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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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The objective of the present study is to investigate the ultimate hull girder strength of an asymmetrically damaged ship under a sagging condition. Two kinds of ships are taken as the object of analysis. The cross section of the ship is considered and assumed to have remained plane. The simply supported boundary condition is applied to both sides of the cross-section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called "critical element" reach its ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by the simplified approach is compared with the progressive collapse analysis to determine effectiveness and for validation.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. Collision and grounding damage may take place on the ship's hull, which may threaten safety of ships and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength as a result of collision and grounding damages. Pedersen (1994) presented a mathematical model to estimate the contact pressure between the grounded ship and the sea bottom. The grounding contact force was compared with the force that would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared with the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Guedes Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on Smith's formulation to predict the ultimate strength of damaged ship's hull. Muis Alie et al. (2016) investigated the influence of the superstructure on the ultimate strength of Ro-Ro ship under a vertical bending moment. The cross section was considered to be analyzed. The results obtained by beam theory with and without superstructure were compared with one another. The assessment of the ultimate hull girder strength was conducted by Muis Alie et al. (2017). The cross-section of Ro-Ro ship was taken to be analyzed. The collision and grounding damages were assumed to be located on the side and bottom areas, respectively. The damages were created by removing the element from the side shell and bottom part. Ohtsubo et al. (1994) showed the experimental and numerical works on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit finite element method codes, such as LS-DYNA and MSC Dytran, to the collision and grounding problems of ships. Özgüç et al. (2005) investigated the collision resistance and residual strength of single-skin and double-skin bulk carriers subjected to damages. Notaro et al. (2010) carried out full nonlinear finite element assessments of hull girder capacity in intact and damage conditions. The effects of several influential factors such as model extend and complexity, damage representations, and model imperfections were investigated on the different vessels. It was found that the effect of damage extent in a vertical direction is more critical than in a longitudinal direction, and the damage varies according to the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels were considered for the damage extent estimation.

When a hull-girder cross-section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross-section is asymmetrically damaged, for example, because of a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Özgüç and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes Soares, 2009; Choung et al., 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial-and-error approach to detect the position of neutral axis. An easier approach to detect the position of neutral axis is suggested.

BASIC ASSUMPTION

The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

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KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.