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BUCKLING AND POST-BUCKLING ANALYSIS OF THIN-WALLED STRUCTURES BASED ON LARGE ROTATION FIRST-ORDER SHEAR DEFORMATION THEORY

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ABSTRACT

This paper presents a large rotation theory for stability analysis of thin-walled composite laminated structures. The formulation of the large rotation theory, which contains fully geometrically nonlinear strain terms at large rotations, is based on first-order shear deformation hypothesis. The proposed large rotation theory has six independent kinematical parameters which are expressed by five degrees of freedom. Apart from the large rotation theory, three other simplified nonlinear shell theories are considered and compared with each other. The equilibrium equation is derived by the principle of virtual work and solved using Riks-Wempner method. The stability problems of composite shells with different stacking sequence are simulated, and the current results are compared with those reported in literature, as with those calculated by other simplified nonlinear theories.

Keywords: nonlinear shell theory, stability analysis, large rotations.

INTRODUCTION

In order to predict stability phenomena of thin-walled structures many nonlinear theories have been proposed. Reddy (1983, 1989, 1990) developed von Kármán type nonlinear theories based on first- and third-order shear deformation hypotheses, respectively. Von Kármán type nonlinearity is the simplest one, which only considers the nonlinear terms that contain squares and products of the derivatives of the transverse deflection. In contrast to von Kármán type nonlinear theory, moderate rotation theory, in which the nonlinearity is modelled more precisely, has been proposed by Librescu and Schmidt (1988), Schmidt and Reddy (1988), Palmerio at al. (1990), Kreja et al. (1996), among others. Even though, this moderate rotation theory is only applicable for structures being in the range of small and moderate deflections. So a large rotation theory is needed for structures undergoing arbitrary rotations. The first large rotation shell theory based on first-order shear deformation hypothesis was developed by Habip [1] in the 1960s.

The aim of this paper is to develop a finite element code for large rotation theory with six parameters that are expressed by five degrees of freedom for stability analysis of composite laminated thin-walled structures, as well as for simplified nonlinear shell theories, e.g. large rotation theory, moderate rotation theory and von Kármán type nonlinear theory with five parameters, respectively. An eight-node quadrilateral element with five degrees of freedom per node is employed in the present calculation. The results obtained by these nonlinear shell theories are compared with each other and those reported in literature.

RESULTS AND CONCLUSIONS

Numerous results for nonlinear FE analysis of composite laminated shells in the pre-and post-buckling range will be presented. The focus is on comparative analysis using various variants of nonlinear shell theory which use simplified nonlinear strain-displacement relations. In this context geometrically nonlinear finite elements available in commercial codes will be critically reviewed-The results obtained allow for conclusions on the range of applicability of a variety of nonlinear shell theories proposed in literature.

Furthermore, it is demonstrated that some so-called large or finite rotation theories available in literature fail to predict the response at large rotations despite fully nonlinear strain-displacement relations are employed. The reason is that these theories are five-parameter theories, thus a priory neglecting the sixth parameter, which is physically the component of the director of the deformed state referred to the unit normal vector of the undeformed mid-surface It is shown that this is approximately admissible only for small and moderate rotations. Thus, these theories do not yield better results than moderate rotation theories, and in many cases they are not able to detect the snap-through buckling at all but predict a stress stiffening behaviour of the structure.

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