International Journal of Offshore and Polar Engineering
Vol. 12, No. 2, June 2002 (ISSN 1053-5381)

New Simplified Model for Collapse Analysis of Stiffened Plates and Its Application to Offshore Structures

Patrick Kaeding
JAFO Technologie, Blohm+Voss International GmbH, Hamburg, Germany

Masahiko Fujikubo*
Graduate School of Engineering, Hiroshima University,
Higashi-Hiroshima, Hiroshima, Japan

ABSTRACT

A new simplified model for stiffened plates in collapse analyses is developed. The model consists of large plate elements and beam-column elements. It is formulated according to the typical collapse modes of stiffened plates under longitudinal thrust, which are investigated by conventional Finite Element Analysis (FEA). Comparisons with FEA show the excellent applicability of the model to typical stiffened plates in marine structures and its accuracy. To demonstrate the application of the model to offshore structures, the collapse behaviour of a transverse strip of a Very Large Floating Structure (VLFS) in longitudinal waves is examined.

INTRODUCTION

Predicting the collapse behaviour of systems of stiffened plates is an essential issue in assessing the strength of offshore structures. For the analysis of large structures, an accurate and efficient approach is required to obtain results within a reasonable time. This is particularly important in order to be able to examine a variety of designs for new types of structures, such as Very Large Floating Structures (VLFS). Despite the enormous developments in computer technology, elastoplastic large-deflection analyses with conventional Finite Element Analysis (FEA) are too time-consuming for large structures. The Idealized Structural Unit Method (ISUM) proposed by Ueda and Rashed (1984) is one framework for implementing a faster model for collapse analysis, and it is used in this paper.

In ISUM, the elements are significantly larger than in FEA. The material and geometrical nonlinearities inside these ISUM elements are idealized and included in their formulation. Because larger elements mean fewer nodes and fewer degrees of freedom to solve for, calculation time with ISUM is much shorter than with FEA.

The stiffened plate is the basic structural element of many marine structures. Not only the ultimate strength of individual stiffened plates, but also their post-ultimate strength behaviour have to be accurately predicted to analyse the collapse behaviour of those structures as a whole. It has been shown by Yao et al. (1997a, 2001) that under thrust in the stiffener direction (hereafter: longitudinal thrust), plastic deformation localises in a part of the plating while the rest of the plate unloads. This phenomenon strongly influences the post-ultimate strength behaviour of plates and stiffened plates and has to be considered in ISUM.

For the plate panel, several idealized plate elements exist. The Simple Dynamical Model by Yao et al. (1993, 1997b) basically consists of Elastic Large Deflection Analysis (ELDA) and Rigid Plastic Mechanism Analysis (RPMA). It has been successfully applied to plate panels (Yao et al., 2001) and, in combination with beam-column elements, to stiffened plates as well (Fujikubo et al., 1998). As the plating is divided into several elements to all of which the Simple Dynamical Model is applied independently, this approach can cope with localized plastic deformation. However, the applicability of the model is limited to purely longitudinal thrust.

The original ISUM rectangular plate element (Ueda et al., 1984) and an improved element (Ueda et al., 1993) are applicable to combined loads; they are based on the effective width concept. However, the original element cannot accurately predict the decrease in load-carrying capacity beyond ultimate strength. The improved element has greater accuracy in this prediction, but its formulation is rather complicated, making it difficult to apply this element to stiffened plates.

Another ISUM rectangular plate element in which the lateral deflection inside its boundary is treated as an additional degree of freedom has been proposed (Masaoka et al., 1998). The lateral deflection of the plate is approximated by its elastic eigenmode throughout the collapse behaviour. This innovative approach is applicable to combined loads, and its formulation is less complicated than that of the previous element. However, the approach of using elastic eigenmodes of plates does not give good results for stiffened plates (ISSC, 2000), because the overall bending deformation of the stiffener and the localization of plastic deformation cannot be considered.

This paper proposes an ISUM stiffened plate model which can cope with the buckling of the stiffener as well as the local panel and the localization of plastic deformation. To accurately consider the buckling/collapse behaviour of stiffener and plate panel including their interaction, stiffeners and panels are modelled individually by beam-column elements and plate elements.

*ISOPE Member.

Received September 12, 2001; revised manuscript received by the editors February 28, 2002. The original version (prior to the final revised manuscript) was presented at the 11th International Offshore and Polar Engineering Conference (ISOPE-2001), Stavanger, Norway, June 17–22, 2001.

KEY WORDS: Collapse analysis, ultimate strength, stiffened plates, idealized structural unit method, plate element, beam-column element, very large floating structure.