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Buckling Analysis of Thin cylindrical FRP composite

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Abstract

The present research work is to determine the buckling load in FRP(fibre reinforced plastic) thin cylinder, which is subjected to uniaxial compression using 2-D finite element analysis. The commercial finite element analysis software ANSYS has been successfully executed and the finite element model is validated. The buckling load is evaluated by varying the boundary conditions, length to diameter ratio (L/d), thickness to diameter ratio (h/d) and number of layers (n). The effect of boundary conditions, (L/d), (h/d), (n) on the buckling load is discussed. The results show that buckling load is more in clamped-clamped boundary condition, decreases with increase in length to diameter ratio, increases with increase in thickness to diameter ratio and remains constant with number of layers.

Keywords: FRP, FEM, Buckling analysis, uniaxial load.

Introduction

The buckling of cylindrical shells has been the study for more than a century. Exact and approximate solutions for cylinders have been derived. There are many exact solutions for linear elastic isotropic thin cylindrical laminates; many treated by N.N. Huang[1] evaluated the post buckling behavior of FRP circular cylindrical shell, operating in hygrothermal environment subjected to uniform external pressure. He used quasi-elastic approach, FEM. Seishi[2]. Krishna kumar[3] investigated the effects of thickness and fibre orientation of reinforcements and geometric imperfections, using linear eigen value buckling. James G.A. Croll[4] has done elastic, nonlinear, ritz analysis to allow the investigation of imperfect behavior of axially compressed orthotropic fibre reinforced polymer cylindrical shells. K. Matsumoto [5] had optimized the linearised classical critical loads with respect to many design variables using mathematical algorithms. M.K. Chryssanthopoulos [6] dealt with the experimental buckling behavior of glass fibre-reinforced plastic (GFRP) anti symmetric 2-ply laminate cylinders under concentric and eccentric compression. S.S Wang [7] investigated the effect of material nonlinearity on buckling and post buckling of fibre composite, laminate plates and shells subjected to general machine loading. He used lagrangian formulation to construct the equilibrium path. S. Mahesh Babu [8] evaluated the buckling factor and buckling load of rectangular laminates with circular delamination using ANSYS software. In the present analysis, the above mentioned paper is extended by changing the geometry of the laminates from rectangle to cylinder. the problem is analyzed by changing various parameters using ANSYS software.

Problem statement

The objective of the present work is to estimate buckling load of four-layered symmetric cross-ply ($0^0/90^0/90^0/0^0$) cylindrical laminates subjected to in-plane compression by varying boundary conditions, length to diameter ratio (L/d), thickness to diameter ratio (h/d) and number of layers (n).

Geometric modeling

The dimensions of thin cylinder of diameter d=1m is fixed. And the length of the cylinder L is varying from 10m, 20m, 30m, 40m and 50m in y-direction.the corresponding L/d ratios are 10, 20, 30, 40 and 50. The thickness of the cylinder is selected from thickness to diameter ratio (h/d) that is varied as 0.04m, 0.08m, 0.1m, 0.14m, 0.18m and 0.2. Modeling includes defining element type, real constants, material properties and modeling. In this study shell, linear layer99 selected as the element type which is suitable for analyzing thin to moderately thick structures and well suited for linear and nonlinear applications. Fig.1 shows the cross-ply orthotropic cylinder under compressive load of 1N and clamped-clamped boundary conditions. The fiber angle is measured from load direction.

Figure 1: FE model (c-c boundary condition, L/d=10, h/d=0.1, n=4).

Material properties

The following material properties are considered for the present analysis.

- Young's Modulus, E_1=147E3MPa, E_2=10.3E3MPa, E_3=10.3E3MPa.
- Poisson's Ratios, v_{12}=0.27, v_{23}= 0.54, v_{13}=0.27.
- Rigidity Modulus, G_{12}=7E3MPa, G_{23}=3.7E3MPa, G_{13}=7E3MPa for orthotropic material.

Validation of FE model

The present finite element model is validated from s. Mahesh Babu**.**

Table 1: validation of buckling factor and buckling load on composite layers for 4 ply symmetric cross-ply.

