ROYAL INSTITUTE OF TECHNOLOGY

Barge Performance Under Ice Condition

Evaluation of inland barges for navigation in ice conditions

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Together with the EMMA partner Avatar Logistics, the Royal Institute of Technology, KTH, has performed a feasibility study for inland barges operating on inland waterways, IWW. The objective of the project is to investigate how an inland motor barge based on European standards can be modified for navigation in Swedish Lake Mälaren under winter conditions including ice. The study of ice navigation for inland barges is an important step to establish inland navigation in Sweden and the BSR Region.

Figure 1. Bulk Barge Amice & Tanker Barge Veendam

Several ice-induced challenges are considered such as the ice load acting on the ship, the ship structural strength and the increased resistance when operating in ice where the latter is strongly related to the ship propulsion capacity. The ice load acting on the ship is dependent of the mechanical properties of the ice that in turn varies with ice thickness, salinity and ice type. Statistical and historic data for these parameters are extracted for Lake Mälaren which is used for both for strength calculations and in the estimation of possible operation time window. The ice strength properties are calculated on basis of empirical formulae together with the above mentioned reference data. Different vessel operating scenarios are identified and considered.

As user case in the current study two barges, the *Amice* from Vigilia Shipping, and the *Veendam* from VT Group are selected. These barges are used to demonstrate both the operation potential and highlight challenges when they are adapted to the Swedish IWW environment. The two ships are seen in Figure 1.

Issue I: Ice Load

Two approaches are used to predict the ice impact load: a deterministic approach and a probabilistic approach. The deterministic approach is suitable when all variables are known and it refers to traditional rule-based ship design. As for first year thin ice condition, FSICR (Finnish Swedish Ice Class Rules) is the most practicable one identified. The current work focuses on the probabilistic design method. Firstly, the design contact area and high-pressure area are calculated. Then, a direct calculation is preformed based on inputs from previous research and references. A more thorough calculation is made where two reference methods are used, Taylor and Rahman. In addition, two different operation scenarios are considered, a

single trip and a full year operation. And finally, a design curve, valid for Lake Mälaren, that describes the relationship between design pressure and design contact area is proposed. It can be expressed as $\alpha = 0.265a^{-0.57}$ where α is the design pressure and a is the design ice-ship contact area.

Issue II: Structural Strength Performance

The bow part of Amice barge is considered for a local strength evaluation. Both the ice impact pressure/load from the FSICR and the Probabilistic method are used as input data. For FSICR, the calculations are made based on equations from the rules. Our findings are that the current bow structure of Amice barge does not meet the scantling requirements. Recommendations for new structure dimensions are proposed based on the FSICR requirements.

A computer simulation (Finite Element) is performed using the predicted pressure/load from the Probabilistic method. Again, it is found that the bow structure will not meet the requirement. Even when the suggested structures based on FSICR are used, the bow will still not meet the requirement. Based on the calculation in this part, the bow structural reinforcements are proposed in order to make sure that the barge can operate in Lake Malaren under winter conditions.

Issue III: Potential Propulsion Problems

The performance of ships running on ice-covered waters are usually described by the speed and the corresponding maximum operational ice thickness, which is known as h-v curve. The concept behind the h-v curve is that the traditional ship resistance, e.g. friction, wave resistance etc. plus new ice-induced resistance shall be equivalent to the net thrust provided by the propeller. Thus, in order to obtain the h-v curve, ship resistance on ice covered waterways are computed using three methods, the Lindqvist method, the Riska method and the Brash channel ice resistance prediction method. The h-v curves are presented both for fully loaded and empty loading conditions. Generally, the Riska method is more realistic when a ship operates in level thin ice. The brash ice-method is more relevant when the ship operates in a channel full of ice floes.

Issue IV: Vessel Operating Scenarios

Based on the resistance calculation, the Operating Time Windows (OTWs) are presented for the user to identify the number of navigable days in relation to speed and ice thickness. The ice thickness probability distribution tables, based on a Weibull distribution, are given as well. This provide understanding of the possibility of a certain operating condition. Two barges, Amice and Veendam, are compared to each other in order to high light the influence of different ship-parameters of OTW for the same navigational area. It turns out the main engine power is the most important influencing factor.
In addition to this, a study on different ice conditions is performed where Lake Vänern and Lake Mälaren are chosen. This study shows that Lake Mälaren has more available operating days.

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