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Shape Optimization System of Bottom Structure of Ship Incorporating Individual Mesh Subdivision and Multi-Point Constraint

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A structural optimization system using the Finite Element Method (FEM) for the initial design stage of a ship is presented in this paper. A general bulk carrier is selected as the object for the optimization. Some dimensions determining the shapes of the ship's bottom structure are taken as design variables. Since the design variables affect the shape of the structure, the FEM model needs to be updated during the optimization. Further, the structure of the ship is so large and complicated that optimizing the shape of the ship's structure is very difficult. The individual mesh subdivision technique and the multi-point constraint method are introduced to make this optimization possible. However, creating the FEM datasets for the ship's structure requires a lot of manpower. To remove this drawback, PrimeShip-Hull is used because it has a function for recognizing the ship's structural members. The FEM dataset which can be applied to the individual mesh subdivision technique and the multi-point constraint method is made automatically from the structural members categorized by PrimeShip-Hull. Five key design variables for shape optimization of the ship's bottom structure—height and width of the double bottom, height of the bilge hopper tank, and the 2 widths of the lower stool—are considered here. A numerical example shows that the proposed method makes it possible to optimize the shape of the ship's bottom structure.

INTRODUCTION

In the initial design stage of a ship, it is usual to design the principal particulars first, followed by the general arrangement and the structural members of the midship section, and finally the bottom structure. It is rational to have distinct design stages, since a ship has different kinds of requirements which are difficult to be taken into account simultaneously although they are related to each other.

Since the design variables determined at a stage affect the design variables at other stages, it is desirable to establish adequate relationships between the design variables over all the design stages. However, it is difficult to achieve sufficient cooperation between these design stages because of obstacles, such as the difficulties in a ship's initial design stages and the restrictions on usable manpower. The FEM analysis is performed at the bottom structural design stage, and the design variables are updated in order to satisfy constraint conditions such as the yield and buckling stresses. The plate thicknesses are the favorite design variables at this stage, since the increases of plate thicknesses don't make extra work to reconsider the previous design stages. In this paper, we focus on the bottom structure of the bulk carrier and consider the effects of the general arrangement on the ship's strength at the bottom structural design stage. The width and height of the double bottom are examples of the design variables in the general arrangement design stage, but they have a great influence on the design variables not only at the general arrangement design stage but also at the midship section and bottom structure design stages. For example, the sizes and numbers of longitudinal stiffeners on the inner bottom plates are heavily dependent on the double bottom's width. The plate thicknesses of the bottom plates, inner bottom plates, longitudinal girders and floor plates are determined so as to satisfy the structural constraint conditions, which are significantly dependent on the double bottom's height. Hence, from the structural and optimization points of view it may be better to consider these design variables at the general arrangement design stage, and this paper investigates such a possibility.

Ship designing software with an optimization module—such as Maestro, led by Hughes (1980, 1983) and LBR-5, led by Rigo (2001a, b)—is available and effective these days, and several examples for the optimization of ship structures have been reported. Andric et al. (2010) showed a structural optimization of corrugated transverse bulkheads with Maestro, where the FEM analysis was executed with the design variables of scantlings. The design variables for the topology and geometry optimizations were determined in the concept design stage without the FEM analysis before the structural optimization stage in the paper. Rigo (2005) showed a cost minimization of FSO offshore structure and LNG gas carriers with LBR-5, where the scantling optimization was performed. Toderan et al. (2008) used LBR-5 for the structural optimization of an LNG carrier with the VERISTAR model where the FEM analysis was performed to see the ship's strength. Klanac et al. (2009) showed an optimization of a crashworthy marine structure where the thickness of the plates and the sizes of the stiffeners were design variables. Kitamura et al. (2003) used a structural analysis based on the FEM analysis for the optimization of a ship with the design variables of scantlings. Yang et al. (2007) determined the hull form; Sekuski (2009) showed a topology and size optimization of a catamaran; and Chen et al. (2010)

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