The Effect of Initial Imperfections and Lateral Loads on the Hull Girder Ultimate Strength of Intact and Damaged Ships

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ABSTRACT

In order to examine the effect of initial imperfections and lateral loads on the hull girder ultimate strength of intact and damaged ships, a series of non-linear calculation is performed using FE analysis code, LS-DYNA. In addition, the hull girder ultimate strength of intact and damaged ships is calculated utilizing the simplified calculation program, which is developed by authors and based on the Smith’s method, and the reduction rate of hull girder ultimate strength is also investigated. Furthermore, to examine the accuracy of this simplified calculation program, the calculation results are compared with the results obtained from FE analysis.

KEY WORDS: Initial imperfections; lateral loads; hull girder ultimate strength; common structural rules for bulk carriers; finite element analysis; simplified calculation method; reduction rate.

INTRODUCTION

The hull girder ultimate strength is the most fundamental strength to ensure the structural safety against the applied loads for not only intact ships but also damaged ships due to collision or grounding. There are several methods to calculate the hull girder ultimate strength, such as the Smith’s method (Smith, 1977), the Idealized Structural Unit Method (ISUM) (Ueda and Rashed, 1984), and the Finite Element Method (FEM). In the previous studies by authors (Maeda et al., 2008), the simplified calculation program named ULST based on the procedure of Common Structural Rules for Bulk Carriers (CSR-BC) (IACS, 2009), which is a kind of the Smith’s method, had been developed for calculating the hull girder ultimate strength of intact and damaged ships. In order to calculate the hull girder ultimate strength applying the Smith’s method, the non-linear stress-strain relationship of structural members, such as longitudinal stiffened plates, is necessary. In CSR-BC, however, the stress-strain relationship is only prescribed for the intact members. Hence, the stress-strain relationship of damaged members under the tensile and compressive condition had systematically been calculated using FE analysis (FEA), and the idealized stress-strain relationship of damaged members was obtained from the FEA results. When ships are asymmetrically damaged by collision or grounding, the neutral axis in the mid-ship section will be inclined. In the calculation by ULST, therefore, the inclined effect of neutral axis in the mid-ship section was also taken into account.

Up to now, many studies have been performed for the intact hull structures. However, only a few studies have been performed for damaged ships and/or ships with initial imperfections. In actual ships, the initial imperfections exist in plates and stiffeners, and the hull girder ultimate strength will be reduced by these initial imperfections. Therefore, the effect of initial imperfections should be considered in the assessment of hull girder ultimate strength of intact and damaged ships. In these days, it is requested that the damaged ships are able to navigate safely until they are repaired. Therefore, it is important to clarify the residual hull girder strength of damaged ships in order to ensure their safety. With regard to the hull girder ultimate strength of damaged structures, Endo et al. (2005) carried out the detailed FEA, and clarified the residual hull girder strength of a ship which was collided by another ship at the side shell. They obtained the result that the hull girder ultimate strength of a 290,000 DWT VLCC collided by a same size tanker at 9~12 knots in speed fell to 75%~90% of intact structures. Luis et al. (2007) investigated the residual longitudinal strength of the double hull Suezmax tanker after collision or grounding. The calculations were performed utilizing a computer code based on the Smith’s method. The damage was simulated by removing damaged elements from the mid-section ship. Yoshikawa et al. (2008), one of co-authors of this paper, investigated the residual hull girder strength of bulk carriers after grounding. The residual strength of stiffened plates, which deformed 1~2 times of the stiffener depth attached to bottom, reduced to 50%~80% of intact plates. By utilizing the incremental-iterative approach not omitting damaged parts but considering the load-displacement relationship of damaged plates, the hull girder ultimate strength of damaged ships was calculated, and the reduction rate of hull girder ultimate strength was found to be very small when the damaged area was limited between two adjacent girders in bottom. As listed above, the study of hull girder ultimate strength of damaged ships is limited. It is necessary to discuss the hull girder ultimate strength of damaged structures in more detail.

When heavy cargoes such as ore are carried by bulk carriers, the cargoes are generally loaded not homogeneously but only in the odd number cargo holds and the even number cargo holds are all empty, which is called the alternate loading condition. Under this condition, the double bottom structure is subjected to the global bending moment as well as the local lateral loads, and this produces the local bending of