A Study of Ultimate Strength for Container Ship Bottom Structures under Bi-axial Loads Considering Corrosion Effects

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ABSTRACT

Container ships are widely used and their strength has always been the concern of designers and engineers because of the large openings in deck. Additionally, container ships are of similar arrangements and structures because the containers are of same standards worldwide. So investigation into the strength of typical structures is meaningful. This paper focuses on the ultimate strength of typical bottom structures in container ships under both longitudinal and transverse loads in corrosive environments. On one hand, the ultimate strength of container ship’s bottom structures is calculated by Nonlinear Finite Element Analysis (NFEA), and the limit state of failure (i.e. interaction relation of bi-axial loads) is derived through Minimum Square Error (MSE) technique based on a series of NFEAs; On the other hand, uniform and not simultaneous corrosion across different structures is studied, and surrogate models by Gaussian Process (GP) are built for both longitudinal thrust and transverse thrust ultimate strengths individually, and the corresponding longitudinal and transverse ultimate strength probabilistic characteristics of the typical bottom structures are investigated. Finally, corrosion effects on interaction between longitudinal and transverse stresses at ultimate state are studied.

KEY WORDS: Ultimate strength; Container ship bottom structures; Bi-axial loads; Corrosion; Probabilistic characteristics.

INTRODUCTION

Corrosion takes place and can be a significant source of ship structural strength degradation. Many researchers have devoted in incorporating corrosion growth models regarding to available statistics, e.g. several researchers supposed corrosion follows a linear decrease of plate thickness with time (Sun and Bai, 2003; Wirsching, Ferensic and Thayamballi, 1997; Guedes Soares and Garbatov, 1996); Melchers (1999) extended original linear and bilinear models (Southwell, Bultman and Hummer, 1979) and introduced second statistical moment; Yamamoto and Ikegami (1998) studied the degradation of coating and corrosion of ship’s hull, and a consistent corrosion model is proposed and verified; Soares and Garbatov (1999) proposed a nonlinear corrosion model which assumes corrosion doesn’t happen until coating life is over, and the probability density function (PDF) can be determined by adopting Weibull or Log-normal distribution assumptions (Garbatov, Guedes Soares and Wang, 2007; Guo, Wang, Ivanov and Perakis, 2008).

Additionally, bi-axial compression exists in the bottom structures. The ultimate strength in this respect is a critical problem in practical structural designs, and many researchers have investigated into this, e.g. Fujikubo and Yao (1999) studied the elastic buckling strength by introducing torsional rigidity to simulate the interaction between stiffener and plate; An extensive study was made on the ultimate strength of continuous plates and continuous stiffened panels under combined transverse thrust and lateral pressure (Fujikubo, Yao, Khedmati, Harada and Yanagihara, 2005; Fujikubo, Harada, Yao, Reza Khedmati and Yanagihara, 2005); Tanaka, Yanagihara, Yasuoka, Harada, Okazawa, Fujikubo and Yao (2014) compared the ultimate strength results of stiffened panels with several existing methods, such as CSR, PULS and FYH, and concluded that the PULS and FYH method can give good estimations. Taking corrosion into consideration, Paik, Lee and Ko (2004) investigated the ultimate strength characteristics of steel plate elements with pit corrosion wastage and under in-plane shear loads, and derived closed-form formulas. Wang, Wharton and Shenoi (2015) studied the behavior of steel stiffened plates subjected to weld-induced grooving corrosion using NFEA, and conclude that grooving corrosion can cause a significant reduction in ultimate strength.

In this paper, the ultimate strength of bottom structures in a typical 5100 TEU container ship under bi-axial loads in corrosive environments is studied. On one hand, uniform and not simultaneous corrosion across different structures is studied, and surrogate models by Gaussian Process (GP) are built for both longitudinal thrust and transverse thrust ultimate strengths individually based on NFEA results, and the corresponding longitudinal and transverse ultimate strength probabilistic characteristics of the typical bottom structures are investigated; On the other hand, the interaction relation of bi-axial loads at ultimate state is derived through Minimum Square Error (MSE) technique based on a series of NFEAs. Finally, corrosion effects on bi-axial interactions are studied.

ULTIMATE STRENGTH OF STIFFENED PANEL UNDER BI-AXIAL LOADS

In ship structures, the stiffened panel is one of the typical local structures for practical design and analysis. Extensive studies have been witnessed during the past decades (Ueda and Yao, 1985; Guedes Soares...