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Practical Evaluation System for Post-buckling Strength of Ship Double-hull Structures

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ABSTRACT

In a double-hull structure, the neutral axis lies near the center of the cross-section, so that high tensile and compressive stress of about the same level occurs alternately on the skin plate. Once skin panels are buckled, the stiffness of the girders decreases consequently. If this stiffness reduction leads to the expansion of the region of panel buckling, the hull's global strength decreases seriously. On the other hand, such panel elastic buckling does not have a serious effect on the hull's global strength if the buckled region is limited to the small area due to the redistribution of the applied load. Thus the assessment of the safety and reliability of a double-hull structure requires the confirmation of the buckling strength of the skin plate and the behavior of the global structure after buckling. However, complicated nonlinear analyses have not yet been effectively applied in the actual design stage because the global hull model is too large for this kind of analysis. In order to accurately evaluate the post-buckling behavior of the whole double-hull structure in a practical time frame, the authors have developed the new assessment system, named SAIAS-PB, by the iteration of linear FEM analysis, introducing a simplified plate element with the equivalent stiffness of the buckled panel. In this paper, we report on the investigation of the stiffness of the panel after elastic buckling, the development of a new plate element for the equivalent stiffness of the buckled panel, and the application to the actual double-hull structure.

INTRODUCTION

To evaluate safety when the ship's double-hull structure receives an excess out-plane load, it is necessary to accurately grasp the buckling strength of the skin plate panel and the post-buckling strength of the entire structure. Thanks to the recent progress of elasto-plastic analysis technology and the increasing capability of computer analysis, the complicated buckling phenomena are gradually being clarified (Fujikubo et al., 1999; Ueda et al., 1991; Yao et al., 1995), but the application of the analysis is limited to small-scale structure elements, and it has been applied to large-scale hull structures in only a few cases. Some classification societies partially cover elastic buckling by means of a simple formula for evaluating decreases in the effective rigidity of girders and frames forming a hull after panel buckling. But this formula cannot be applied for direct analysis on the scale of the transverse strength calculation model, making it impossible to consider the redistribution of the load, and it is not effectively reflected in the hull structure design. If it were possible by the analysis of post-buckling behavior to easily identify buckling without a structural problem, to lead to a permanent data set and adopt the most effective and optimum reinforcing method against buckling, it would be possible to remarkably enhance the reliability of the structure design.

Against such a background, the authors have developed a method of evaluating the strength after buckling that can be applied to a large-scale hull structure model at the level of transverse strength calculation.

In this paper, we report on methods we investigated to accurately express decreases in in-plane rigidity of buckled panels based on the relationship between the effective width of the buckled panels and the out-plane deformation. Through our investigation, we improved the simulation system that can sequentially trace the post-buckling load redistribution after buckling by means of the elastic FEM, and we verified its validity with a small-scale model. Finally, we applied this method to the hold structure model of an actual ship and showed that it was possible to evaluate the post-buckling strength with reasonably sufficient accuracy.

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