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A Case Study of the Wind Impact on Ship Ice-sticking

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ABSTRACT: In the paper, the impact of wind on a ferry sailing in ice field is described and analysed. Two ice-sticking events on the Gulf of Finland are taken for the case study. The wind, especially its direction, is stated as an important factor to entrap a vessel in the ice. The wind blowing across the vessel longitude axis caused both the ships to stick.

1 INTRODUCTION

The objective of the present paper is to determine the wind impact to a vessel interacting with sea ice. Here we consider two ship ice-sticking events on which a sufficient description is available.

The Gulf of Finland has a special combination of intense winter shipping and extensive seasonal ice cover. The Gulf of Finland is ice-covered in normal and severe winters [1]. Strong winds blow offten on the Gulf of Finland. The wind generates ice pressure and also it impacts directly on a vessel. A vessel hull appears to the wind as a sailing. Maximum day-average wind speed stayed below 15 m/s in the winter seasons 1971-2005 [2]. In severe winters strong winds blow from N and NE. In mild winters SW winds dominate in the Gulf of Finland [3].

The ice-sticking of ships causes a tremendous economic loss. The ship loses its speed or even sticks in ice. In the moderate winter 2009/10 about 250 entrapment events are reported. According to the data, the ships spent in ice-catch totally 67 days [4]. The need for detours to avoid hard-ice areas raises the trip duration. Vessel hull may get damage when sailing in ice. 49 ship hull damages took place in the Gulf of Finland in the severe winter 2002/03 [5].

The ice pressure is rarely measured on the GoF. Tukker and Perovich [6] got ice stress up to 350 kPa in pack ice in the Arctic area. This characteristic depends on the lot of factors: the ice thickness and concentration, ice type and its shape, wind speed and direction. The ice pressure varies greatly along area and time.

2 CASE DESCRIPTIONS

We observe the two ice-sticking events on which a sufficient description (the location, time and the event record in the log journal) is available.

2.1 *Case 1: Nordlandia, 29th January 2010*

The ferry Nordlandia, 153 m long, ca 40 m high with 9 decks. Usually it gets from Helsinki to Tallinn (Fig. 1 and 2) in 3.5 hours. But on the January 29th 2010 the voyage took 10 hours as the vessel got stuck in the ice [7]. The ice condition during the event: the area 100% ice-covered, ice thickness 0.05 - 0.25 m, ridge fraction 10%.

Figure 1. Wind force acting on the ferry Nordlandia. The ship is (A = 100%) surrounded by ice (photo: vastavalo.fi).

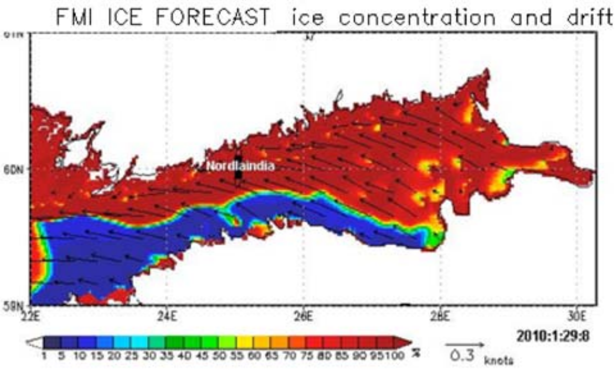

Figure 2. The FMI ice model product for the ice concentration and drift. The ice drifted to the NWW. The location of Nordlandia is shown by the black item with white inscription. The red colour indicates the full (100%) ice cover in the area.

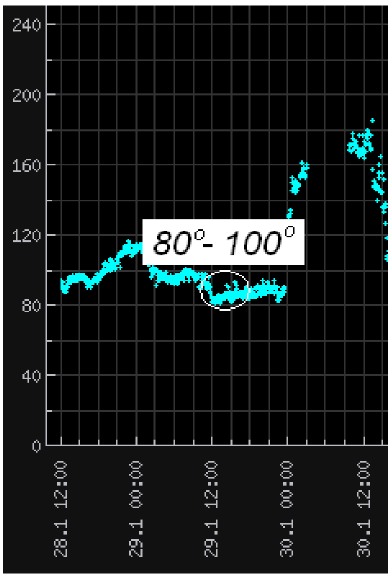

Figure 3. The wind directions on the 29th Jan. 2010. The wind changed its direction on the dawn 30 th Jan. thus enabling the ferry to move.

At this entrapment event, the wind blew from the East (Fig. 3) all the day with the speed 8 to 18 m/s (Fig. 4). Thus the wind blew across the ferry movement direction.

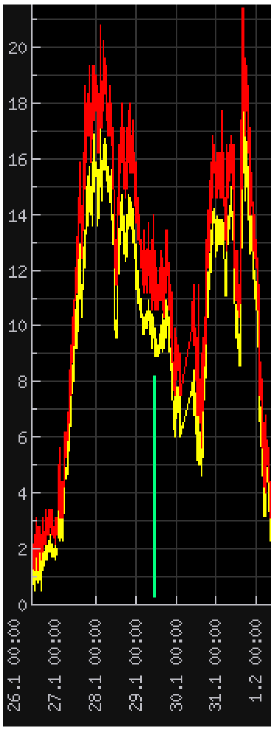

Figure 4. The wind speed durig the Nordlandia event.

2.2 *Case 2: Saxen, 7/8th january 2003*

The tanker Saxen, 99.6 m long, was sailing from Tallinn to Porvoo (Fig. 5). It was caught in ice for 5 hours. Its hull got damage [8]. The ice condition during the event: the area 100% ice-covered, ice thickness 0.3-0.4 m.

