thus the requirements for the power of the propulsion is also higher. Moreover, snow falling down and accumulating into the wet and broken shipping channel will make the resistance even bigger. The required larger power means also instantaneous large propeller flows, which may cause rapid erosion problems for jetties.

Finnish ports could be divided into basic transportation and frequency harbours. The export of forest and metal industries in Finland has faced the new demands of effective transportation policy, and the whole transportation chain will be controlled and taken care of from the industrial sites up to the customer's warehouse. Parts of the industrial companies, as well as ports, are buying their services from stevedoring companies. The same often holds for the ice breaking services in ports: the ice breaking will be taken care of by a private company on a contract basis. The use of various kinds of ice handling methods, however, is usually taken care of by ports themselves. The general trend among port personnel has been the decrease of employees, but having more specialised tasks. Thus, there is only a limited amount of personnel available for ice handling. The ice handling tasks could normally be taken care of successfully, but in severe winters, there is a lack of devices, methods and manpower, and special services are temporarily needed.

The requirement for ice handling is larger for ports with frequent traffic. Ships having strict time tables could not be left laying long times off the berthing places while the ice blocks are removed away, or if the harbour ice breaker is reserved for other tasks. Modern logistical production tools have been adapted in ports; thus, the transportation chains must be faster and more reliable. The unit size of the transportation has been decreased with an increased shipment density. This also means an increased requirement for the optimum timing of the transportation [12].

Finland’s export and import activities are largely dependent on marine transportation. The total volume of sea transports in the foreign trade of Finland was 76.6 million tons in 1998. Thus, it is quite clear that the well soluble traffic without delays is an essential task for maritime traffic. The ice breaking fleet of Finland is an effective tool to serve the merchant fleet outside the harbour area. However, depending on the winter conditions, traffic density and local conditions, there exist certain delays. These delays are caused by severe ice formations, waiting for the icebreakers, etc. There are estimations, that these delays correspond in the normal winter time to approximately 6 - 12 hours.
waiting which causes extra costs for ship owners and finally increases the transportation costs.

In order to find out the current state of the art of ice handling in ports the Ministry of Transport and Telecommunications ordered a study from VTT [1][2][3]. The main aim was to evaluate the ice handling methods in Finnish sea ports, to report the successful methods as well as to report on less favourable efforts. Almost all Finnish ports were interviewed, including the inland ports, and the basic ice handling methods were reviewed and analysed. One important goal was also to estimate the delays for ship owners, extra costs for ship-owners and ports, and finally to find out certain recommendations to speed-up the winter traffic in ports. The study was co-ordinated by the Finnish Port Association and carried out during the winter 1999-2000.

Figure 1: The Finnish ports. The figures denote the quantity of goods (in millions of tons) of the foreign trade transported by sea in 1997 [13].

2 Ice conditions in Finnish ports

In Finland, the differences in air temperatures, both annual and areal, are significant. Figure 2 shows the level curves of the sum of the freezing degree-days in severe, average and mild winters. From the curves it can be seen that in
an average winter the sum in the northernmost part of the Baltic Sea is over double the sum on the south-western coast of Finland. In a severe winter the sum is about threefold on the northernmost and easternmost sea areas, on the southwestern coast of Finland tenfold, compared with the sum in a mild winter.

![Figure 2: The level curves of the sum of the freezing degree-days. a) In a severe winter according to the temperatures measured in the winters of 1929, 1940-42 and 1947 [5]. b) The average curves from the period of 1961-1980 and c) the minimum curves from the same period [7].](image)

The Baltic Sea is an almost closed and quite shallow sea area, with only the Strait of Denmark connecting it to the Atlantic Ocean. The average water depth of the Baltic Sea is 56 metres. Several rivers are discharging into the Baltic Sea decreasing the salinity of the water. The salinity of the water in the Baltic Sea is in the top layer 3-6 \( ^0/\text{o} \) and in the bottom 4-10 \( ^0/\text{o} \) whereas in the oceans the salinity is about 35 \( ^0/\text{o} \).

As a result of the above-mentioned seasonal facts, the Baltic Sea has ice cover each year, the extent and thickness as well as the duration of which are strongly dependent on the coldness of the winter.

