

Design and Thermal Analysis of Container using Kevlar for an Automotive Application

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Abstract – It is necessary for a researcher to identify the effect of buckle on diverse structures. The reason behind the issue is most of the successful designs fail at the practical application. In this paper, a solid Kevlar structure container various layers has been designed and analyzed thermally its buckling effect with or without a hole using ANSYS and FET. A circular cylindrical shell elliptical headed container is considered due to its outstanding demand in the pressure vessel and automobile engineering. The attention-grabbing stage of buckling phenomena occurs before the deformed or non-deformed and a partial deformed sometimes contour of structure. Finally, concluded with pros and cons of using Kevlar composites in high temperature environment.

Keywords – Kevlar – buckling – with and without hole – storage tanks --- finite element technique and elliptical head structure

I. INTRODUCTION

A pressure vessel is a container designed to hold gas or liquid at high pressure at distinct ambient pressure. However, vessels must be designed with a formal code like ASME and BPVC etc., include Storage tanks, glassware, autoclaves, compressed gas cylinders and compressors in refrigerators. However, the most common type of pressure vessel is storage tanks to store liquids and gases for industrial and automotive purposes or processes. Heat exchangers and Process vessels are used to remove, combine, agitate, or break down products in a controlled environment in engineering industry. The pressure tank creates high water pressure using compressed air to open and close the valve by pushing or pulling. The Kevlar is a material that chemically, thermally stable with a high tensile and toughness. It can withstand at a high temperatures in polyamides. It is used as a friction, combustion protector material in the automotive industry and an aerospace industry respectively. Recent researches put forward the usage in advanced and modern technological application Nevertheless of its disadvantages of efficiency quickly absorbs moisture, it is used in both bulletproof and stab proof vests manufacturing. Now days, the material Kevlar weaving is most popular protective tool in defense industry. But Kevlar products are most costly to produce due to difficult process of spin fibers and use of sulfuric acid.

II. LITERATURE REVIEW

In a thin laminated composite cylindrical shell a static and buckle analyses is done to determine the stress and deformation fields with an elliptical head without cutout and with cutout is presented. A self designed steel structure is modeled using PRO/E and the analysis is done by using ANSYS. The result has been concluded that the steel displacement without cut is much higher than with cut. The buckling factor is increasing with the increase in displacement [6]. A result is obtained by an analysis that maximum tangential stress resultant concentration near a circular cutout in a tension-loaded, circular, quasi-isotropic shell increases by approximately 18% as the shell radius-to-length ratio decreases. [1]. an efficient finite element model developed based higher order zigzag theory covering different features of laminated composites such as boundary conditions, ply orientations aspect ratio, thickness ratio and loading. A numerical result on buckling responses for different problems defined finite element model for laminated composite plates was capable to the exact solutions and recommended for research and industrial applications [2]. The critical buckling load factor of anti symmetric composite laminates presented on the effect of the skew angle, aspect ratio, length-to-thickness-ratio, fiber orientation angle, numbers of layers in the laminate and laminate sequence on the critical buckling load factor was found to increase with the skew angle depends on the laminate was large, the variation of critical buckling load factor with the number of layers was not appreciable [3]. The study for elastic buckling behavior of laminated composite plates with through-the-width de-laminations are focused on various parameters, such as size of de-lamination, support condition, aspect ratio, width-to-thickness ratio, stacking sequences, and location of de-lamination and multiple de-laminations It was noted that variations in length-to-thickness ratio affects the critical buckling load. The buckling load decreases as the a/t ratio increases. [4] [5].

