Buckling analysis of composite cylindrical Shell under compressive load

Y. Pratapa Reddy, B. Aditya Mani Sai Pavan, K Satyanarayana, T. Veeraiah

ABSTRACT--- The cylindrical components generally are subjected to buckling load in many of the applications. The shear stresses and the deformation of the material play key role in the life of the component. The present research involves the evaluation of such cylindrical component made of epoxy material, subjected to compressive load. The cylinders are made in two types, without and with reinforcement of fibres, with 0, 1, 2 and 4 holes equally spaced around the lateral surface. The system is simulated using ANSYS. The results obtained from the experimentation are analysed.

Key Words: Composite material, Buckling Factor, Graphite, Epoxy, Cylindrical Shell, Inter-laminar Stresses, Intra-Laminar Stresses.

I. INTRODUCTION

A composite material means, the material is prepared by a combination of two different materials but it acts as a single material and providesa unique properties which are differentcompared to their parent materials.It maintains a special features like high strength with low weight, so that it is commonly considered in differentindustrieslike Aerospace, Automobile, etc., It also exhibits high thermal conductivity, and some other mechanical properties like fatigue, stiffness, temperature dependent behaviour, corrosion resistance, thermal insulation, wear resistance.

These thin-walled cylindrical shells have much importance in aerospace structural applications due to better loading capacity and less structural weight. These aerospace shell structures have various shaped openings used as doors, windows, etc.,In general, any cylindrical component which has openings often require some type of reinforcing structure to control the internal structural deformations and stresses which shows the initiation of cracks and flaws at openings under loading conditions.Their buckling response characteristics play a key role and should be accurately predicted in order to make effective designs and to specify safe operating conditions for these structures.

In the present work, an attempt is made to analysethe deformations occurred during compressive load on a cylindrical shell with the presence and absence of openings by using the finite elementanalysis. On shell the load was applied as compressive load and parameters like Inter-laminar, Intra-laminar stresses, buckling factor and deformation under with and without reinforcement of Graphite /Epoxy composite laminate material was studied.

II. LITERATURE REVIEW

A critical load is applied which leads the material to failure under compressive when it is applied on cylindrical shells to find the buckling factor of shell[1].To reduce the overall weight ,these shells are made of composite materials which exhibits different properties other than its parent material and are dependent upon different factors like inter-laminar structures, types of fibres filled ,procedure of lamination ,composition of material etc.,[2].Theses shells are maintained by small openings which acts as doors and windows ,but when the shell undergoes a compressive load , these openings should be supported with a reinforcement to avoid the initiation of cracks. The failures and responses in these shells when they are taken as quasi static isotropic laminated under compressive load was numerically studied.[3].The cracks are initiated may be due to degradation of material at laminated panels which occurs due to both inter and intra laminar failures and also due to shear mode and failure mode of fibre matrix [4,5]. By preference, a flat plate under linear analysis by its preliminary design wit square shaped opening was analyses by standard method and a curved panel was tested under axial compression load which shows a geometrically non-linear response and failure [6,7]. The effects of initial geometrical imperfections was accurately predicts the shell under buckling analysis due to compressive load [8]. A high feasibility analysis was applied successfully on other similar compression loaded shells which has openings of circular holes and are verified comparing with weak sections of circular holes [9, 10]. The stability of cylindrical shells with different shaped cut-outs like circular and rectangular cut-outs are demonstrated [11]. The theoretical and experimental investigations are carried out on local inter laminar axisymmetric imperfections under different axial loads [12].

III. FINITE ELEMENT METHOD

Finite element method is used to analyse the component by discretising into finite elements of different shapes. Element selection and mesh generation plays a key role in analysing the component. SHELL-99 element is usually preferred for structural shell models with layered

Revised Manuscript Received on December 22, 2018.

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applications. Though some nonlinear capabilities are missing from SHELL-91, however it has smaller element formulation time and allows up to 250 layers. A user-input constitutive matrix is considered which is available if more than 250 layers are required. This element has six degrees of freedom, translations and rotations in the nodal x, y, and z directions The geometry of Shell-99 element is shown in below Fig-1.

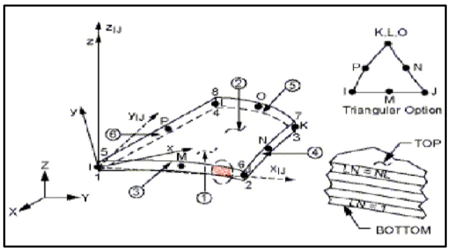

Fig-1 Geometry of Shell-99 element

Dimensions, Properties and Assumptions

Dimensions:

- ❖ Length of the Shell =16mm
- ❖ Radius of the Shell =8mm
- ❖ Thickness of Shell =0.04mm
- ❖ Thickness of ply =0.005mm
- ❖ No of plies =8
- ❖ Dimension of cut-outs =1mm*1mm

Properties of Material:

- ❖ Longitudinal modulus,El = 18.5E6 MPa
- ❖ Transverse modulus,Et =1.64E6MPa
- ❖ In-plane shear modulus, Gxy =0.87E6MPa
- ❖ In-plane shear modulus,Gyz =0.51E6MPa
- ❖ Major Poisson's ratio,υ = 0.30

- ❖ A compressive load applied is 200 Nat the top of the shell.

