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Thin-Walled Structures 43 (2005) 83–105
THIN-WALLED STRUCTURES
www.elsevier.com/locate/tws

A systematic approach towards the structural behaviour of a lightweight deck–side shell system

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Received 12 November 2003; accepted 27 July 2004

Abstract

Lightweight structures are increasingly used for high-speed ships. This paper presents a systematic approach to analyse the structural behaviour of a lightweight deck–side shell system using high strength steel. An analytical model of the deck–side shell system was first given, which includes the effects of stiffeners for the deck and side shell, the support conditions of the centreline girder (CL-girder), the influence of transverse beams, and the interaction between the side shell and the lightweight deck as parts of problems to the solution. By changing several geometric parameters, the sensitivity of both overall and local stress and deflection for the deck–side shell system was investigated. The different geometric parameters analysed comprise the influence for variation in the thickness of the web for transverse beams, longitudinal stiffeners and the CL-girder, the thickness of lower flange for the transverse beam and, the thickness for the panel. Furthermore, the influence of the lightweight deck and loads from the deck above on the side shell, the effects of the side shell and loads from top deck on the deck, the support conditions for the CL-girder, and the influence of deck loads on the eigenmodes were also analysed. By evaluating the results obtained from FE simulation, the support conditions of the CL-girder, the thickness of the panels and the lower flange of the transverse beams were found to be the most relevant parameters affecting both the stress and the deflection distribution of the structure. The dynamic characteristics of the structure were also analysed. The FE analysis concerning buckling of the structure was present. The results enable naval architects and structural engineers to design new extreme lightweight deck

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0263-8231/$ - see front matter
doi:10.1016/j.tws.2004.07.005

structure more reliable and economical. And some suggestions for future research are also given.

Keywords: Lightweight deck; Deck–side shell system; Systematic approach; Structural behaviour; Parametric study; Modes of vibration; Buckling

1. Introduction

1.1. Review

During the last two decades, lightweight ship's deck–hull structure is widely used in high-speed ships and the research concerning this type of structures has attracted a lot of research efforts recently. When lightweight ships are developed, different kinds of questions and problems have appeared. Complex structures and the use of non-conventional materials are factors that make the structural analysis of these types of ships more challenging. It is expected that the natural frequencies of the ship deck will decrease and new problems of vibration and damping can be expected.

There are mainly three types of lightweight deck–side shell system, the first type is to use the aluminium for the material of panel, which can significantly reduce the weight, but the cost for construction and material will be higher than the conventional steel deck–side shell. The second type of deck–side shell structure is characterized by employing composite material (such as FRP) to fabricate the structural members and the panels for the deck and side shell. The third type belongs to those that the high tensile steel is employed to form stiffened plates.

Although lightweight deck–side shell structure is widely used, the information available in respect of the design recommendations is still under development.

Smith [1] has carried out considerable research on the deck and side shell structure using composite material such as FRP, and gave some guidelines on the design and fabrication of composite deck and side shell structure. Because of the cost he concluded that structure using FRP seems unlikely to become competitive with steel for construction of ships over about 40 m in length. However, the production of sandwich structure may change this situation in particular, if problems concerning fire and smoke are solved.

Based on an FE analysis of a deck structure using box shape aluminium panel, Jia and Ulfvarson had presented the static and dynamic behaviour of a lightweight ship deck on a PCTC (pure car truck carrier) vessel [2,3]. By varying special parameters, such as material in the panel, numbers and locations of loaded cars, the speed of running cars on the deck during loading and the frequencies of the propeller excitation, they contributed to the understanding of how a conventional steel structure is improved by introducing lightweight material. They also made both theory study and finite element simulation to show that the chassis of the car parked on the deck influence the dynamic behaviour of the loaded structure.

With the recent trend to widely use high tensile strength steel in decks, much effort has been given to study the buckling of the structure. By conducting parametric