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Global Ice Load Prediction for Icebreaking Vessels

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ABSTRACT

One of the concerns that arise while navigating ice-covered waters is the magnitude of the ice load encountered by ships. However, the accurate estimation of ice load still remains as a rather difficult task in the design of icebreaking vessels. This paper focuses on the global ice load for the icebreaking vessels. The extreme ice loads are expected from large ice features and these loads are most likely to be concentrated at the bow area of a ship. Ice load data of six icebreaking vessels in public domain, from the model tests and also from full-scale sea trials, are collected and then organized in the same format to give an insight for trend in global ice load variation according to various ship-ice interaction processes. Global ice load prediction formulas are compared with these data and are applied to a newly constructed DWT 70,000 class icebreaking tanker. Based on collected data, a semi-empirical ice load prediction formula is recommended for large sized icebreaking cargo vessels.

KEY WORDS: Icebreaking Vessels, Global Ice Load, Model Test Data, Full Scale Sea Trial Data, Semi-empirical Ice Load Prediction Formula

INTRODUCTION

Recent trends in the change of oil and gas prices have accelerated the development of natural resources in the Arctic region. Expansion of Russian economy, partly by world-wide high oil and gas prices, has boosted the transportation through the Northern Sea Route. Year-round navigation through the NSR requires powerful icebreaker fleets and the maximum width of sea route in ice-covered water, therefore the size of ships, depend on the breadth of escort icebreakers. These days the dimensions of newly constructed ice class cargo vessels are so increasing that even the most powerful Russian nuclear icebreaker alone may not perform the role of icebreaking escort. The lack of larger and more powerful escort icebreakers operating in Arctic Sea suggests that the construction of independent ice-capable cargo vessels will be necessary in shipping industries (Choi and Lee 2006).

One of the important issues for the construction of ice class ships is determining the exact ice load on ship's hull. The accurate estimation of ice load still remains as a difficult task and the understanding of ice-structure interaction process is essential. The best method for understanding ice load is to analyze full-scale measurements data recorded on board icebreaking vessels, but there remain many technical difficulties in measuring the magnitude and distribution of ice loads on ship's hull.

In general, ice load depends on ice properties such as failure mode, ice strength, ice thickness and it also depends on the characteristics of a ship such as ship's dimension, speed, operating condition. Following operational modes are commonly found for the icebreaking vessels in Arctic waters (Keinonen 1983).

- Continuous icebreaking
- Ramming or charging
- Motion in broken channel
- Motion in drifting ice field or open pack ice

Table 1 summarizes the various ice-ship interaction modes during navigation in Arctic waters. Table 2 shows various ice and ship properties involved in ice failure modes and determination of ice loads. It may be possible to decide specific ice loading scenarios with a combination of Table 1 and Table 2.

A continuous icebreaking is the most common operational mode in level ice condition of Baltic Sea. In this case, the magnitude of ice load is not significantly high, so it is believed that other operational modes of icebreaking such as ramming, beaching or jamming are more serious problems to ship structures.

Fig. 1 schematically describes various stages of global ice load in one ramming cycle. The impact phase extends rapidly from when the bow section first touches the ice and the load increases to its first peak at the moment when the bow section penetrates into the edge of ice. This is dynamic situation that lasts only 0.5~1.0s. During this stage there is an increase in vertical velocity of the bow frame from zero to its maximum. Horizontal velocity of the ship decreases as the contact area between ice and ship's bow section increases. The failure mode is basically crushing during this impact phase. As the ship slides up on ice,