In mild winters, only the northernmost part of the Gulf of Bothnia and the easternmost part of the Gulf of Finland are covered with ice, whereas during the most severe winters, the whole of the Baltic has ice cover (Figure 3). According to the statistics, the maximum thickness of the fast ice outside Ajos, the Port of Kemi in the northernmost part of Gulf of Bothnia, is about 110 cm, while the minimum thickness is about 60 cm. The corresponding values outside the Port of Kotka on the eastern Gulf of Finland being about 90 cm and 10 cm respectively (Figure 4). The ice thickness decreases when going from Ajos towards the southern part of the Gulf of Bothnia and from Kotka towards the western part of
Gulf of Finland, for example, outside Helsinki, the capital city of Finland, the maximum ice thickness is about 80 cm and the minimum about 15 cm.

The duration of the ice season is at its longest, 190 days, in Tornio, the northernmost port of Finland (Figure 5). In Hanko, the southernmost port of Finland, the ice season is shortest, 70 days and in Hamina, the easternmost port of Finland, 130 days.

The ports can be classified based on their layout in three types:

- ports with a closed basin,
- ports locating between islands where a water exchange is possible and
- ports locating in river mouths.

In closed ports with a restricted opening leading to the port, the water exchange is minimal; thus, the thermodynamic conditions are not favourable. Ice is developing rapidly, and these ports have severe problems especially in the turning basin, the bends of the shipping channel and in the corners of the quays.

Ports located between islands usually have lighter ice conditions due to the sufficient water exchange and flow patterns. The ice formation is slower, and there exist ports where ice is drifting away due to the sea currents.

The ports near the river mouths can have positive or negative effects. There are rivers constructed for the hydropower production, and the warm water will make the ice thinner. Some rivers, such as the Kymijoki River, have many open rapids with super-cooled water, and the river flow can have a totally adverse effect in the port area (Kotka).

The volume of traffic, too, has an influence on the thickness of the brash ice in the port area. The more often the ice cover is broken by ships during the frost season the bigger is the heat loss from water to air and the faster is the ice formation. There are reported observations available, that in severe winters some part of the basin can be filled with rubble ice from the surface to the bottom. If the whole basin is filled with ice, there is only a limited possibility to make space for an entering ship.

![Figure 3: The extent of the ice cover in a mild, average and cold winter.](image-url)
Figure 4: The minimum, average and maximum thickness of fast ice during winter at three sites on the Finnish coast: a) outside Ajos, the Port of Kemi, b) outside Helsinki and c) outside Kotka. The curves are based on the statistics from the winters of 1937-1985 [4].

3 Ice control methods in Finnish ports

The ice handling methods were found to vary in every port. There is a lot of factors affecting on the proper selection of the methods such as the environmental conditions, traffic density, size of the vessels, the availability of
thermal energy (waste water out-takes), economic and the devices. The experiences vary in each of the ports and the best available technique for a certain port could not be found. All the ice-handling methods were found out to be laborious.

3.1 Conventional methods

The basic ice handling method in all of the Finnish ports was the use of harbour ice breaker to break the ice near the jetties, berthing places and in the turning places of the harbour areas. These tasks are usually performed just before the ship enters the port or just before the take off. The ice breaking is usually performed on the contract basis between the port authority and the private tug company. This service is free of charge for the shipping company, but if some additional towing or assisting is needed the ‘ship pays’. Usually the ship is approaching the quay diagonally with the quayside. The propeller flow of the harbour icebreaker can be used in removing ice blocks from the space between the ship and the quayside (Figure 6). The average dimensions of the icebreakers used in Finnish seaports are: length 28 meters, breadth 8 meters, draught 4 meters and shaft power about 1500 kW.

![Figure 6: Different ways to clear the quayside from ice blocks. The arrow is showing the direction of the propeller flow [6].](image)

3.2 The use of warm waste water

The use of warm industrial waste water was found to be a good solution for the ice handling in ports. Not only the relative temperature of the wastewater, but the salinity-differences with the turbulence patterns will affect on the ice conditions. The salinity of the Baltic Sea is only one tenth of the Ocean salinity. For the salinity of 0,5 % the maximum water density, 1004,054 kg/m³, is reached with the ambient temperature of +3,0°C. When the sea water starts to freeze the density equals the density for the sea water having the temperature about +7°C,
thus waste waters having the temperature between 0...+7°C are sinking below the freezing surface layer, and will not lighten the surface ice conditions.

