Buckling Analysis of Composite Cylinders Subjected to Axial Compressive Loads

A. Eswara Kumar*
Asst. Professor
Dept. of Mechanical Engineering,
Dhanekula Institute of Engineering & Technology
Vijayawada,

Naveen Janjanam
Asst. Professor,
Dept. of Mechanical Engineering
K L University, Vaddeswaram

V. Diwakar, M. Nagaraju
Dept. of Mechanical Engineering,
Dhanekula Institute of Engineering & Technology.
Vijayawada

***Abstract*—Slender structures will buckle when subjected to pressure or compressive loads. Buckling is also important factor to decide the failure of the structure. Generally columns and higher length cylinders will buckle and they will be manufactured by the metals. In the present work slender cylinder subjected to axial compressive load manufactured by different composite materials is analyzed. The effect of cylinder length to thickness ratio, materials and stacking angle are analyzed. It results that as the cylinder length to thickness ratio is increasing, the buckling load is decreasing and carbon epoxy woven fabric with stacking angle of 90^{o} shows higher buckling load.**

Keywords—Buckling; Composite material; Axial compressive load; Ansys; E-orient; Stacking angle

I. INTRODUCTION:

Buckling is special phenomenon of the slender structures. They will bend when subjected to axial compressive loading. Buckling is also important factor to decide the failure of the structure. Pressure vessels, submarines and long columns will tend to buckle. To avoid the buckling failure, large amount of material will be used, it results the higher weight of the structure. Generally pressure vessels are manufactured by steel alloys. In present days to reduce the weight of the structures, these are manufacturing by composite materials like carbon epoxy, Glass epoxy etc. Buckling strength will also depends on the boundary conditions of the structure.

Buragohain et al [1] performed the optimal design analysis for the filament wound grid stiffened structures. He concluded that structurally, with specific buckling load as the criterion, a lattice cylinder with high rib thickness and without any skin is optimal. Tan hailin et al [2] performed the buckling analysis of pressure vessels by using the finite element analysis and concluded that all the different thickness of the autoclaves can obtain higher safety coefficient under the vacuum condition. Baoping cai et al [3] performed the buckling analysis of composite long cylinders by using the probabilistic finite element method and he concluded that the thickness of composite layers, transversal modulus, inside radius and longitudinal modulus have significant effects on the performance of composite long cylinders, whereas shear modulus, Poisson’s ratio, winding angle of outer layers, winding angle of inner layers and unsupported length have small influence. Subash et al [4] performed the buckling analysis of composite high pressure vessels and concluded that T-Sai Wu failure criteria can yield fairly good results with consistent accuracy for the composite pressure vessels. Priya darsini et al [5] performed the buckling analysis of cylinders with advanced composites. She said shown that the ultimate strength is affected by the method of loading (static, harmonic), the layup sequence, radius to thickness ratio and geometric imperfections. Rao et al [6] performed the buckling analysis with lamina sequence in both theoretical and numerical methods.

II. Problem Statement:

In this present work, Effect of the material, cylinder length to thickness ratio (L/T) ratio and stacking sequence are analyzed on the buckling load. The materials chosen for the analysis are carbon epoxy woven fabric, Glass epoxy, S2 glass epoxy. The L/T ratios are 300, 150, 75, 37.5, 50, 30. The stacking sequences are 0,15,30,45,60,75,90. Degrees

A. Problem Modelling:

The slender cylinder is modeled in Finite element simulation tool Ansys 12. The shape of the slender cylinder is as shown in Fig 1. The height of the cylinder is 1500 MM and inner diameter is 55mm and thickness is changing as described in above section.

Fig 1: Diagram of the cylinder.

B. Finite element meshing:

It is the process of converting the geometrical entities into finite element entities. The model is meshed with 8 node hexahedral element termed as Solid 46 in Ansys. It is a layered element can be accommodate up to 250 layers. Fine mesh is chosen to get the meshing convergence. The typical meshed model is as shown in Fig 2.

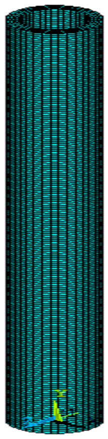


Fig 2: Meshed model of the Cylinder

C. Loads and boundary conditions:

A cylindrical co-ordinate system is created and numbered as 21. Nodes are rotated to cylindrical co-ordinate system because the cylinder is in cylindrical shape. For all the elements in the cylinder, cylindrical co-ordinate system is assigned. Both ends of the cylinder is clamped as shown in Fig 3. At the top end an axial compressive load is applied by removing DOF in that direction.

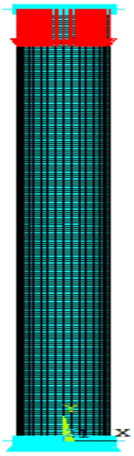


Fig 3: Loads and Boundary conditions

D. E-orient:

It is the necessary part when analyzing the composite structures. Composite materials have direction dependent properties. Generally they have higher stiffness in the direction of the fiber. So setting the direction of the fiber in Ansys E-orient is done. The small dash in the highlighted elements represents the fibers. The fibers are placed along the circumferential direction as shown in Fig 4, it represents the 0^o fiber orientation.

