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Evaluation of the limit ice thickness for the hull of various Finnish-Swedish ice class vessels navigating in the Russian Arctic

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ABSTRACT

Selection of suitable ice class for ships operation is an important but not simple task. The increased exploitation of the Polar waters, both seasonal periods and geographical areas, as well as the introduction of new international design standards such as Polar Code, reduces the relevancy of using existing experience as basis for the selection, and new methods and knowledge have to be developed. This paper will analyse what can be the limiting ice thickness for ships navigating in the Russian Arctic and designed according to the Finnish-Swedish ice class rules. The permanent deformations of ice-strengthened shell structures for various ice classes is determined using MT Uikku as the typical size of a vessel navigating in ice. The ice load in various conditions is determined using the ARCDEV data from the winter 1998 as the basic database. By comparing the measured load in various ice conditions with the serviceability limit state of the structures, the limiting ice thickness for various ice classes is determined. The database for maximum loads includes 3-weeks ice load measurements during April 1998 on the Kara Sea mainly by icebreaker assistance. Gumbel 1 distribution is fitted on the measured 20 min maximum values and the data is divided into various classes using ship speed, ice thickness and ice concentration as the main parameters. Results encouragingly show that present designs are safer than assumed in the Polar Code suggesting that assisted operation in Arctic conditions is feasible in rougher conditions than indicated in the Polar Code.

1. Introduction

IMO has adopted the International Code for Ships Operating in Polar Waters (Polar Code) and related amendments to make it mandatory under both the International Convention for the Safety of Life at Sea (SOLAS) and the International Convention for the Prevention of Pollution from Ships (MARPOL). One of the aspects of Polar Code addresses the operational limitations of ships of different categories (A, B and C) according to ice conditions. The approach for evaluating the ice conditions and setting limitations for ships assigned an ice class is called POLARIS – Polar Operational Limit Assessment Risk Indexing System, details of which are given in IMO amendment document (MSC 94, 2014). Therein the ice classes are associated with the limiting thickness by combining the experience from three existing approaches used in ice-covered waters: the Canadian Arctic, Baltic (Finnish/Swedish), and Russian Northern Sea Route systems. The assessment given in MSC 94 (2014) categorizes ships designed according to Finnish Swedish Ice Class Rules (FSICR) for different operational conditions according to Table 1; assisted operation corresponds to scenario where icebreaker assistance is provided or the ice concentration is less than 100%.

Similarly, the objective of this work is to provide a limiting ice thickness for assisted operation, but through systematic evaluation of structural response to prescribed loads, which are later compared with actual measured loads. This will be achieved using numerical finite element simulations whereby permanent deformations of structures are determined along with the corresponding load level. Analysis are performed for three ice classes according to FSICR notation: IA Super, IA and IB. The permanent deformations comply with DNV serviceability limit state of $s/12$ used by surveyors, Lepik et al. (2010). For the selected structure, long term measured data in different ice thicknesses is available meaning that we can associate the ice thickness with resulting

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Table 1
Safe operation of ships in first-year winter ice regime for the Finnish-Swedish ice classes, MSC 94 (2014).

	Ice class	WMO description of the ice regime	Thickness of ice floes. At,
Assisted	IA Super	Medium first-year ice	h_i, up to about 100 cm
	IA	Medium first-year ice	h_i, up to about 80 cm
	IB	Thin first-year ice	h_i, up to about 60 cm
	IC	Thin first-year ice	h_i, up to about 40 cm

permanent deformation. The latter association lends itself to explicit definition of limiting ice thickness for safe operation.

2. Case study

As a case study, we selected M/T Uikku. Ship is classified according to DNV as class +1 A Tanker for Oil corresponding to FSICR as ice class IA Super. Ship was built 1976 in Werft Nobiskrug Gmbh. Ship has a diesel electric propulsion system with four diesel generators. It is important to note that Uikku, in contrast to normal tanker, has a bow shape especially designed for operation in ice. The ship hull and propulsion system was instrumented on 1997 for the EU funded ARCDEV project and the instrumentation was extensive, detail description of the instrumentation can be found in Kotisalo and Kujala (1999) (see Fig. 1).

