Simulation of Ice Pressure Distribution and Structural Response of Ship Hull in Level Ice

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ABSTRACT

This paper calculates the distributions of ice pressure and contact area on the ship hull when a ship advances in level ice. The structural response of a simple stiffened panel of the ship hull under the estimated pressure-area relation is investigated using finite element model. The calculated ice pressure-area relations show similar relationship as the measured data, which is the ice pressure decreases with increasing contact area. The localized deformations and stress distributions of the ship side shell model under the calculated pressure-area relations are strongly depending on the local ice pressure distributions.

KEY WORDS: Ice pressure; ice pressure-area relationship; ice loading; stiffened panel; structural response; level ice.

INTRODUCTION

For the structural design of the ice-going ship, the local ice force distribution on the ship hull is essential problem. The local ice force has a small pressure area and a small duration time. The local ice force distributions measured from the real ship trial are usually estimated by the structural response derived by the strain gauges or the load cells on the plate or the frame constituting the ship structural component (e.g. Frederking, 2003). The estimated ice force distributions from these data has a time and spatial limitation depending on a resolution of the measurement system, the arrangement of the strain gauges and so on. In the model test, Izumiyama et al. (1999) directly measured the ice pressure distribution along the ship hull with the sheet-shaped pressure sensors which installed on the ship outer hull. The pressure sensors can measure the exact location of the ship-ice contact point, the ice force and the ice pressure area along the ship hull. However, there are many uncertainties so that the exact local ice pressure distribution for calculating the structural response have not been estimated due to the complexity of the ice breaking mechanism. Watanabe et al. (1983) and Riska et al. (2002) have investigated the relationship between the ice pressure distribution and the structural response of the stiffened panel. Watanabe et al. (1983) has carried out the experiment of the stiffened panel model which was indented into the level ice with the triangle and the rectangular ice wedge. They have calculated stress in the frames and plate with the assumed ice pressure distributions, and have compared with the experimental results. They suggested that there are two reasons that the ice pressure cannot be assumed to be the uniform distribution; spatial scatter of the ice pressure in the contact area and effect of plate flexibility. Riska et al. (2002) has showed that the non-uniformity of the

ice pressure was related to the rigidity of the plate by the laboratory experiment of the stiffened structures and the theoretical model of the multiple analysis method. Both of researches have a limited ship-ice contact conditions. The ice pressure distributions subjected to the stiffened panel have not been directly measured. Therefore, the real distribution of the ice pressure have not been clear. Daley (2010) and Wang (2008) have calculated the structural response by the finite element method (FEM) when the ship collides with the ice floe. Some assumptions are needed to estimate the ice pressure distributions acting on the FE model of the ship structures. The sufficient investigation of the relationship between the ice pressure distribution and the structural response for the ice-going ship has not yet been obtained.

This paper calculates the ice pressure distribution and the structural response of the ship hull when the ship advances in a level ice. The key aspect of this work is that the structural response of the stiffened panel is simulated under the ice pressure-area relation which is directly calculated by the numerical simulation when a ship maneuvers in a level ice. The ice force distributions along the waterline for ice-going ship is calculated by authors developed numerical simulation (Sawamura et al., 2009) which can calculate the repetitive peak force of the ice breaking induced by the ship-ice contacts. The contact area is calculated by the geometrical conditions between the ship hull and the ice edge. The calculated ice pressure-area relations are compared with the measured data Frederking (2003) and Frederking and Ritch (2009). The FE model of a ship stiffened panel is modeled to calculate the structural response. The FE model is subjected to the ice pressure-area relation obtained by our numerical method. The localized deformation and the stress distribution of the stiffened panel are calculated. The relationship between the structural response and the ship-ice contact conditions are investigated.

SIMULATION OF SHIP MANEUVER IN LEVEL ICE

The ice force distributions along the waterline when a ship advances in a level ice are calculated by authors developed numerical simulation (Sawamura et al., 2009). The breaking process of a level ice consists of two phases: the bending failure of the plate ice and the rotating and sliding of the broken ice floes. In this paper, the rotating and sliding phase is ignored because of the relative smaller force of the rotating and sliding phase than the ice breaking phase. The simulations focus on peak force induced by the ice bending failure in the breaking process in a level ice. The repetitive peak force distributions induces by the ship-ice contact around the waterline are simulated .