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Buckling/Plastic Collapse Behaviour and Strength of Stiffened Plates Under Thrust

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ABSTRACT

A series of elastoplastic large deflection analyses are performed on stiffened plates with flat-bar and angle-bar stiffeners subjected to thrust, and the influences of sectional geometries of stiffeners on the buckling/plastic collapse behaviours are investigated. It has been found that: (1) Local panel buckling strength among stiffeners, post-buckling inplane rigidity and ultimate strength is increased owing to the stiffener; (2) stiffened plates undergo elastoplastic secondary buckling after local panel buckling; (3) higher ultimate strength is attained by stiffeners with lower depth-to-thickness ratio of a web, but, the reduction in capacity after the ultimate strength is more rapid for stiffened plates with such stiffeners; (4) when stiffeners with relatively high depth-to-thickness ratio are provided, the ultimate strength is lower than with a lower depth-to-thickness ratio, but the capacity reduction after the ultimate strength is rather moderate.

INTRODUCTION

One of the critical failure events of a ship structure is the occurrence of overall buckling/plastic collapse of deck or bottom structure under longitudinal bending. So, the deck and the bottom plates are reinforced by a number of longitudinal stiffeners to increase their strength and rigidity. For a rational design avoiding such a failure, it is very important to know the buckling/plastic collapse behaviour of such stiffened plates under thrust.

Plenty of research works have been performed both theoretically and experimentally on the buckling/ultimate strength of isolated plates as well as stiffened plates subjected to thrust. The results are put to practical uses establishing design rules or deriving design formulae.

However, in most of the previous research studies, plates and stiffeners are separately considered. In general, stiffened plates are so designed that local panel buckling first takes place between stiffeners. So, buckling/ultimate strength of isolated plates are first investigated assuming that edges of the plate are simply supported. This boundary condition gives the lowest/conservative buckling strength. On the other hand, stiffened plates have been often modelled as a beam-column with plating between stiffeners as a flange.

In the actual ship structures, however, interactions between plates and stiffeners can not be ignored. The interactions depend on the sectional geometry of a stiffener. When stiffeners with high flexural-torsional rigidity are provided, the buckling strength of panels between stiffeners is expected to increase.

Here, the stiffeners in ship structures can be grouped into three types, which are flat-bars, angle-bars and tee-bars. As for stiffened plates with flat-bar stiffeners subjected to thrust, one of the authors performed a series of FEM elastoplastic large deflection analyses and discussed the buckling/ultimate strength and the collapse modes of stiffened plates. It was found that there exists the minimum stiffness ratio of the stiffener to plate, $\gamma^U_{\min}$, which guarantees the maximum ultimate strength (Ueda and Yao et al., 1976, 1978 and 1979). In this investigation, however, the stiffener was assumed not to have resistance against torsion.

Caridis et al. (1986, 1988 and 1989) considered both the panel and flat-bar stiffener as plates, and performed elastic large deflection analyses applying the Finite Difference Method. In their analysis, flexural-torsional behaviour of a flat-bar stiffener was exactly simulated. Tanaka and Endo (1988, 1991) proposed a simple approximate method to simulate the collapse behaviour of a stiffened plate with flat-bar stiffeners. The calculated results were compared with experimental results, and good correlation was observed between measured and calculated results, although interaction between plate and stiffeners was ignored in their analyses. Panagiotopoulos (1992) discussed the interactions between plate and flat-bar stiffeners based on the results of FEM analyses.

Although useful information has been obtained on the buckling/ultimate strength of stiffened plates with flat-bar stiffeners, that for stiffened plates with angle-bar or tee-bar stiffeners is not abundant (Ghavami, 1982).

In the present paper, a series of FEM elastoplastic large deflection analyses is performed on a stiffened plate with flat-bar and angle-bar stiffeners of the same flexural rigidity. Uniaxial thrust is applied, and the influences of cross-sectional geometries on collapse behaviour are discussed. Thin stiffened plates are considered to examine fundamentals in the buckling/plastic collapse behaviour of stiffened plates under thrust.

MODELLING OF STIFFENED PLATES

Stiffened Plates for Analysis

In general, the deck and the bottom panels in a ship structure are stiffened by equally spaced longitudinal stiffeners of the same size. Under longitudinal bending, compressive inplane force acts on the deck or the bottom plate in its longitudinal direction. In general, the plate and the stiffeners locally buckle under longitudinal thrust as illustrated in Fig. 1. In this case, considering the continuity and symmetry conditions, the buckling/plastic collapse bahaviour of a continuous stiffened plate can be simulated analysing only the shaded part in Fig. 1.

Along the four edges, symmetry conditions are prescribed, and their inplane movements perpendicular to themselves are consid-

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KEY WORDS: Stiffened plates, local buckling strength, post-buckling inplane rigidity, secondary buckling, overall buckling, ultimate strength, buckling/plastic collapse.