2.1. Description of full scale measurements

The ice load is measured on-board tanker M/T Uikku during one voyage to Ob-estuary in the Russian Arctic waters, from April to May in 1998. The voyage started from the port of Murmansk on 26th of April 1998, where the weather and ice conditions were harsh for the representative area. During the voyage M/T Uikku was always either in convoy or lead by an icebreaker. The route of the convoy is presented in Fig. 2 (Kotisalo and Kujala, 1999). 20-minute maximum loads on-board M/T Uikku were measured in the bow, bow-shoulder and stern combined with visual observations. But since visual observations were not conveniently measured with the

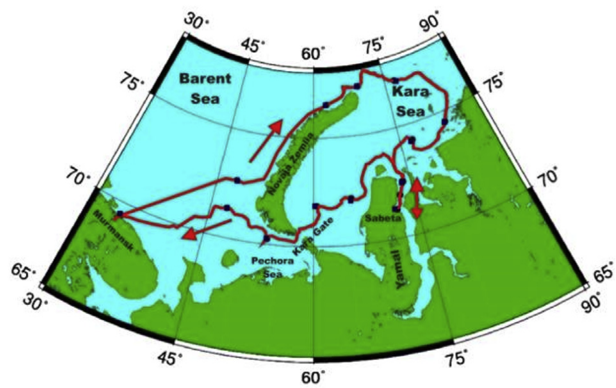

Fig. 2. Route of the convoy during ARCDEV voyage.

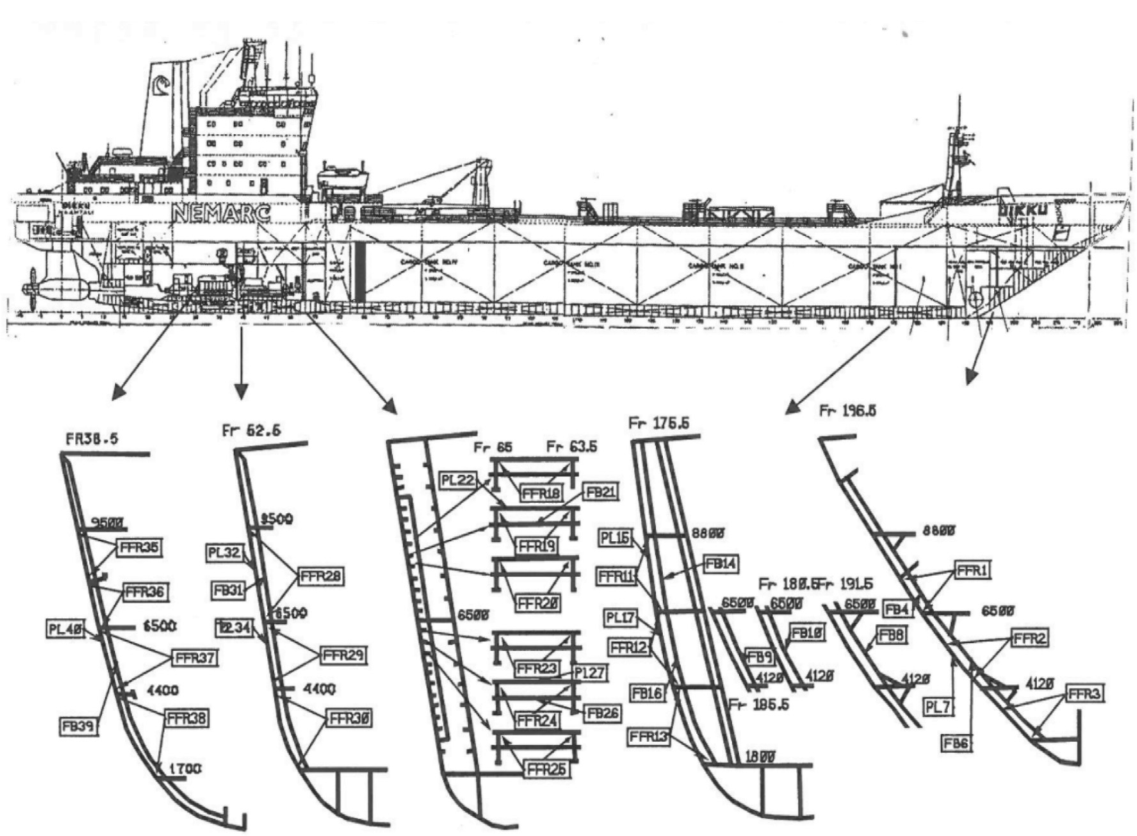

Fig. 1. Picture of Uikku showing the instrumented areas (Kotisalo and Kujala, 1999).

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