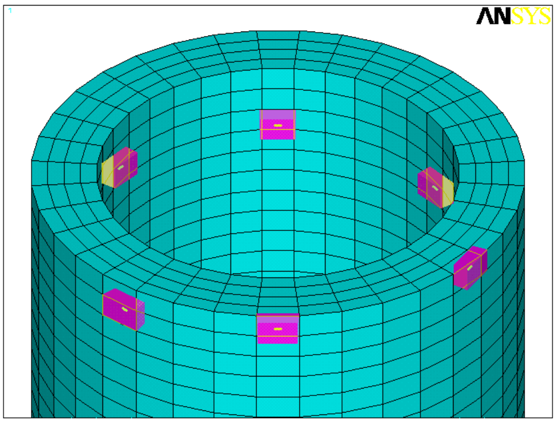


Fig 4: E-orient of the elements

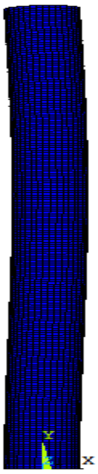
E. Materail Properties of composite materials:

Table 1: Properties of materials

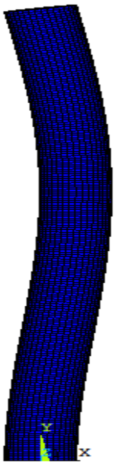
Material/Property	Carbon Epoxy woven fabric	S-2 glass FGI-1800	E-glass M10E /3873
E_1 (MPa)	77000	22200	24500
E_2 (MPa)	75000	20300	23800
E_3 (MPa)	13800	10000	11600
υ_{12}	0.06	0.11	0.11
υ_{23}	0.37	0.17	0.20
υ_{13}	0.5	0.14	0.15
G_{12} (MPa)	6500	4500	4700
G_{23} (MPa)	4100	3900	3600
G_{13} (MPa)	5100	3400	2600

III. RESULTS & DISCUSSIONS

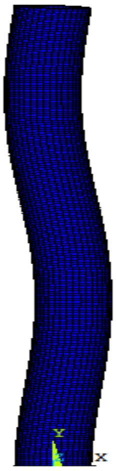
A. Buckling Mode shpes



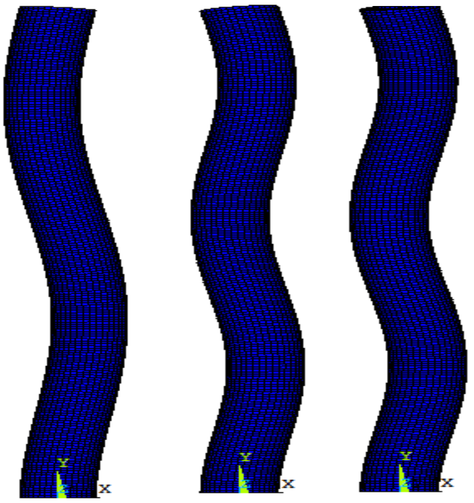
Mode-1



Mode-2



Mode-3



Mode-4 Mode-5 Mode-6

Fig 5: Buckling Mode shapes 20mm thick cylinder

The above figure shows the typical buckling shapes of cylinder having 20mm thickness. Even though the 1st and 2nd mode values are equal as shown in Fig 6, the mode shape is different. Same type of phenomenon can be observed in mode 3,4 and mode 5,6. It can be observed that from the mode 3 onwards, cylinder showing more than one half sine wave.

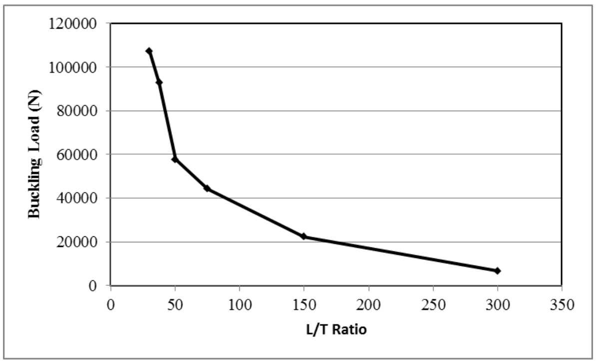


Fig 6: Variation of buckling load w.r.t L /T ratio (Mode-1,2)

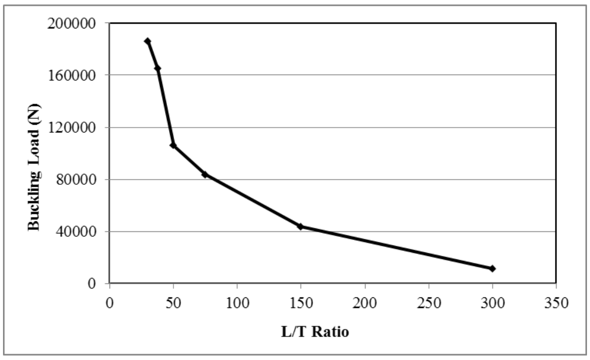


Fig 7: Variation of buckling load w.r.t L /T ratio (Mode-3,4)