III. STRAIN ANALYSIS OF PRESSURE VESSEL WITHOUT CUT

1. Import iges Model from Pro/Engineer

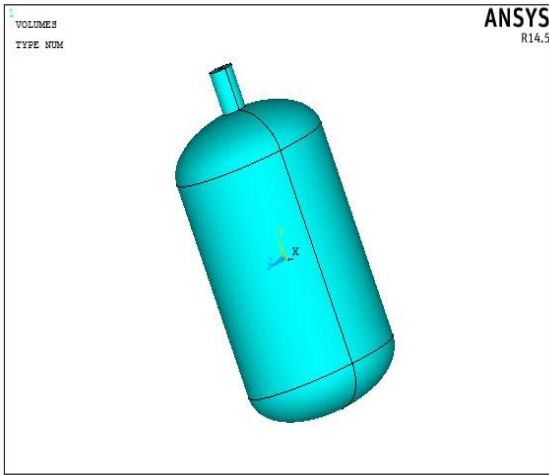


Figure 1. Import iges Model from Pro/Engineer

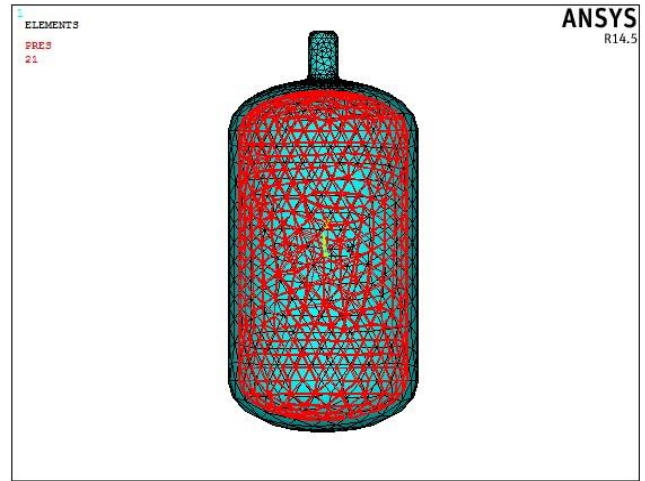


Figure 3. Loads sharing on the container all areas

Enter units in command prompt: /units, si, mm, kg, sec, k
 Preferences: structural
 PREPROCESSOR:
 Main Menu> Preprocessor> Element Type> Add/Edit/ Delete
 ADD Element Type: solid 20 nodes 95
 Material Properties
 Structural Properties: (KEVLAR)
 Density – 0.0000144Kg/mm³
 Young's Modulus – 112000Mpa
 Poisson's ratio - 0.36

1. Meshed Model

Main Menu> Preprocessor> Meshing> Mesh
 Tool>Smart size set to7
 [Mesh]
 [Pick All]
 [Close] Warning.
 Meshed Model

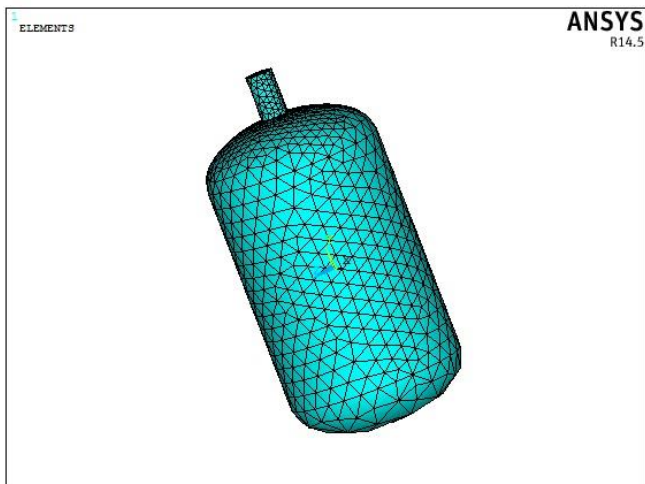


Figure 2. Meshed Model

LOADS

>Apply>Structural>Displacement >On Areas>All
 Dof >ok

>Apply>Structural>Pressure> On Areas – 21

Solution
 Solution – Solve – Current LS – ok
 Post Processor
 General Post Processor – Plot Results – Contour Plot - Nodal
 Solution – DOF Solution – Displacement Vector Sum

