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Comparison of Safety Levels of Ship's Hull Girders in Longitudinal Bending Designed by Different Criteria

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ABSTRACT

Choosing four Panamax-size bulk carriers designed by different criteria in different times, reliability analysis has been performed to compare their safety levels from the viewpoint of ultimate hull girder strength in longitudinal bending. For evaluation of the ultimate hull girder strength and its sensitivities with respect to design parameters, a series of progressive collapse analysis is performed applying the Smith's Method. On the other hand, applying the nonlinear Strip Method, time-dependent nonlinear ship motion analysis is performed to estimate wave-induced bending moment on the basis of the time history of wave bending moment. Utilising the calculated results, reliability index and failure probability are calculated applying the Mean-Value First Order Second Moment (MVFOSM) Method. Investigating into the obtained results, it has been found that the safety level fundamentally becomes high wit the times depending on the design criteria.

KEY WORDS: Safety level; Reliability analysis; Ultimate hull girder strength; Smith's method; Nonlinear strip method; Safety index; Failure probability.

INTRODUCTION

After fatal oil spill accidents were experienced caused by braking of Nakhodka, Erika and Prestage, the IACS (International Association of Classification Societies) developed common structural rules for oil tankers and bulk carriers, which came into effect from April, 2007. In parallel with this, the IMO (International Maritime Organisation) has been trying to establish the GBS (Goal-Based New Ship Construction Standers) to ensure the safety of ships. The construction of GBS started in a prescriptive approach limiting the ship types to oil tankers and bulk carriers. A little later, however, a safety level approach has also started in parallel. In the safety level approach, an appropriate safety level is first set and then the existing design rules by Classification Societies are verified if the goals for safe ships can be achieved by the rules. To set an appropriate safety level as a goal, first of all, the safety level of existing ships has to be estimated and compared to those of other existing structures. In this connection, it is worth while to know how the safety level has been affected by design rules in different times.

In the present paper, four Panamax-size bulk carriers are chosen for comparison. Three of them were built in 1987, 1999 and 2007 and the last one is in the design stage. Their safety levels are assessed from the viewpoint of ultimate hull girder strength in longitudinal bending. For the reliability analysis, both hull girder capacity and the extreme load acting on the hull girder have to be evaluated together with their statistical characteristics. A series of progressive collapse analysis is performed applying the Smith's Method to evaluate the ultimate hull girder strength and its sensitivities with respect to design parameters. On the basis of the calculated results, the mean value and the standard deviation of the ultimate hull girder strength are evaluated. On the other hand, time-dependent nonlinear ship motion analysis is performed to obtain the time history of the wave-induced bending moment applying the Strip Method considering the influence of large motion, and the mean value and the standard deviation of the extreme wave-induced bending moment are evaluated. Utilising these results of calculations, reliability index and failure probability are calculated applying the Mean-Value First Order Second Moment (MVFOSM) Method.

FOUR BULK CARRIERS FOR ANALYSIS

Principal dimensions of the four Panamax-size bulk carriers analysed in this paper are given in Table 1 together with years built and the applied design criteria. The oldest bulk carrier was designed in 1985 according to the Pre-UR rule, the second oldest one by the IACS Unified Requirement (UR) S11 (IACS, 1989), and the third by IACS UR S25 (IACS, 2002) in addition to S11. In UR S25, design criteria for loading and ballasting conditions are introduced. The last one is the same as the third one but thicknesses are determined according to the Common Structural Rules (CSR) for Bulk Carriers (IACS, 2006). The mid-ship cross-sections of the four bulk carriers are shown in Fig. 1.

All the four ships are typical Panamax-size bulk carriers of a single hull with transverse frames between hopper tank and top side tank. Material of the ship's hull is high tensile strength steel. HT36 is used for almost all the structural members in Ship D. On the other hand, in Ships A, B and C, HT 36 is used for upper deck and upper parts of side shell plates and slant plates of the top side tank, whereas HT32 is used for the