To analyse the shell we need to assume some basic assumptions which are mentioned below. They are

- ❖ The material at its each level of layer / ply is assumed as quasi –homogeneous and orthotropic.
- ❖ Orientation of fibres may vary from lamina to lamina
- ❖ The displacement occurred in the lamina due to load is assumed to be continued equally throughout the lamina in 2D plane.
- ❖ Similarly the deformation is also assumed to be the same like that of above and assumed to be small.
- ❖ The thickness of the lamina or layer is very thin and is load is assumed to be applied in its plane surface only.
- ❖ Plane stress is assumed to be applied at the edges only.

The front view and top view of composite shell with hole in the shell is modelled in ANSYS Workbench which is shown in Fig-2.

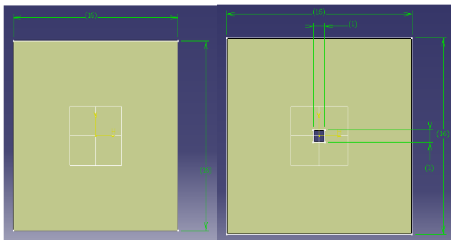

Fig-2

The composite shell with reinforced hole and its top view is shown in below Fig-3.

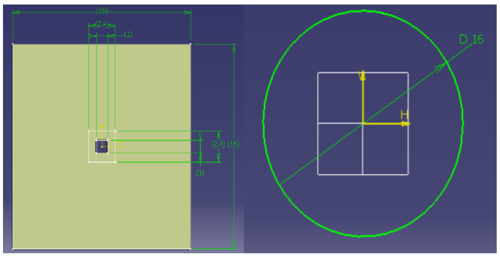

Fig-3

IV. METHODOLOGY

The analysis is done in various steps. At first a composite shell is modelled in ANSYSworkbenchconsidering an element of SHELL-99 withdesired dimensions. Asquare shaped cut-out is made with 1 mm size, with reinforcement and without reinforcement was modelled. The compressive load of 2KN was applied to find out the buckling factor,deformation and inter-laminar shear stress occurred in the composite shell.The deformation,buckling factor of the shell is determined by providing one hole, two holesand at four holes.

V. RESULTS AND DISCUSSIONS

Nodes and Elements: To make an analysis and to find the buckling factor the shell is modelled and meshed without cut outs and without reinforcement and later it is meshed with number of holes in it. The number of nodes and elements formed during mesh generation under reinforcement and without reinforcement are shown below figures from Fig-4 to Fig-7.

Without reinforcement:

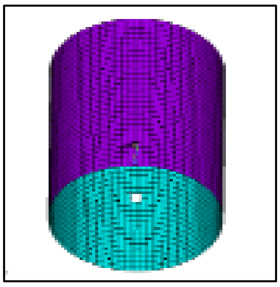

Fig - 4

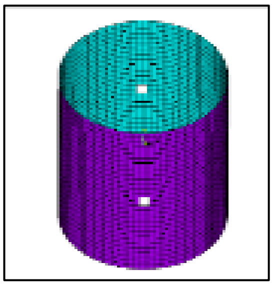

Fig-5

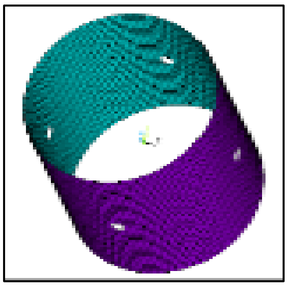

Fig-6

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With reinforcement:

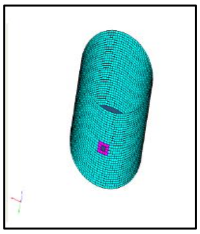

Fig - 7

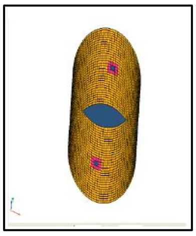

Fig-8

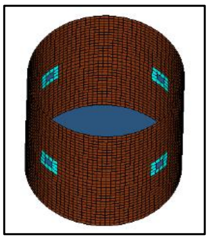

Fig-9

From the above figures, the first figure ie., Fig-4 shows the mesh generation of shell without reinforcement and with one square cut out of size 1mm X 1mm is provided in shell, and the remaining figures of Fig 5 and Fig -6 shows the meshgeneration by providing two holes and four holes respectively.