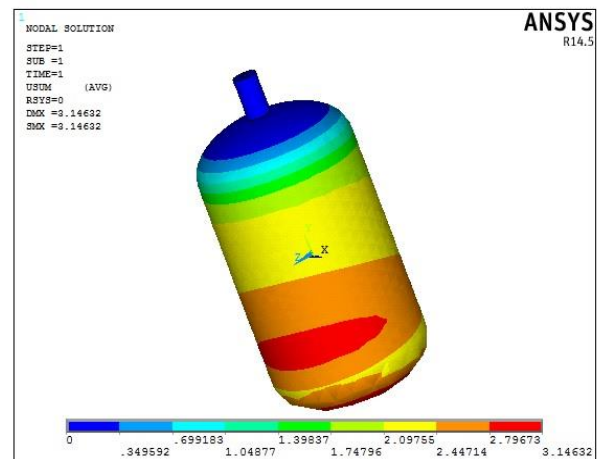


Figure 4. Displacement vector

The maximum displacement is 7.68906mm and the minimum is 0.85434mm.

General Post Processor – Plot Results – Contour Plot – Nodal
 Solution – Stress – Von Mises Stress

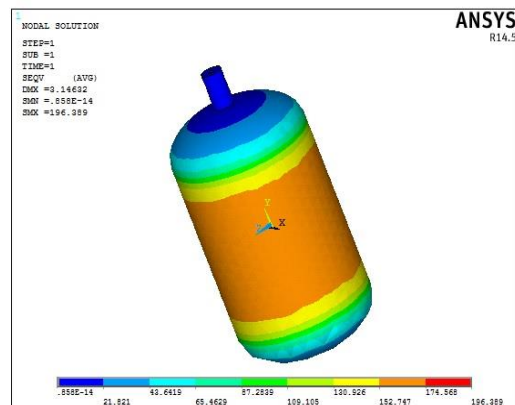


Figure 5. Von Mises Stress

The maximum stress is in the range of 310.949 N/mm² to 38.8687 N/mm² which is at the head of the pressure vessel.

The maximum displacement is 2.60512mm and the minimum is 0.289458mm.

General Post Processor – Plot Results – Contour Plot
 Nodal Solution – Stress – total mechanical Von Mises

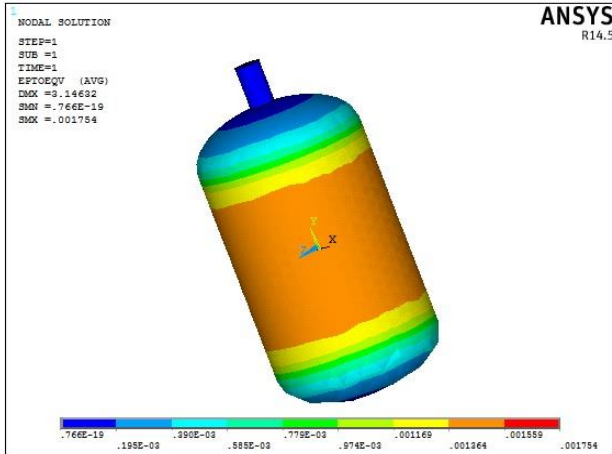


Figure 6. Strain propagation

Strain

The maximum strain is 0.372e⁻³ and the minimum strain is 0.003351

TABLE1. Displacement, Stress and Strain Kevlar

	KEVLAR
DISPLACEMENT (mm)	3.14632
STRESS (N/mm ²)	196.389
STRAIN	0.001754

IV. STRAIN ANALYSIS OF PRESSURE VESSEL WITH CUT

1. Import Model

Material Properties: Kevlar
 Young modulus- 112000mpa
 Poisson's ratio - 0.36
 Density- 0.00000144
 Displacement vector sum

