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ANALYTICAL, NUMERICAL AND EXPERIMENTAL PREDICTIONS FOR FREE VIBRATIONS AND BUCKLING OF PRESSURIZED ORTHOTROPIC CYLINDRICAL SHELLS

Abstract

The critical failure criterion for the design of primary launcher structures, which can be regarded as orthotropic shells, is predominantly buckling. As consequence, there is interest for a proper non-destructive method to estimate the buckling load from the pre-buckling stage of such structures. The Vibration Correlation Technique (VCT) allows determining the actual buckling load of the structure without reaching the instability point by loading the specimen at different axial load steps. At each load step, the structure is broad into vibrations and the natural frequencies are measured. A relationship between the natural frequency of the loaded structure and the axial load level can be identified and extrapolated to estimate the actual buckling load of the structure. This paper exploits and validates an analytical formulation for the free vibration of pressurized axially loaded orthotropic cylindrical shells towards a suitable VCT. The effects of the axial loading can be split into contributions due to constant pressure level (1) and due to additional axial compression (2). This procedure allows an analytical evaluation of the square of the drop of the loading carrying capacity for a proper VCT method. The study considers an orthotropic metallic cylindrical shell structure, which represents a simplified downscaled model of a launcher propellant tank. The analytical equations and the VCT approach are both verified by a detailed numerical model accounting for geometrical nonlinearities effects associated with measured initial imperfections. The results are validated with experimental ones and corroborate the applicability of VCT as a non-destructive experimental procedure to assess the buckling load of imperfection sensitive orthotropic cylindrical shells with or without internal pressure.