Boundary condition	s.maheshbabu buckling factor for mode 1	s.maheshbabu buckling load in kN	Present results Buckling factor for mode 1	Present buckling load In kN	Error in %
c-c	0.099	4.97	0.0947	4.739	4.68

Results and discussion

After solving the static analysis, then performed the eigen value buckling analysis. From fig.2 to fig.6 are the first five buckling modes given below.

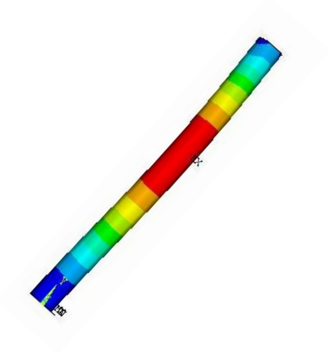

fig 2: Buckling mode 1 of the cylinder
(c-c boundary condition,L/d=10,h/d=0.1,n=4)

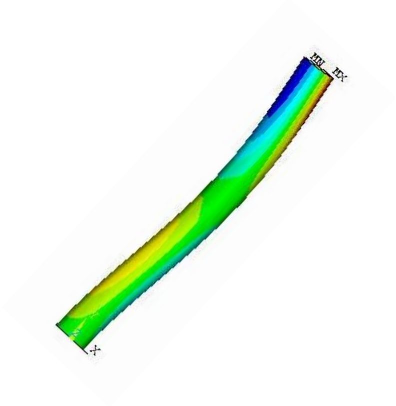

fig 3: Buckling mode 2 of the cylinder
(c-c boundary condition,L/d=10,h/d=0.1,n=4)

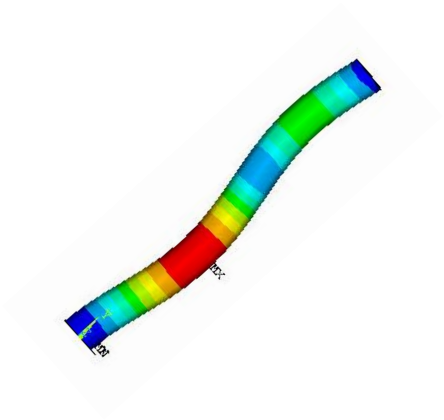

Fig 4: Buckling mode 3 of the cylinder
(c-c boundary condition, L/d=10,h/d=0.1,n=4)

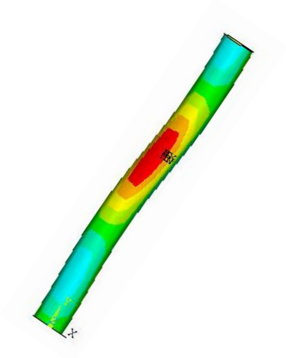

fig 5: Buckling mode 4 of the cylinder
(c-c boundary condition, L/d=10,h/d=0.1,n=4)

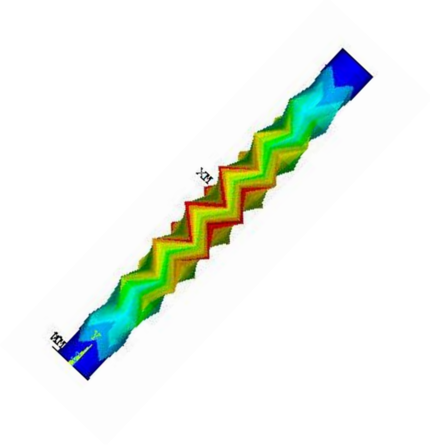

Fig 6: buckling mode 5 of the cylinder(c-c boundary condition, L/d=10,h/d=0.1,n=4)

Effect of boundary conditions

Fig. 7 shows the variation of buckling load with respect to mode number for c-c, c-s and s-s boundary conditions, which increases from mode 1 to mode 5. It is also further analyzed that for c-c condition, buckling load per unit length is more.