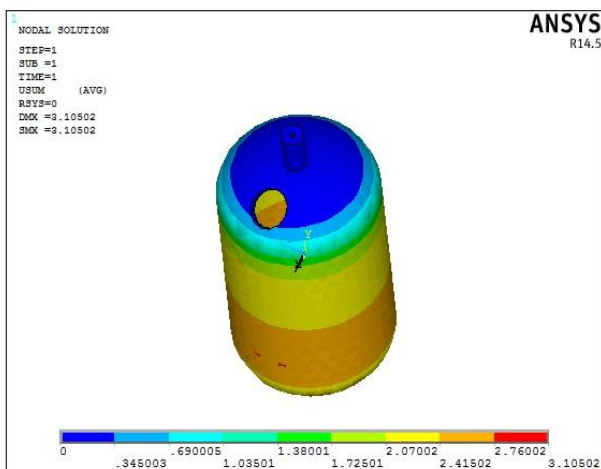


Figure 7. Imported model with cut

Stress

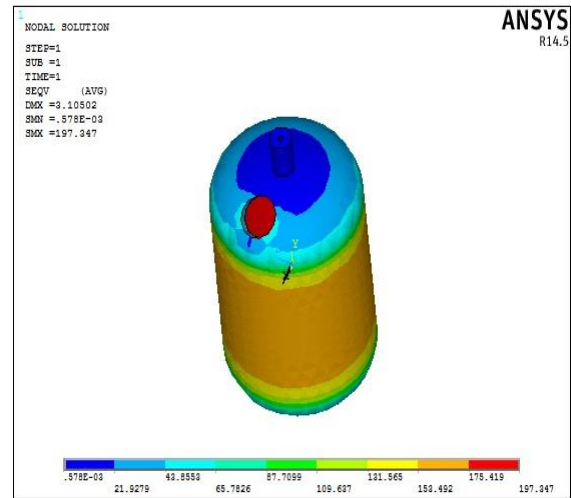


Figure 8. Stress Analysis with cut

The maximum stress is in the range of 147.185 to 165.583N/mm² which is near the hole

Strain

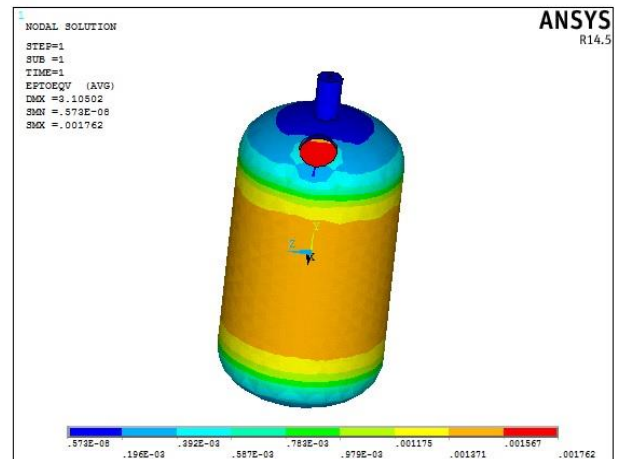


Figure 9. Strain Propagation with cut

The maximum strain is 0.001479 and the minimum strain is 0.164e⁻³

TABLE 2. Displacement, Stress and Strain with cut

	Displacement(mm)	Stress(N/mm ²)	Strain
KEVLAR	3.10502	197.347	0.001762

2. Kevlar Material

Young's Modulus – 112000Mpa
 Poisson's ratio – 0.36
 Density – 0.00000144Kg/mm³
 First Set

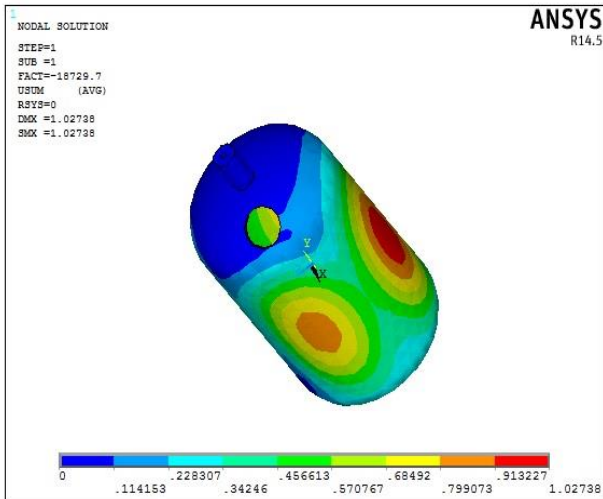


Figure 10. Kevlar with cut For the first mode, the maximum displacement is 1.02738mm and buckling factor is 18729.7.

