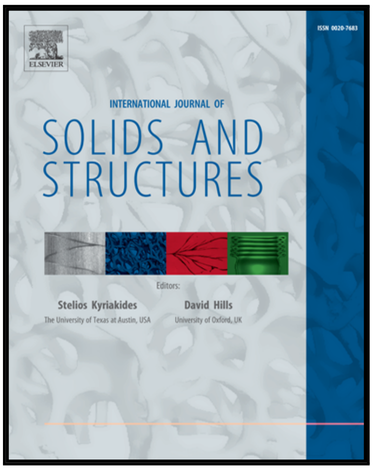

A high-fidelity approximate model for determining lower-bound buckling loads for stiffened shells

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A high-fidelity approximate model for determining lower-bound buckling loads for stiffened shells

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The Worst Multiple Perturbation Load Approach (WMPLA) has been validated by full-scale tests to be an effective and credible determination method for the lower-bound buckling load of stiffened shells. In spite of its high prediction accuracy and robustness, the large computational time is a burden because this method is based on the large-scale optimization of detailed finite element (FE) models. Therefore, a high-fidelity approximate modeling strategy is proposed in this paper, to improve the efficiency of WMPLA and then promote its application for the preliminary design stage of stiffened shells. In the first step, an initial approximate model is established by means of the Representative Volume Element (RVE) equivalent method. In the second step, a modified equivalent model is generated after optimizing the effective stiffness coefficients of the initial equivalent model. In the optimization process, the objective is minimizing the relative error in buckling load between a detailed FE model and the modified approximate model. The constraint condition is controlled by the Modal Assurance Criterion (MAC) coefficients for buckling mode. In particular, the global and local deformation features are simultaneously considered in the MAC coefficients. After the establishment of the high-fidelity approximate model, it is then integrated into WMPLA. By optimization of the positions and amplitudes of the multiple perturbation loads, the minimum buckling load is obtained as the lower-bound value. By comparison against known methods, the lower-bound buckling load predicted by the proposed strategy is quite close to the test result, succeeding in providing a safe design load prediction. The proposed strategy reduces the computational time sharply by 94% compared to the WMPLA based on detailed FE models, indicating high efficiency. Additionally, an illustrative example is shown to highlight the importance of the prediction accuracy of buckling mode on the fidelity of approximate models for WMPLA. Finally, it is concluded that the proposed strategy is a potential and efficient approach to predict lower-bound buckling loads of stiffened shells.

Keywords: Shell buckling; Imperfection sensitivity; Modal Assurance Criterion; Representative Volume Element method; Optimization.

1. Introduction

The stiffened shell is a high-performance aerospace thin-walled structure, and has been extensively used in launch vehicles, air and space vehicles, large marine and civil structures and the space shuttle (Hao et al., 2016b; Hao et al., 2016d; Wagner et al., 2017b). Generally, a stiffened shell is composed of the skin and stiffeners, exhibiting high efficiency in resisting axial compressive loads. Typical stiffener patterns include triangle stiffeners, orthogrid stiffeners, honeycomb stiffeners and corrugated stiffeners. For a stiffened shell, buckling is a critical design consideration under axial compressive loading. Many efforts

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