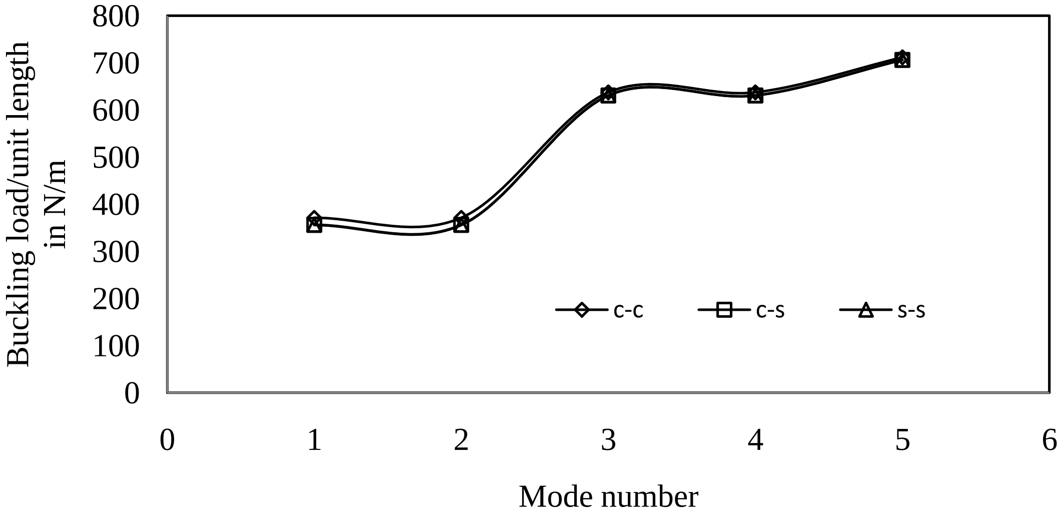

Figure 7: Effect of boundary conditions on buckling load per unit length (L/d =10, h/d= 0.1, n=4)

Effect of L/d ratio

From figs. 8 and 9, it is observed that buckling load per unit length for first mode reveals the fact that buckling load decreases with increase in L/d ratio.

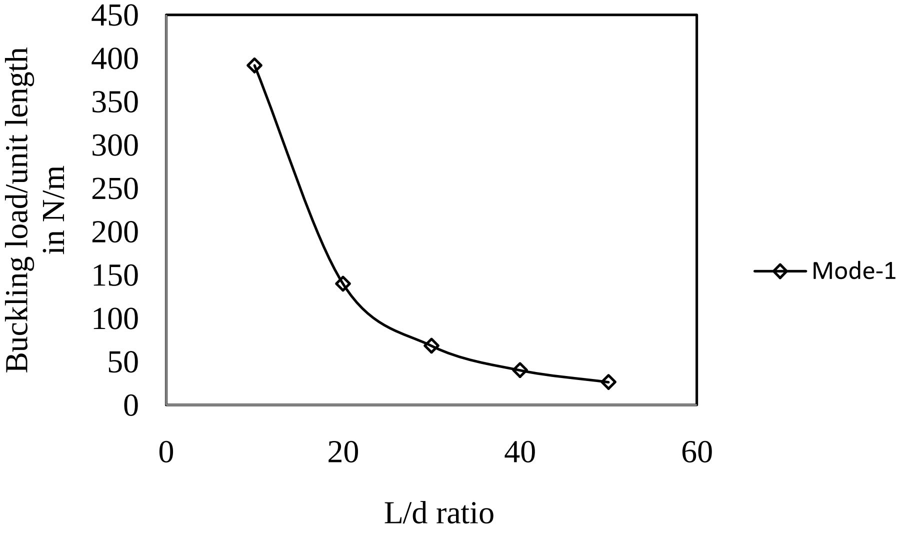

Figure 8: effect of L/d on first mode of buckling load/unit length (c-c, h/d=0.1, n=4)