Second Set

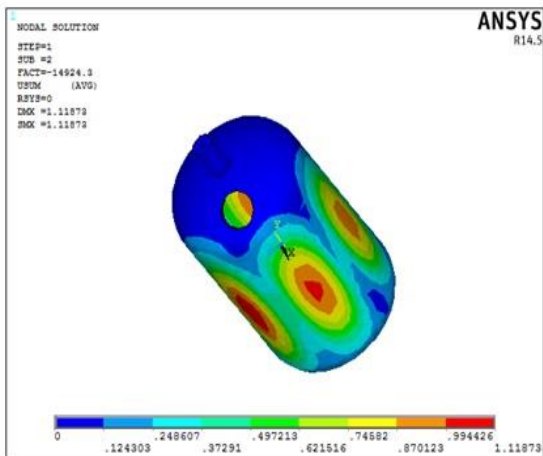


Figure 11. For the second mode, the maximum displacement is 1.11873mm and buckling factor is 14924.3.

Third Set

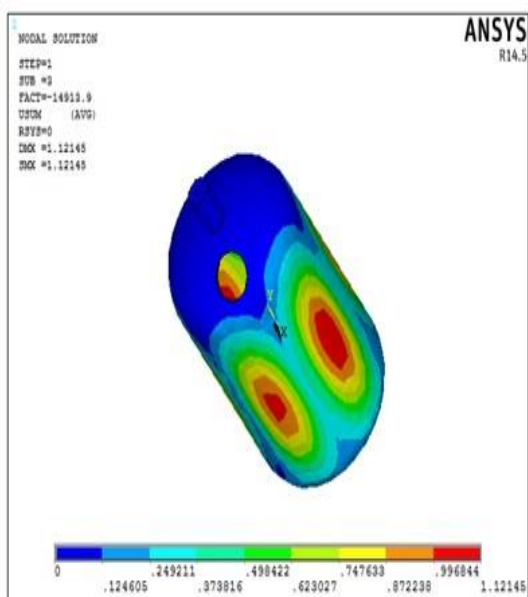


Figure 12. For the third mode, the maximum displacement is 1.12145mm and buckling factor is 14913.9.

TABLE 3. Sets and factors

	First Set		Second Set		Third Set	
	DISP (mm)	FACTOR	DISP (mm)	FACTOR	DISP (mm)	FACTOR
Kevlar	1.02738	26142.2	1.11873	10771.2	1.12145	14913.9

