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Collapse Behaviour of a Bulk Carrier under Alternate Heavy Loading Conditions

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For a bulk carrier in alternate heavy loading conditions, it is noted that the double bottom of an empty hold is subjected to both longitudinal thrust due to hull girder bending in hogging and local bending caused by high pressure loads on bottom plating. In order to examine the influence of local bending of the double bottom on the ultimate hull girder strength, a series of nonlinear calculations is performed applying three different methods. The first method is Smith's method using in-house code, HULLST, to evaluate ultimate hull girder strength under pure bending. The second is the application of a new system recently developed by the authors. This method is a combination of load/motion analysis by Singularity Distribution Method and progressive collapse analysis by ISUM/FEM. The third is nonlinear FEM analysis using a commercial code, MSC.Marc. It has been found that bending deformation is produced not only in the double bottom but also in the bilge hopper tank, and the ultimate hull girder strength is reduced by roughly 20% due to this local bending.

INTRODUCTION

Recently in international society, attention has increasingly focused on marine environment issues such as pollution by spilt oil from wrecked ships. In order to ensure the safety of ships and to protect the environment from pollution, the evaluation of ultimate hull girder strength is required in Common Structural Rules (CSR) specified by International Association of Classification Societies (IACS, 2006). Many researchers have devoted themselves to developing efficient and accurate methods to evaluate ultimate hull girder strength. In general, one frame space model is used imposing forced rotation on end cross-sections assuming that the cross-section remains plane even after the ultimate hull girder strength has been attained. The ultimate hull girder strength obtained in this manner may be accurate when the ship hull girder is subjected mainly to bending. For a bulk carrier in alternate heavy loading conditions, however, it is noted that the bottom structure of an empty hold is subjected to both longitudinal thrust by overall bending in hogging and local bending caused by high pressure loads on bottom plating. In this case, strain distribution over the cross-section is no longer linear due to local bending in the double bottom, and one frame space model cannot be used any more. The ultimate hull girder stiffness and strength will be reduced due to the influence of local bending.

To investigate the effect of local bending of the double bottom on the ultimate hull girder strength of a bulk carrier in hogging, Amlashi and Moan (2008, 2009) performed a series of progressive collapse analyses using nonlinear FEM code, ABAQUS. A $1/2 + 1 + 1/2$ holds model was used. The forced rotation was imposed on the end cross-sections to apply hogging moment. In their calculation, local pressure defined by DNV and CSR rules is firstly applied and then forced rotation on boundary cross-sections of the model. It has been indicated that the ultimate hull girder strength in hogging is significantly reduced by the local bending of the double bottom structure under alternate heavy loading condition. Ostvold et al. (2004) also performed a similar analysis and pointed out that the ultimate hull girder strength is reduced by 14% due to the influence of local bending of the double bottom. However, their loading conditions were fictitious ones and the interaction between overall hull girder bending and local bending of double bottom was not exactly considered. Furthermore, the forced rotation imposed on end cross-sections is far from the reality. This is because it is actually distributed pressure or forces that shall act on a ship's hull, as pointed out by Lehmann (2006) in his official discussion on the report of committee III.1 in ISSC 2006 (Yao et al., 2006).

In order to simulate the actual collapse behaviour of the ship hull girder in waves, the authors' group developed a simulation

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KEY WORDS: Progressive collapse analysis, ultimate hull girder strength, alternate heavy loading condition, bulk carrier, nonlinear FEM, three-dimensional Singularity Distribution Method, ISUM (Idealised Structural Unit Method).