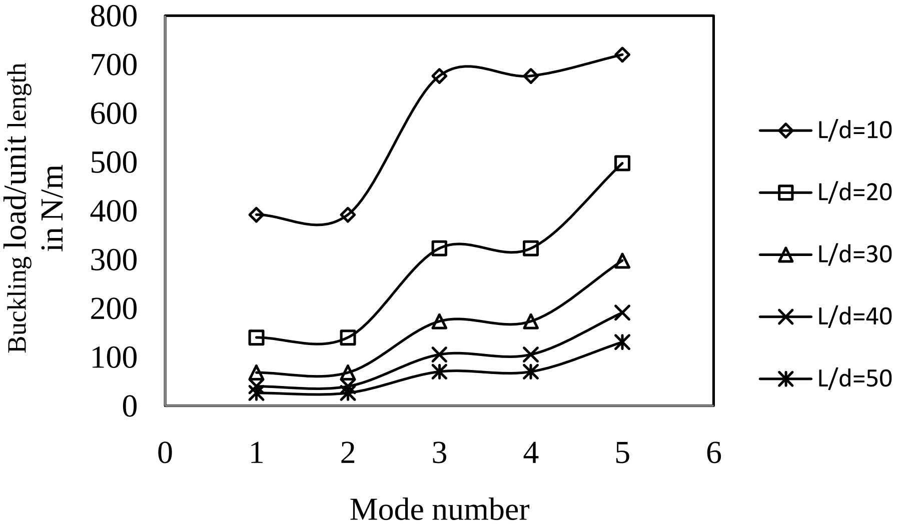

Figure 9: Effect of L/d on buckling load per unit length(c-c boundary condition, h/d=0.1)

Effect of h/d ratio

From figs. 10 and 11, it is observed that h/d ratio is influencing buckling load. Fig. 10 shows that buckling load for mode 1 with respect to h/d ratio. Here it is observed that the Buckling load increases with increase in h/d ratio. Fig. 11 shows the buckling load with respect to mode number. When the mode number increases from 1 to 5, buckling load is also increases.

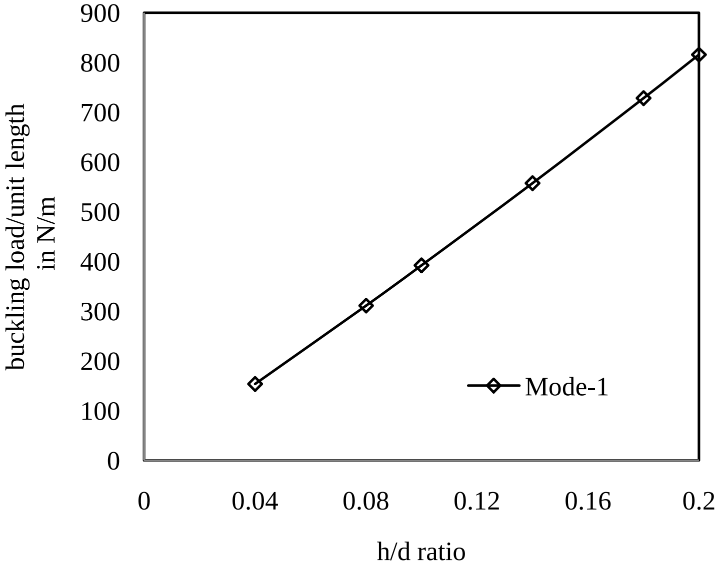

Figure 10: Effect of h/d ratio on the first mode of buckling load per unit length(c-c, L/d=10)

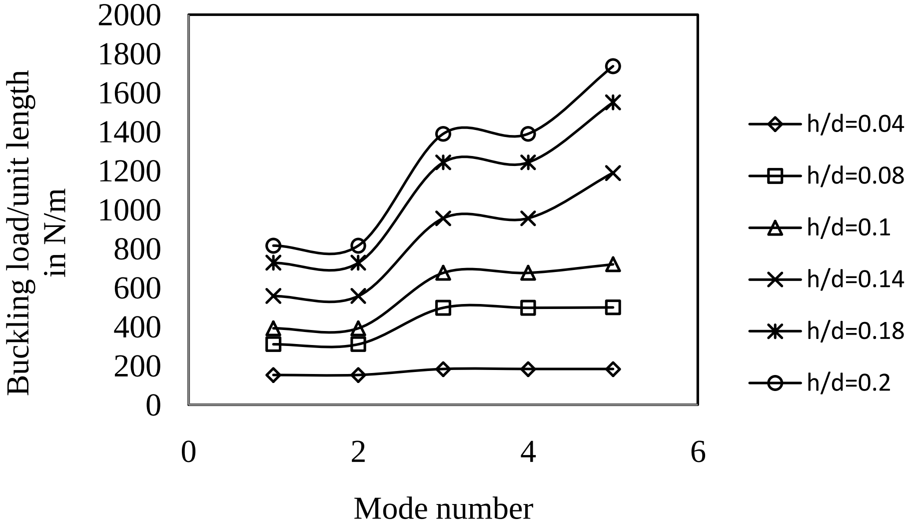

Figure 11: Effect of h/d ratio on buckling load per unit length (c-c boundary condition, L/d=10)

Effect of number of layers (n)

Figs. 12 and 13 show the effect of number of layers on the buckling load per unit length. Fig 12 shows that the buckling load increases from no.of layers 4 to 8, and then maintains a constant value with increase in number of layers. fig 13 shows the effect of buckling load on number of layers with mode number. It is observed that buckling load increases with increase in mode number.