V. SHELL ELEMENT - 5 LAYERS

1. Import Kevlar Material

Preferences>select structural>ok

Preprocessor>element

type>add/edit/delete>shell>linear layer99>ok

Real constants>add/edit/delete>enter no of layers 5>ok

Material properties of KEVLAR

Young's Modulus – 112000Mpa

Poisson's ratio – 0.36

Density – 0.00000114Kg/mm³

Sections>Shell>lay-up>add/edit>enter thickness>ok

Plot section>range of layers 1-5>ok

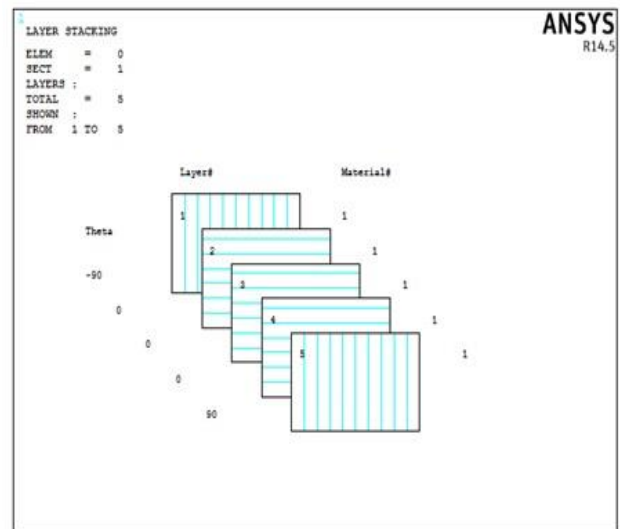


Figure 13. 5 layered kevlar Material

Meshing>mesh tool>ok

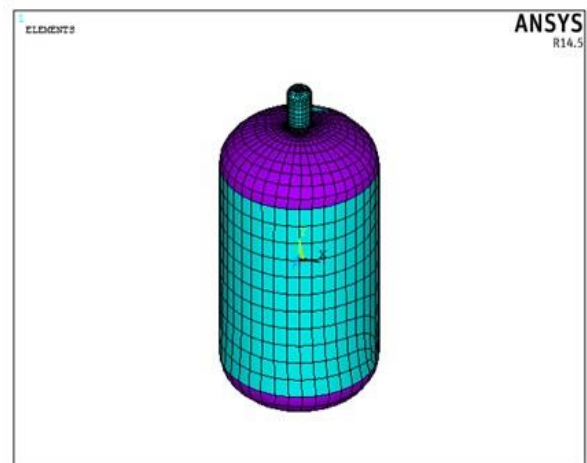


Figure 14. Mesh model kevlar Material

Apply loads
 Pressure=0.0139MPa
 Solution>solve>current Is>ok
 General post processor>plot results>counter
 plot>nodal solution>ok
 Displacement>displacement vector sum>ok

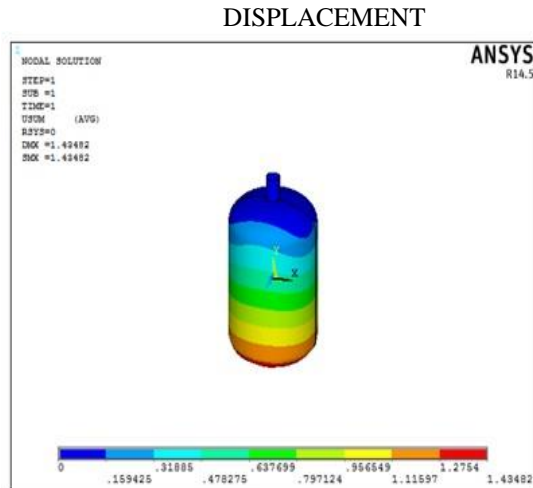


Figure 15. The maximum displacement is 1.43482mm and minimum displacement is 0.159425mm

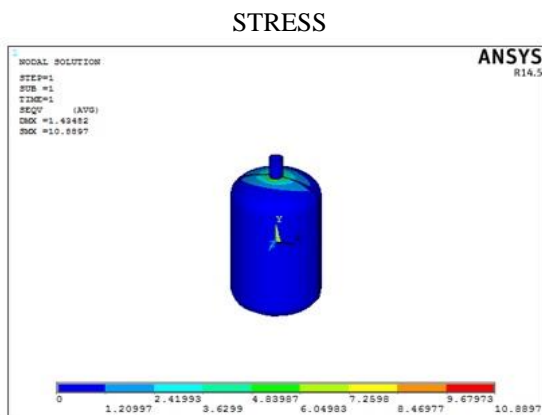


Figure 16. The maximum stress is in the range of 9.67973N/mm² to 10.8897N/mm².

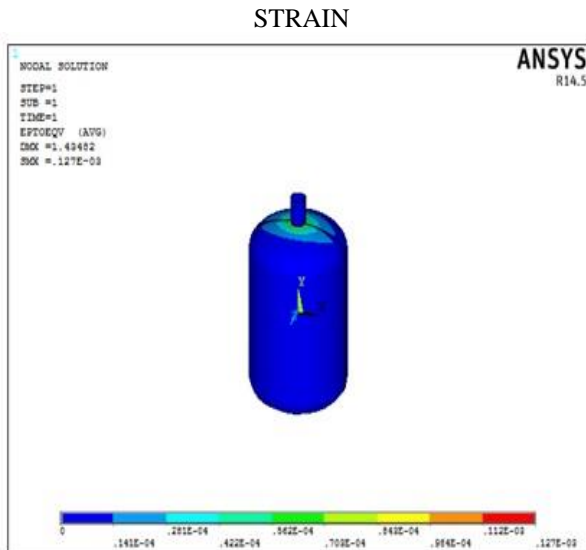


Figure 17. The maximum strain is 0.127e⁻³ and minimum strain is 0.141e⁻⁴

VI. SHELL ELEMENT - 11 LAYERS

Preferences>select structural>ok
 Preprocessor>element
 type>add/edit/delete>shell>linear layer99>ok
 Real constants>add/edit/delete>enter no of layers
 11>ok
 Material properties of KEVLAR
 Young's Modulus – 112000Mpa
 Poisson's ratio – 0.36
 Density – 0.0000114Kg/mm³
 Sections>Shell>lay-up>add/edit>enter thickness>ok
 Plot section>range of layers 1-11>ok