Similarly in the second stage shell is analysed and mesh is generated with reinforcement in the shell and Fig-7 shows the mesh generation of shell with reinforcement and with one square cut out of size 1mm X 1mm is provided in shell, and the remaining figures of Fig -8 and Fig -9shows the mesh generation by providing two holes and four holes respectively.

The Table -1 shows the comparison of nodes and elements formed during mesh generation of shell and observed that the number of elements gets decreased with number of holes increases in both the conditions of with and without reinforcement.

Table -1 Comparison of Elements and Nodes

	without Reinforcement		with Reinforcement	
	Elements	Nodes	Elements	Nodes
With 1 hole	3196	9765	3196	9795
With 2 holes	3192	9790	3192	9790
With 3 holes	3184	9780	3184	9780

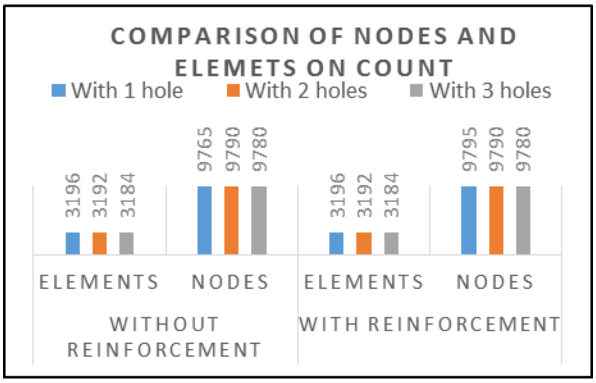

Fig-10 Graphical Comparison of elements and nodes

The above fig-10 shows the graphical comparison of nodes and elements formed during mesh generation.

Buckling Factor and Deformation: By the application of compressive load on the shell under two considerations of with and without reinforcement, the shell undergoes buckling and deformation which occurs in the shell are shown in the below figures from Fig-11 to Fig-13.

From the figures, the Fig-11 shows the buckling and deformation analysis of shell without reinforcement and with one square cut out in it, and the remaining figures of Fig 12 and Fig -13 shows the buckling factor and deformation analysis by providing two holes and four holes respectively.

Similarly in the later stage, shell is analysed to find out buckling factor and deformation with reinforcement in the shell which is shown in Fig-14 and the remaining figures of Fig -15 and Fig -16 shows analysis of shell with reinforcement and with two and four holes respectively.

Without Reinforcement:

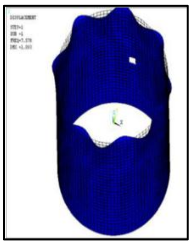

Fig - 11

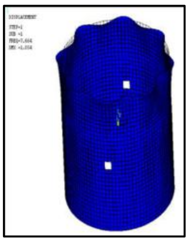

Fig-12

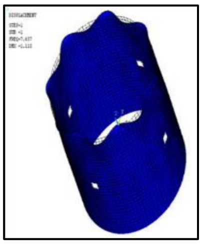

Fig-13

With Reinforcement:

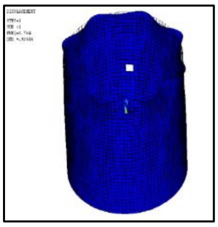

Fig - 14

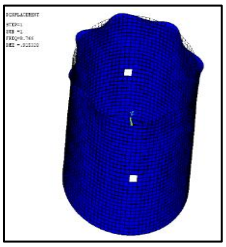

Fig-15

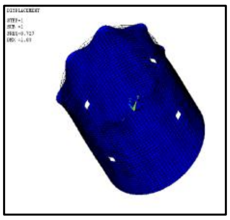

Fig-16

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From the above analysis the buckling factor and deformation values of composite shell under compressive load of 200KN is tabulated in the below Table 2.

Table 2Comparison of Buckling Factor and Deformation

	without Reinforcement		with Reinforcement	
	Buckling Factor	Deformation	Buckling Factor	Deformation
With 1 hole	7.75	1.093	8.764	0.9344
With 2 holes	7.664	1.094	8.766	0.9153
With 3 holes	7.637	1.113	8.727	1.03

From the above table, we observe that the buckling factor is decreased by increasing the number of holes in the shell when the reinforcement is not considered in the shell and the buckling factor has undergone variations when reinforcement is considered for analysis of shell.The deformation is getting increased by the increasing the number of holes when the analysis of the shell is done without considering the reinforcement but it has undergone little variations when the analysis is done with reinforcement. It is mainly due to the Young's Modulus(E)of material which restricts.

The below fig-17 shows the graphical comparison of buckling factor and deformation of shell during analysis.

