Study on Ultimate Strength Analysis and Reinforcement Methods of Side Structure with Openings of Large Cruise Ship Superstructure

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ABSTRACT

The superstructure of large cruise ships is characterized by disjunctively distributed openings on side plates. These diverse openings are designed to meet the functional requirements of large cruise ships and to reduce the weight of the superstructure, guaranteeing the stability of ships. As the side plate is the main path of transmitting the external loads from the main hull to the superstructure, these openings would have influence on the load bearing performance of side plates. Moreover, the buckling and ultimate strength of side plates is reduced due to the existence of these openings. Therefore, it is important to consider the influence of openings on side structures in designing the superstructure of large cruise ships. The purpose of this study is to analyze the ultimate strength and load-transmitting path on side structures, and evaluate the reinforcement methods of side plates of superstructures with openings. In this paper, the ultimate strength analyses of side structures with openings in different sizes, locations and aspect ratio are performed by employing nonlinear finite element method. Furthermore, this paper evaluates the effect of two reinforcement methods on the ultimate strength of side structures with openings. All these investigations make an extensive study of side structure with openings of cruise superstructure and may have reference value for the design and safety evaluation of cruise ships.

KEY WORDS: Ultimate strength; reinforcement methods; side structure; openings; large cruise ship.

INTRODUCTION

Compared with conventional ships, the design of superstructure on cruise ships has many special features. In order to meet requirements of the ship stability, the superstructure of cruise ships is designed with many openings in side plates to reduce structural weight. Besides, for the sake of the comfortable environment for passengers on cruise ships, the cabins usually located on the outboard side of the superstructure with balconies, floor windows or glass curtain walls, which allow light into the cabin. This is also the main reason for the large opening on side plates of superstructure, which brings higher demand for the structural strength design of cruise ships.

The superstructure almost has the same length and width as the main hull. It plays an important role in undertaking the overall longitudinal bending strength of ship hull. The side plates of the superstructure are the main paths for transferring the external loads from the main hull to the superstructure. Meanwhile, in order to meet the functional requirement, the area of openings in the side plating of the cruise ship takes up more than 40% of the total side plate area. The buckling and ultimate strength of side plates is reduced by these large openings. They also cause stress concentration near the corners of openings. Besides, large openings in side plating of superstructure may facilitate potential structural damage to superstructure, and bring great risks to the structural safety of cruise ships. Therefore, the effect of openings on the buckling and ultimate strength of side plating of superstructures must be evaluated in cruise ship design stage.

Paik et al. (2008) carried out a series of numerical studies on the ultimate strength of perforated steel plates under combined biaxial compression and edge shear loads, which represented loads from cargo weight and water pressure. They developed a closed-form empirical formula for ultimate strength of perforated plates using nonlinear finite element analyses.

Moen et al. (2009) summarized the closed-form expressions for evaluating the critical elastic buckling stress of plates with single or multiple holes under bending or compression loadings, which was applied to plates supported on 3 or 4 sides.

Wang et al. (2009) performed a series of linear and non-linear finite element method (FEM) analyses on both buckling strength and ultimate strength of plates with opening, in which several different variables of panels and openings, such as slenderness ratio and aspect ratio of panels, shape and dimensions of openings, were investigated.

Kim et al. (2009) performed a series of experimental and numerical studies on buckling and ultimate strength of plates and stiffened panels with an opening subjected to axial compressive actions. They tested a total of 99 perforated plates and stiffened panels with an opening with different parameters of plate aspect ratio, slenderness ratio, opening shape, size and location.