Numerical Modelling of the Boundary Conditions on Ship Structural Components under Accidental Loading Conditions

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ABSTRACT

It is very important to define the procedure and boundary condition setting in experimental programs to simulate the response of ship structures under accidental loading conditions, such as in collision scenarios, to obtain the reliable results. The present paper aims to identify an appropriately experimental program for the unstiffened panels subjected to lateral impact. The influence of different configurations on the impact force and lateral displacement of the unstiffened panels are investigated in the FE analysis, including the boundary conditions, thickness of the plates and velocity of impact, which provide the basis idea for the further experimental program of the structural components analyzed. The results of the plates with the simply supported, clamped and box girder supporting are very close, which are slightly different to that with the steel block supporting with bolt constraint. It is vital that the experimental program have enough number bolts to reduce the influence of the local stress concentration.

KEY WORDS: unstiffened panels; ship; collision; boundary condition; force-displacement response.

NOMENCLATURE

\( l \) - length of the plates; \( s \) - width of the plates; \( \sigma_y \) - yield stress of material;
\( t \) - thickness of the plates; \( E_s \) - hardening modulus;
\( E \) - Young’s modulus of material; \( \beta \) - plate slenderness;
\( F_l \) - lateral force; \( v_{in} \) - impact velocity of the indenter;
\( F_{Max} \) - maximum lateral force; \( R_i \) - radius of the indenter; \( \delta \) - displacement of the indenter;

INTRODUCTION

Each ship in service suffers on the average hull damage once in ten years, and 2% of damaged ships may be lost (Guedes Soares and Teixeira, 2001). The analysis of ship collision is divided into two parts: external and internal mechanics. The external mechanics deals with the global motion of the ship under the action of the collision force and the hydrodynamic pressure exerted on the wetted surface (Petersen, 1982, 1998, 2009; Tabri, 2010). Petersen (1982) used the transient equations for the horizontal motion of a ship, the forces acting on each section are described by means of unit response functions. The deformations of the ship structures during the collisions are modelled as non-linear springs.

The empirical formulations, numerical analyses and experiments were commonly adopted to assess the collision force, penetration and energy absorption of ship structure. Zhu and Faulkner (1994) compared the results in the numerical and experimental analysis considering the deformation interaction between the struck and striking ships, in which the side panel of struck ship were assumed as clamped rectangular plates and the bow of striking ship were simulated by a rigid knife-edge indenter. Haris et al. (2013) conducted a comparative analysis by using empirical formulations, experimental method and numerical analysis.

FE codes have been used to analyze the stress distributions and deformation of very complicated structures with the accuracy demanded in engineering applications under all kinds of loading conditions, which are also a suitable tool for the crashworthiness analysis of ship structures. When the nonlinear finite element simulation technology is used to calculate the impact behaviour of the side panels of ship structures, the boundary conditions of panels are vital. Naar et al. (2002) calculated the force - penetration of double bottom structure in the FE analysis, in which the stiffened panels were constrained on the four edges of the flat bottom to simulate the real situation. Simulation of the collision response of three different ship side structures were performed in the FE analysis to determine the influence on the collision results from different failure criteria including the mesh size sensitivity (Ehlers et al., 2008). Karlsson et al. (2009) simulated and compared different collision scenarios by parameter variations to establish a reliable and robust FE modeling procedure for ship-ship collision simulations. The supporting frame was constrained in all displacement and rotation degrees of freedom along the lower outer edges.