Ice Resistance Test Simulation of Arctic Cargo Vessel using FSI Analysis Technique

Sang-Gab Lee and Tuo Zhao
Division of Naval Architecture & Ocean Systems Engineering, Korea Maritime University
Busan, Korea

Gyu-Sung Kim and Kyung-Duk Park
Hyundai Maritime Research Institute, Hyundai Heavy Industries Co., Ltd.
Ulsan, Korea

ABSTRACT

For the prediction of ice load of arctic cargo vessel, model test and empirical formula have been adopted. Since most of empirical formulas were derived from the design results of small and/or medium arctic cargo vessels, they could be hardly applied directly to the large one due to their low reliabilities. A lot of time and cost would be required for the model test in ice tank. In this study, ice load of arctic cargo vessel was estimated through the resistance test simulation of arctic cargo one in pre-sawn ices using Fluid-Structure Interaction (FSI) analysis technique of LS-DYNA code, and together through the investigation of the behaviors of pre-sawn ice pieces and their interactions with vessel.

KEY WORDS: Ice Load; Arctic Cargo Vessel; Resistance Test Simulation; Fluid-Structure Interaction (FSI) Analysis Technique; LS-DYNA code; Pre-sawn Ice.

INTRODUCTION

These days, model test and empirical formula have been applied to predict the ice load of arctic cargo vessel. In the case of sufficient many design records, empirical formula can be adopted based on the result data, whereas its reliability becomes low in other case. Since most of empirical formulas were derived from the design results of small and/or medium arctic cargo vessels, moreover, they have many problems to apply directly to the large one due to their low reliabilities. Since a lot of time and cost would be required for the model test in ice tank, it is necessary to develop a technique of prediction of ice load for the arctic vessel model and to understand the ice sheet behavior based on the numerical simulation.

The objective of this study is to establish the technique of prediction of ice load of arctic cargo vessel and to investigate the behaviors of pre-sawn ice pieces and their interactions with vessel through the resistance test simulation of arctic cargo one using Multi-Material Arbitrary Lagrangian Eulerian (MMALE) formulation and Fluid-Structure Interaction (FSI) analysis technique of LS-DYNA code (2011), which stands for the construction of base technology of Numerical Ice Tank. In this study, straight resistance test simulations were carried out in the pre-sawn ice for two ship hull forms (HFs). MAT_124 (MAT_PLASTICITY_COMPRESSION_TENSION) model of LS-DYNA code was adopted for the pre-sawn level ice, and its tensile and compressive failure strengths were derived using flexural strength and unconfined uniaxial compressive test simulations from their test results in ice test tank.

FSI analysis could be conveniently simulated by moving mesh algorithm and overlap capability of grid to structure mesh using the MMALE formulation and the Euler–Lagrange coupling algorithm of LS-DYNA code, as shown in Fig. 1. VOF method is adopted for solving a broad range of nonlinear free surface problems and coupling algorithm is more suitable for the FSI problems with complicated ship and pre-sawn ice sheet structure, where fluid grid can overlap the structural mesh (Aquelet et al., 2003 and 2006; Souli et al., 2000).

![Fig. 1 Sketch of penalty coupling algorithm (Aquelet et al., 2006)](image-url)

TEST SIMULATION SCENARIO AND MODELING

Characteristics of two cargo vessel models, pre-sawn ice sheets, and fluid (fresh water and air) are overviewed, and test simulation scenario and modeling are demonstrated in this chapter. Figure 2 shows the finite element configurations of two target ship models, where two