During the entrapment event, the wind blew from NNW and W with speed 5-9 m/s. Thus the wind blew almost across the longitudinal axis of the ship. From the ship log journal we know that some time later the wind changed in direction and then the ship got free from the ice stick.

Figure 5. The location where the Saxen got stuck. The black arrows show the winds directions and the blue arrow depicts the vessel movement direction.

3 THE WIND IMPACT ANALYSIS ON THE SHIP

Here we reconstruct the Nordlandia ice-sticking event with respect of the wind blowing on the ship. Also this event is compared here to the Saxen case because the circumstances are similar enough at the both events. The ice covered 100% the ship vicinity in both the cases. At both the events the wind blew almost across (assumed orthogonally for the reconstruction) the ship longitudinal axis.

The wind-generated forces impact on the ship got in touch with the ice is considered. The wind pushes the ship against the ice (Fig. 6) whereas underpressure takes place on the other side. We do not take the impact of the ice in front of the ship into account here. Here we consider neither the ice pressure nor the impact of under-ice currents.

The ship area with respect to the wind is ca 5000 m² whereas we do not take the ship geometric shape into account. A force acts to the ship by the wind blowing orthogonally to the ship longitudinal axis. The wind force is described by the formula:

$$F_{wind\ to\ ship} = \rho_a U_{ship}^2 C_d A / 2 \quad (1)$$

where ρ_a is air density, U is wind speed, C_d is drag coefficient (3.5 for the open air on sea).

In the Nordlandia case the wind blowing with speed 8 m/s pushes the ship with force 600 kN. Then the ship impacts on the side ice with the pressure 15 kPa (Fig AS). We estimate how much engine power is needed to keep the ferry speed 20 knots in spite of the friction force provided by ice.

The necessary power is characterised by the formula $W = \alpha F_{wind\ to\ ship} v$ where F is the side wind force, v is the ferry speed and α is the friction coefficient between steel and ice. Thus W = 180 kW is calculated by the formula. Thus, to overcome the side ice friction force, the ferry engine has to develop W = 180 kW additionally to the power needed to sail in free water. For a comparison, typical 27 m long ferry-boat has the engine power 220 kw.

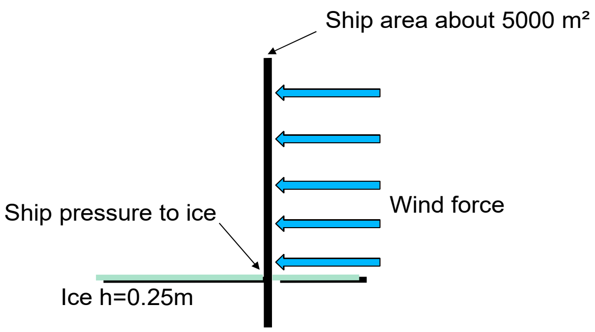

Figure 6. The forces acting on the vessel.

4 CONCLUSION AND DISCUSSION

Sticking the ship in the ice is a result of a few natural factors acting together. In this paper we focus on wind acting to vessel sailing in ice, on the example of two entrapment events in the Gulf of Finland. In the both studied cases the natural factors sufficed to stick the vessels in the ice.

The wind-generated pressure resists the ship movement as the wind is blowing across the vessel longitudinal axis. At both the entrapment events the wind blew so. Sticking is probable when the cross-wind is accompanied by ice pressure and under-ice currents.

We evaluated the wind impact to the Nordlandia. In this case the wind provided pressure 15 kPa. This pressure caused an additional friction between the hull and the ice. To overcome the side ice friction force, the ferry engine has to develop power additional to the power needed to sail in free water. Typical 27 m long ferry-boat commonly has the engine power 220 kW .

The present study belongs to the research area aiming to determine the necessary and sufficient conditions of sticking a vessel in the ice. Knowing these conditions enables to avoid navigating ships from being caught in ice.

ACKNOWLEDGMENT

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REFERENCES

[1] J. Rjazin and O. Pärn, "Determining the ice seasons severity during 1982-2015 using the ice extents sum as a new characteristic," *Geophysical Research Abstracts,* vol. 18, EGU2016-3020, EGU2016-3020, 2016 EGU General Assembly 2016.

[2] O. Pärn, "Sea Ice Deformation Events in the Gulf of Finland and Their Impact on Shipping,". Marine Systems Institute at Tallinn University of Technologyrsity, TTÜ Press, 2011.

[3] O. Pärn and J. Haapala, "Ice deformation in the Gulf of Finland in the severe winter of 2002/2003," vol. 62, Estonian Journal of Earth Sciences, 2013, pp. 15-25.

[4] Baltic Icebreaking Management. (2010). *Baltic Sea Icebreaking Report 2009-2010* [Online]. Available: http://www.ieee.org/documents/ieeecitationref.pdf

[5] S. Hänninen, "Incidents and Accidents in Winter Navigation in the Baltic Sea," Finnish Maritime Administration, Helsinki, Finland, Rep. 54, 2003.

[6] W. B. Tucker, III, D.K. Perovich, M. A. Hopkins and W. D. Hibler, III. "On the relationship between local stresses and strains in Arctic pack ice," Ann. Glac., vol. 15, 1991.

[7] H. Villak. (2011, Feb. 12). Nordlandia jäi Soome vetes jäävangi (Nordlandia got stuck in ice in Finnish waters) [Online]. Available: http://reis.postimees.ee/224007/nordlandia-jai-soome-vetes-jaavangi

[8] Veeteede Amet (Estonian Maritime Administration). (2003). Laevaõnnetused 2003 (Ship damages 2003) [Online]. Available: http://www.vta.ee/index.php?id=727&highlight=Saxen