In order to optimise the use of warm wastewater leading to the harbour basin the outlet of the pipe is often not directed in an optimum way. The use of diffusers will spread the water better for those locations where the warm water will get best results. There are theoretical evaluations, that a 10 MW thermal power will keep approximately 10 hectares area free of ice [3][11]. In reality, however, the warm wastewater will be distributed more uniformly to the whole water column, thus the "optimum" icefree zone will easily be reduced to 10...20 % of the "theoretical maximum."

The use of warm wastewater can be 'boosted' with surface flow generators, pneumatic bubblers and diffusers. There are many ports in Finland where a certain amount of wastewater is led to the harbour area, but with rather insignificant benefits. Modern industrial units are using closed wastewater circuits, thus minimising the environmental impacts, thermal energy is taking away from the wastewater, and thus there is only insignificant thermal energy available for ice handling. There are only limited amounts of data available on the temperature and ice conditions in the port areas, thus more detailed evaluation on the usefulness of the thermal energy is difficult to carry out. However, there are ports, such as Raahe, which can be kept open throughout the winter due to the warm wastewaters of the local steel factories.

3.3 Surface flow generators

The surface flow generators have been used satisfactorily in Finnish inland ports, but in seaports their use is rather limited. In most cases the surface flow generators are sensitive and will often sink down due to the ship collisions or pressure of moving ice. The use of these devices, however, could be optimized when combined with thermal methods. In closed and restricted ports the use of surface current generators could be designed in a way not to lead to the super-cooling effect of the basin. Thus better to thinner the ice level, than to totally try to keep the area open. The thin ice layer could be easily broken by the harbour ice breaker, and it also offers an insulation layer against the freezing. The size of the surface flow generators used in Finnish ports was 10...30 kW generating an icefree area of 25...1000 m² if no warm waste water was available [3].

3.4 Pneumatic air bubblers

Pneumatic air is also found to work well in certain ports, while there are also rather insignificant experiences. The most advanced way is to keep the harbour wall free of ice, thus the ship can easily move near the jetty. Some of the unsatisfactory experiences were due to the sensitivity of the underwater airlines, freezing of their nozzles and the rather laborious service operations with a high power consumption. The pneumatic air bubbling systems are in use for example
in the Port of Hamina, and will be constructed in the new Mussalo terminal in the Port of Kotka.

4 Extra costs due to winter

The extra costs due to the annual ice handling has been estimated to vary between 0.2...0.3 million USD for a single sea port in an average winter. In some ports the costs of ice handling are only a few ten thousands USD's due to the use of thermal energy. However, the total costs of the ice handling for the port owner is in the order of 4 - 8 million USD in an average and in a severe winter. The costs for the ship owners are more difficult to be estimated. The extra costs for the ship owners are mainly caused by various delays in ports, the use of harbour ice breakers, larger fuel consumption, damages of the ship, manual removal of ice from the decks, extra fees for the stevedoring companies, fairway fees etc. The questionnaire performed among the ship owners showed, that the average additional costs for a single shipment are in the order of 1 200 - 1 300 USD. The average extra waiting due to the ice is normally ½ to one hour, which in the severe winter can be essentially longer. It should be mentioned here, that in the open sea area the waiting periods (for ice breaking) typically vary between 6 to 12 hours, which cause extra costs for the shipping company. These costs have estimated to be 7 000 - 10 000 USD / one call. On the basis of these additional costs it has been estimated, that the average winter causes approximately 6 million USD extra costs for the shipping companies, and 12 million USD in severe winter. Thus summing the additional costs of the port owners and shipping companies, it can be estimated, that the additional costs due to the winter are in the order of 10 million USD and 20 million USD in average and severe winters, respectively.

5 Conclusions

Due to the northern and sub-arctic location sea areas surrounding the Finnish coastline tend to freeze every year. The prerequisite for effective transport and the economics is to keep the maritime traffic running year round, thus there must be certain solutions in the ports developed for the winter-time. One of the most common examples of these ice control methods is the use of harbour ice breakers, so all the Finnish seaports have at least one such a vessel available having the length of about 30 meters and powering of about 1500 kW.

From the other ice handling methods, the use of warm industrial wastewater was found to be the most effective method if the use of it is carefully designed. With a thermal power of about 10 MW, an area of 1 hectare can be kept ice-free. The other methods are the use of surface flow generators and pneumatic air bubblers.

The winter affects extra costs for the ship-owners and ports. When summing the additional costs of the port owners and shipping companies, it can be estimated, that the additional costs due to the winter are in the order of 10 million USD and 20 million USD in average and severe winters, respectively.
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