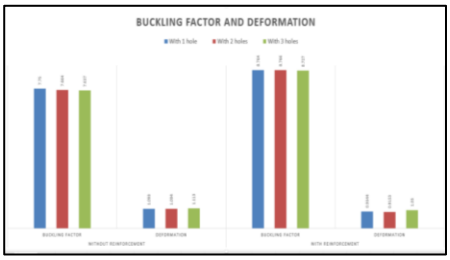

Fig-17 Graphical comparison of buckling factor and deformation

Interlaminar Shear Stresses: The compressive load applied on the shell induces stresses in the material and the stress analysis are shown in below figures from Fig 6.14 to 6.17

By observing the below figures, the values of interlaminar stresses are analysed and compared.

Without Reinforcement:

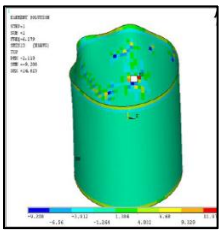

Fig - 18

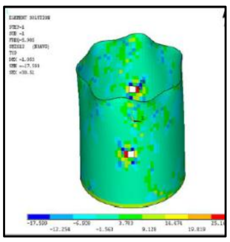

Fig-19

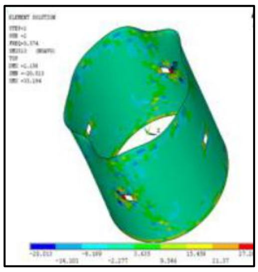

Fig-20

With reinforcement:

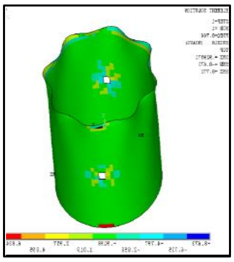

Fig - 21

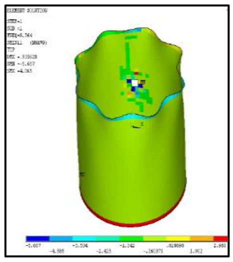

Fig-22

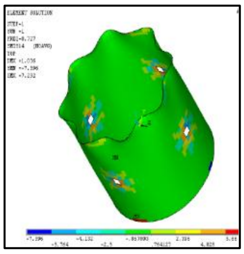

Fig-23

From the above figures, the Fig-18 shows the Interlaminar stress analysis of shell without reinforcement and with one square cut out made in it, and the remaining figures of Fig-19 and Fig -20shows the same analysis is done by providing two holes and four holes respectively.

Similarly in the next stage, shell is analysed to find out Inter-laminar stresses with reinforcement in the shell which is shown in Fig-21 and the remaining Fig-22 and Fig-23shows analysis of shell with reinforcement and with two and four holes respectively.

From the above analysis the Interlaminar stress values of composite shell under compressive load of 200KN is tabulated in the Table 3

From the Table 3 below, it is observed that the Inter-laminar stress are increased when holes are increased in case of without reinforcement,but in the case of reinforcement is considered these stresses are varied.

Table 3 Comparison of Interlaminar Shear Stress

	without Reinforcement		with Reinforcement	
	Max	Min	Max	Min
With 1 hole	14.625	-9.208	4.065	-5.667
With 2 holes	30.51	-17.599	8.772	-8.673
With 3 holes	33.134	-21.413	7.292	-3.396

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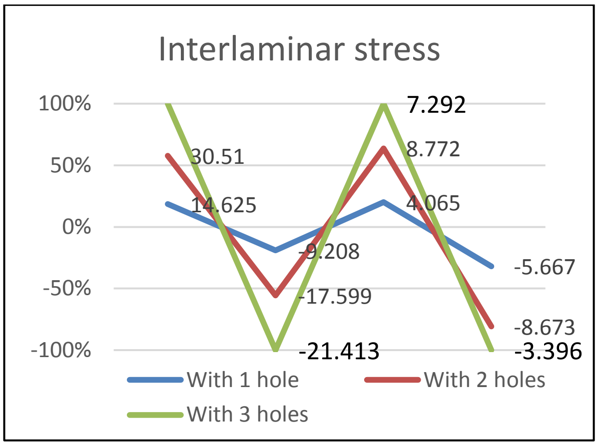

Fig -24 Graphical Comparison of Interlaminar stresses in shell

The above Fig -24 shows the graphical representation of Interlaminar stresses occurred in the shell under compressive load with reinforcement and without reinforcement.

VI. CONCLUSIONS:

The results which are shown in above Figures are occurred by simulation analysis done on cylindrical shell made of Epoxy material. The objective of this analysis is to find out the buckling factor, deformation and Inter-laminar stress caused in the shell.

From the above analysis the below conclusions are made. They are

- The Buckling factor is maximum of 7.570 and deformation is 1.093 with one hole in the shell.
- The maximum buckling factor and deformation without a hole in a shell are 7.664 and 1.094
- The maximum buckling factor and deformation is observed as 7.637 and 1.113 of shell with and with reinforcement at the hole
- Inter-laminar shear stress occurs as maximum at the bottom of shell and also at free edge of the shell.

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