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Ultimate Strength Analysis of Stiffened Panels in Ships Subjected to Biaxial and Lateral Loading

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ABSTRACT

Ultimate strength analysis of stiffened panels subjected to biaxial and lateral loading is performed. The objective is to assess the beam-column approach used in rules for ships and offshore structures. Nonlinear finite element analyses of two representative midship bottom and deck panels from an offshore oil production ship are made, for which the corresponding ultimate longitudinal compressive strengths are calculated accounting for the effects of initial imperfections. The calculated results are compared with the predictions using a beam-column formulation. For the interaction of axial compression and significant lateral pressure, it is found that the considered beam-column model is nonconservative in plate-induced failure mode. In the presence of a considerable transverse compressive stress, the model is generally very conservative in stiffener-induced failure mode. The bias associated with the model is found to be a function of the transverse stress and lateral pressure.

INTRODUCTION

It has been generally accepted that the ultimate longitudinal strength of ships is well represented by the strength of representative longitudinally stiffened panels, which are composed of plate panels, longitudinal stiffeners and transverse frames. For panels in compression, the basic load case usually consists of the following loads applied simultaneously:

- longitudinal compression arising from the overall hull girder bending moment
- transverse compression arising from the in-plane pressure loading
- local bending arising from the lateral pressure

Large research efforts have been made on the buckling and collapse behaviour of unstiffened or stiffened panels/flanges since the 1970s; see e.g., Smith (1975), Valsgård (1979, 1980), Carlsen (1980), Smith et al. (1987, 1991) and Davidson et al. (1991). Based on these studies, several codes and design recommendations for both onshore and offshore structures have been developed, including API RP2V (1987), BS 5400 (1982), DnV (1992) and ECCS (1990). While API RP2V (1987) is based on a formulation utilizing a reduced slenderness concept, the other three codes are all based on the beam-column approach, each using a different plate panel effective width formulation and a different load interaction equation. The main feature of this approach is that a single longitudinal stiffener with an associated width of plating is considered representative of the behaviour of the longitudinally stiffened panel.

In a recent assessment of current design codes, Bonello et al. (1992) observed that both the DnV and BS 5400 model predictions are in better agreement with the numerical data, and the DnV prediction tends to be comparatively more conservative. Noticing that the former formulation is the only one accounting for interaction of biaxial compression and lateral pressure, which is the basic load condition for stiffened panels in ships, the most recent DnV (1992) code is thus a natural focus for further investigation.

Hence, the objective of this paper is to perform nonlinear finite element analysis of stiffened panels, accounting for geometric and material nonlinear behaviour. Focusing on ships, both bottom and deck panels are to be analyzed, for which lateral pressure may be applied on either plate or stiffener side. The numerical results will be used for estimation of model bias associated with the DnV (1992) formulations. However, the design approach may be easily extended to other formulations as well.

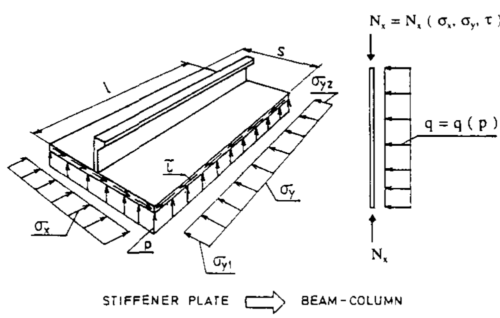

Fig. 1 Beam-column approach, DnV (1992)

BEAM-COLUMN APPROACH

The beam-column approach is depicted in Fig. 1 and the failure modes of a stiffened panel can be categorized into plate-induced failure and stiffener-induced failure. The basic interaction equation is:

$$\frac{\sigma_a}{\sigma_{acr}} + \frac{\sigma_b}{\left(1 - \dfrac{\sigma_a}{\sigma_E}\right)\sigma_K} = 1 \tag{1}$$

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