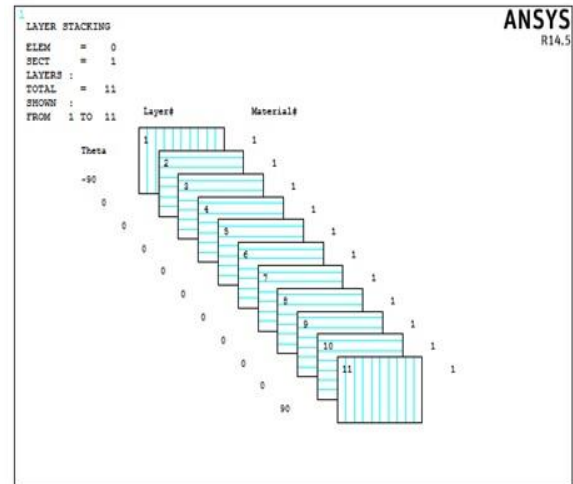


Figure 18. 5 layered kevlar Material

Meshing>mesh tool>ok

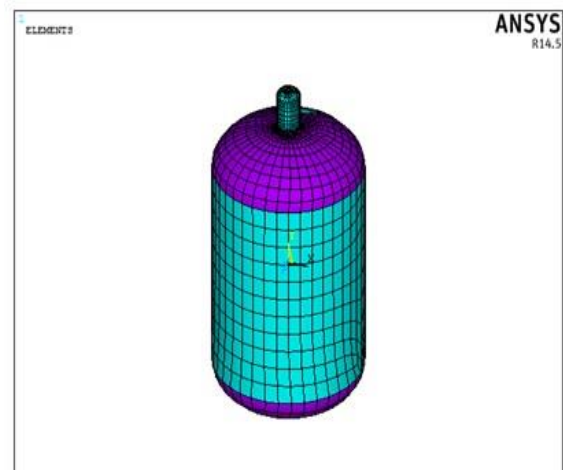


Figure 19. 11 layered meshing kevlar Material

Apply loads
 Pressure=0.0139MPa
 Solution>solve>current Is>ok
 General post processor>plot results>counter
 plot>nodal solution>ok
 Displacement>displacement vector sum>ok