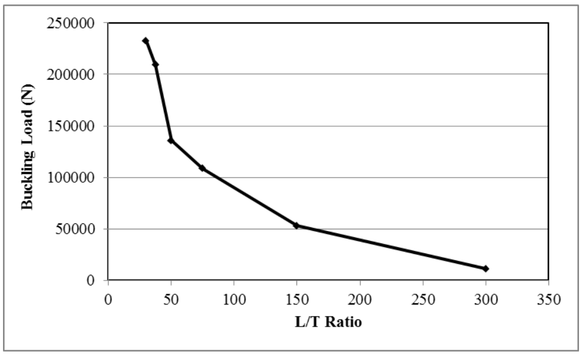


Fig 8:Variation of buckling load w.r.t L /T ratio (Mode-5,6)

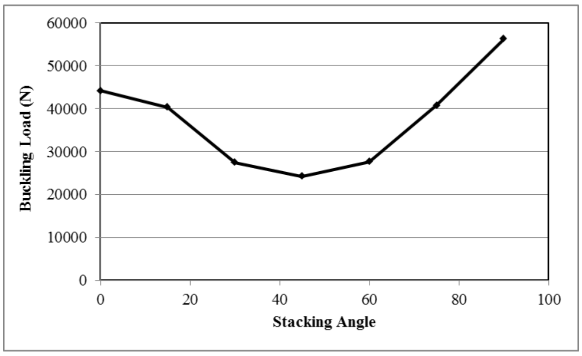


Fig 9: Variation of buckling load w.r.t stacking angle (Mode-1,2)

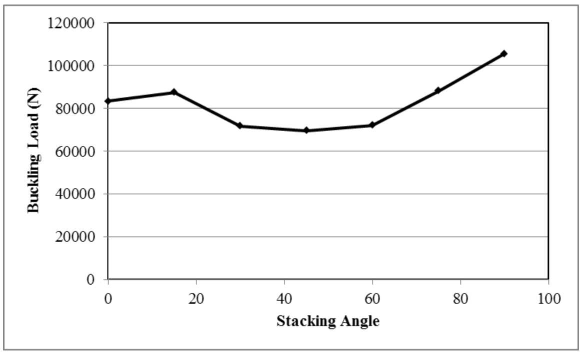


Fig 10: Variation of buckling load w.r.t stacking angle (Mode-3,4)

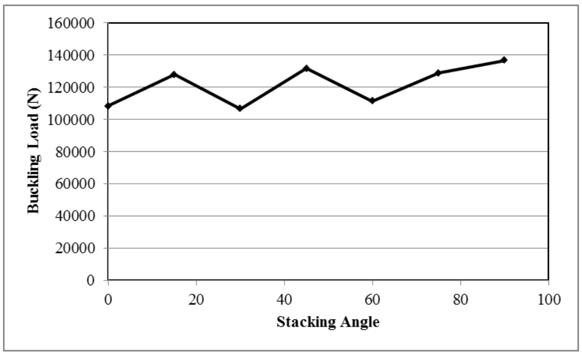


Fig 11: Variation of buckling load w.r.t stacking angle (Mode-5,6)

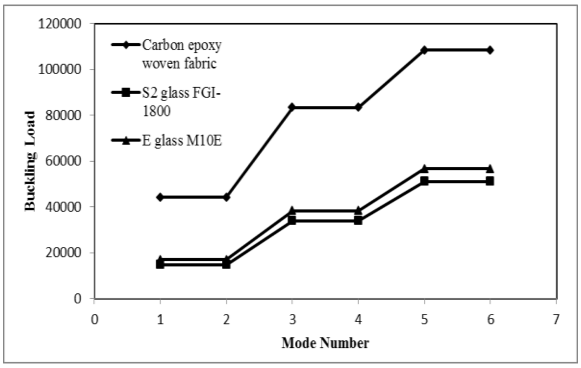


Fig 12: Variation of buckling load for different composite materials

From the Fig.6 to 8 it can be observe that as the L\T ratio is increasing (the thickness of the structure is decreasing), the buckling load is decreasing. i.e for the lower thickness structures, lower load is sufficient to buckle the structure. In aspect of the stacking angle from Fig 9 to 11, it can be observed that stacking angle 90 has higher buckling load followed by 75 deg. But one has to see the possibility of the stacking while manufacturing. In the aspect of the material from the Fig 12, it can be observed that carbon epoxy woven fabric has better buckling load than the remaining composite materials for all modes.

IV.CONCLUSIONS:

From the above discussions it can be concluded that as the L\T ratio is increasing, the buckling load is decreasing. Carbon epoxy woven fabric is the best material in the point of buckling for materials considered with a stacking angle of 90 deg. It is necessary to select the appropriate L\T ratio based on the application.

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