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A Modified Formula for Predicting the Ultimate Strength of Stiffened Panels Under Longitudinal Compression

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The aim of the present paper is to investigate the ultimate strength of stiffened panels under longitudinal thrust. A modified formula is proposed to express the ultimate strength as an equation of two dominant parameters, namely the plate slenderness ratio and the column (stiffener) slenderness ratio. Two undetermined coefficients α and η are introduced in terms of material yield stress and plate-stiffener stiffness ratio. To have a full verification of the proposed empirical formula, 221 finite element models of stiffened panels have been developed, and other researchers' data have been collected for comparison. The proposed formula shows good agreement with the finite element method (FEM) results compared with other methods and can be directly used in the ship design.

INTRODUCTION

The buckling and postbuckling behaviors of plate structures have been studied as a fundamental subject for many decades. It has been confirmed that the slenderness ratio of the plate is one of the main parameters governing a single plate's compressive strength. Previous scholars proposed various formulas using Faulkner's (1975) well-known formula (which is widely used at present) to predict the ultimate strength of plates under axial compression.

Considering the fact that the stiffener has great influence on increasing the ultimate strength of plate structures, extensive research has been done to assess the ultimate capacity of stiffened plates. Over years of study, various methods have been employed to investigate the collapse behavior of ship plate structures including analytical methods, the semi-analytical method, experimental tests, and the nonlinear finite element (FE) method. Hughes and Ma (1996) developed a simple energy approach to study the flexural-torsional and lateral-torsional buckling behavior of flanged stiffeners subjected to axial forces. Fujikubo and Yao (1999) studied the elastic local buckling strength of a continuous stiffened plate, dealing with the stiffener web as a plate and considering both the continuity of rotation and the transfer of bending/torsional moment between plate and the stiffener web. Byklum and Amdahl (2002) analyzed the coupled buckling and postbuckling of stiffened plates by deriving the energy formulations analytically through large deflection theory. Paik and Lee (2005) developed a semianalytical method by directly solving the differential equations that govern the elastic large deflection response of steel stiffened panels using the incremental energy method, and the effect of initial imperfections was considered in the form of initial deflection and welding residual stresses. Yang and Wang (2016) studied the dynamic buckling of the stiffened plates with elastically restrained boundary conditions subjected to an in-plane half-sine impact load, and a new dynamic buckling criterion was developed.

The model test can always provide valuable information about the ultimate strength value and collapse behavior as well as the initial imperfection of real specimens, which can be used to calibrate numerical methods, semianalytical methods, and empirical formulations. The early test programs on the stiffened panels under compression were usually conducted with transverse frame limitation on both ends of the specimens, and only one bay along the longitudinal direction was considered (Horne and Narayanan, 1976; Faulkner, 1977; Yao, 1980; Ghavami, 1994; Paik and Thayamballi, 1997). Tanaka and Endo (1988) began to take three bay specimens to eliminate the influence of the boundary conditions on the collapse behavior of the stiffened panels. Gordo and Guedes Soares (2008a, 2008b, 2011) conducted series of tests on the ultimate strength of the stiffened panels with three longitudinal bays to investigate the difference of mechanical performance with various types of stiffeners, panel aspect ratios, and material properties under longitudinal compression until specimen collapse.

Other authors have compared the numerical results in the FE analyses with previous experimental results. With the verification of the specimen tests, sensitivity studies of the ultimate structural strength of the corresponding parameters including the plate thickness, material properties, and stiffener type and geometry, as well as the boundary conditions, could be carried out (Ghavami and Khedmati, 2006; Xu and Guedes Soares, 2012; Xu et al., 2013). Khedmati et al. (2009) investigated the postbuckling behavior of high-strength aluminum alloy stiffened plates subjected to combined axial compression load and lateral pressure using a nonlinear FE approach. The influence of variable parameters including the plate thickness, boundary conditions, stiffener geometries, width of the welding heat-affected zone, and welding residual stresses were considered in detail. Tanaka et al. (2014) investigated the ultimate strength of stiffened panels subjected to longitudinal thrust by changing numbers, types, and sizes of stiffeners. With the comparison of existing methods such as Common Structural Rules (CSR) and panel ultimate limit state (PULS), they pro-

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