A Study on Buckling of Sandwich Cylindrical Shells

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1. Introduction

The use of sandwich structures is growing very rapidly around the world. Its many advantages, the development of new materials, and the need for high-performance, low weight structures insure that sandwich construction will continue to be in demand. Among the many types sandwich structural elements, the sandwich cylindrical shell is one of the most emerging in the field of civil engineering. Ever expanding applications of the sandwich cylindrical shell have lead to many imperfectly understood buckling problems. Therefore, in this paper a comparison of the already proposed classical and reduced stiffness buckling methods with the results obtained form the finite element analysis is made. Both axially compressed and externally pressure-loaded simply supported sandwich cylindrical shell models were considered. In the finite element analysis, non-linear behavior of the geometrically imperfect simply supported sandwich cylindrical shell was considered. The comparison was also made by varying the parameter L/a of the sandwich cylindrical shell. Finally, The maximum strength of the sandwich cylindrical shell was shown to reach from and above the reduced stiffness lower bound.

2. Classical and RS buckling methods

A convenient way of examining the various possible equilibrium paths described by the stationarity of the total potential energy is to first define the fundamental state. For the externally pressure loaded problem, this is given by,

$$N_s^F = -qa, N_x^F = N_{xs}^F = M_x^F = M_s^F = M_{xs}^F = 0 \tag{2.1}$$

And, for the axially compressed sandwich cylinder the fundamental state is given by,

$$N_x^F = -q, N_s^F = N_{xs}^F = M_x^F = M_s^F = M_{xs}^F = 0 \tag{2.2}$$

Where, N^F and M^F are the fundamental loads and moments respectively. And, q is the applied load. The model consists of a core of thickness h_c sandwiched between two equal thickness (h_f) face sheets (Fig. 1). The mean radius of the shell was taken as a, while the length and the total thickness of the cylinder were designated as L and h respectively. The core of the shell was assumed to carry only transverse shear. While, on the assumption of thin shell, transverse shear in the face sheets were assumed to be zero. Energy methods and variational principles were used in the classical and reduced stiffness buckling analysis of the sandwich cylindrical shell.

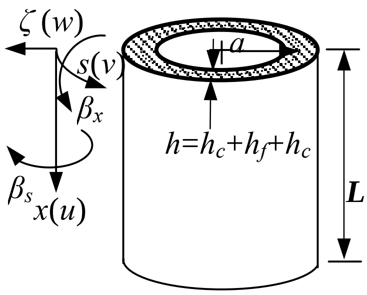


Fig. 1. Geometry and sine conventions

3. Buckling analysis of geometrically imperfect sandwich cylindrical shells

A non-linear analysis method has been developed into a finite-element code to allow investigation of the non-linear behavior of

Key words: *sandwich shell, buckling, RS method, lower bound buckling*

geometrically imperfect sandwich cylindrical shells. The FEM program developed for this purpose uses so called 9-node isoparametric shell element with five independent displacement degrees of freedom for the discretization of the model. A layered approach was employed in order to allow different material properties through the thickness of the shell. The critical mode shape from the classical buckling method was introduced as the initial imperfection in the FEM analysis of the externally pressure loaded sandwich cylindrical shell. While, that from the reduced stiffness method was introduced in the case of axially compressed sandwich cylindrical shell.

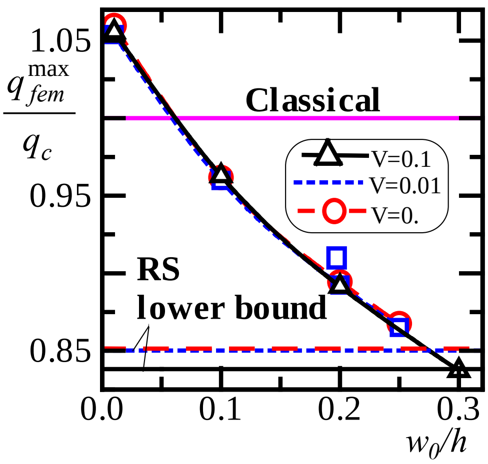
Buckling analysis of the geometrically imperfect shell was carried out by varying the amplitude of the initial imperfection (w_0/h). Firstly, from the results obtained from the FEM analysis, the plot of equilibrium paths of each case was produced. Using those figures, when the maximum stress parameter ($q_{fem}^{max}/\ q_c$), where q_c is the classical buckling strength, on each equilibrium path is plotted against the respective initial imperfection (w_0/h), the imperfection sensitivity plot results. The same for the case of L/a equals two is given in Fig. 2(a) (externally pressure loaded sandwich cylindrical shell) and Fig. 2(b) (axially compressed sandwich cylindrical shell). Here, V [$=E_f h_f/\{4aG_c(1-\nu_f)\}$] where, ν_f –the Poison ratio, E_f – Young's module of face material, and G_c is the core material shear strength. w is the lateral deformation of the shell. As it is evident from Fig. 2, as the initial imperfection increases, the maximum stress parameter reach from and above the reduced stiffness lower bound. Anyhow, for smaller initial imperfections the classical buckling method still can provides safe lower bounds for the buckling of externally pressure loaded sandwich cylindrical shells. However, in the case of axially compressed sandwich cylinder, this is true only for smaller V values. Therefore, as a whole, the reduced stiffness method can be expected to provide safe lower bounds for the buckling of externally pressure loaded and axially loaded sandwich cylindrical shells.

4. Conclusions

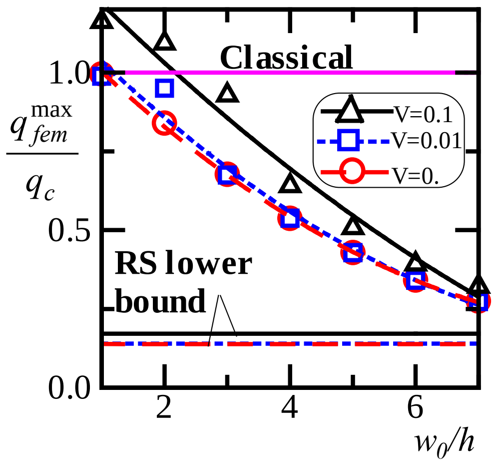
The reduced stiffness method provides safe lower bounds for the buckling of externally pressure loaded and axially compressed sandwich cylindrical shells.

5. Reference

Plantema, F. J. (1966). *Sandwich Construction: The bending and buckling of sandwich beams, plates and shells*, John Wiley & Sons Inc., New York, London, Sydney.



(a) Pressure loaded



(b) Axially compressed

Fig. 2. Imperfection sensitivity plots of sandwich cylindrical shells (L/a=2.0)