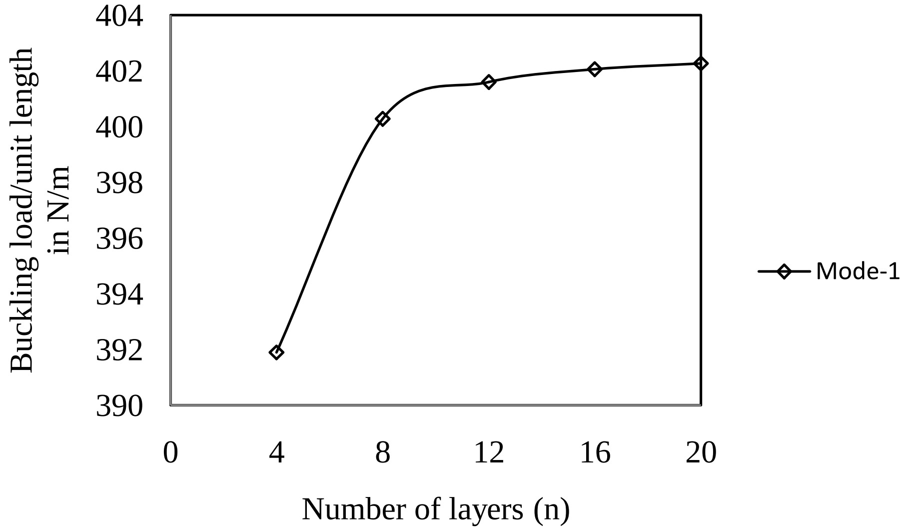

Fig 12: Effect of number of layers on first mode of buckling load per unit length(c-c, L/d=10)

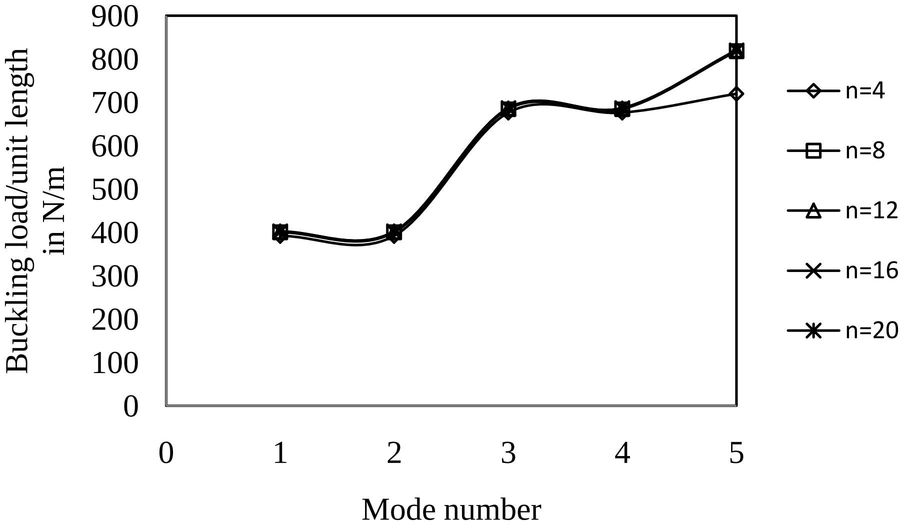

Fig 13: Effect of number of layers on buckling load per unit length (c-c boundary condition, L/d=10)

Conclusions

Buckling response of a four-layered thin symmetric cross-ply cylinder under uniaxial compression is predicted using finite element analysis based on classical laminate theory. The effect of boundary conditions, length to diameter ratio (L/d), thickness to diameter ratio (h/d) and number of layers on the buckling load is discussed. The study is useful in selecting the above said parameters in designing the laminates in buckling point of view.

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