DISPLACEMENT

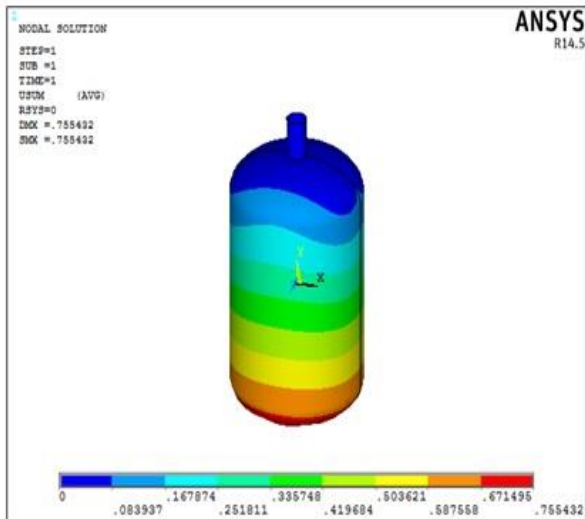


Figure 20. The maximum displacement is 0.755432mm and minimum is 0.83937mm

STRESS

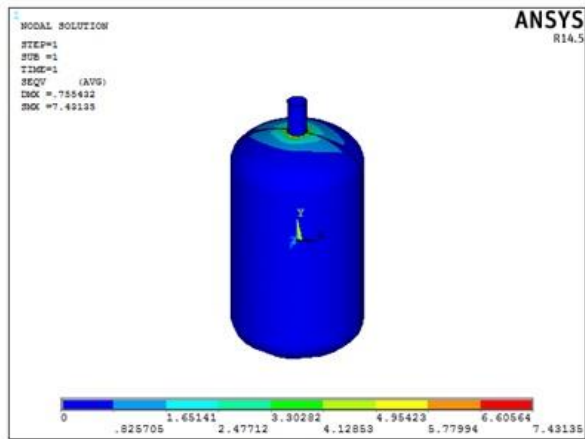


Figure 21. The maximum stress is in the range of 6.60564N/mm² to 7.43135N/mm²

STRAIN

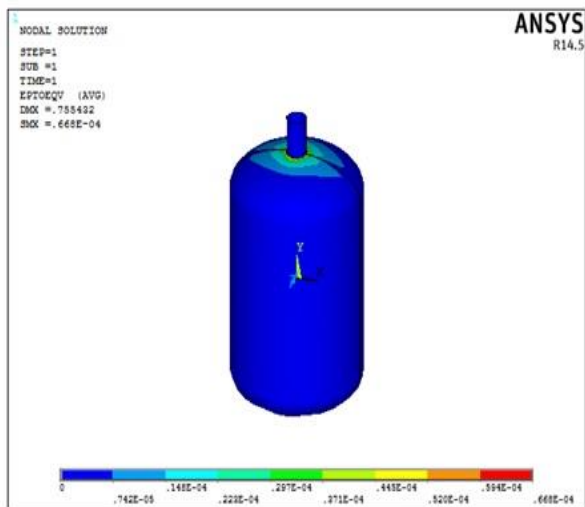


Figure 22. The maximum strain is 0.668e⁻⁴ and minimum is 0.742e⁻⁵.

TABLE 4. Comparative 5 and 11 layers

		Displacement(mm)	Stress(N/mm ²)	Strain
Kevlar	5 layers	0.755432	7.43135	0.668E-04
	11 layers	0.945379	7.39653	0.859E-04

TABLE 5. Displacement, stress and strain Kevlar

	KEVLAR
DISPLACEMENT (mm)	7.68906
STRESS (N/mm ²)	349.818
STRAIN	0.003351

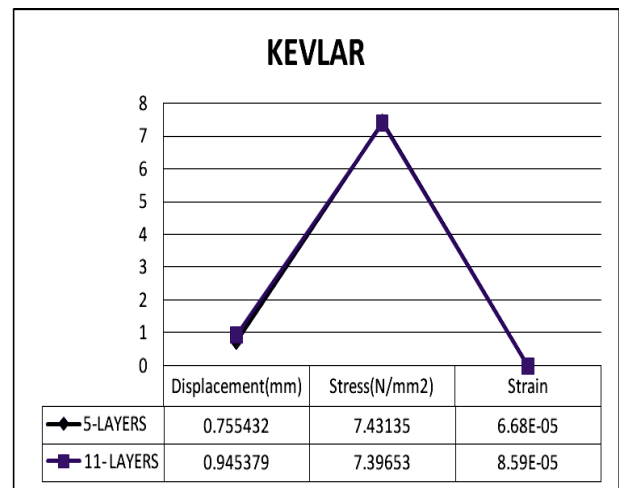


Figure 23. 5 and 11 layers results

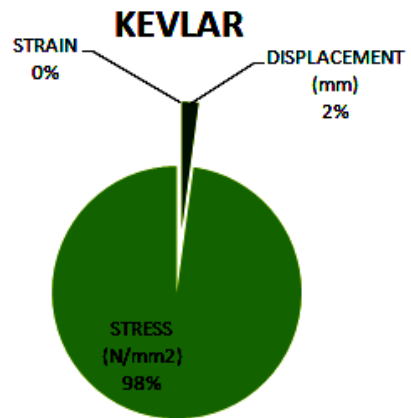


Figure 24. The maximum Stress

VII. RESULTS & DISCUSSION

1. WITHOUT & WITH HOLE SOLID STRUCTURAL ANALYSIS

TABLE 6. Kevlar material

	Displacement(mm)	Stress(N/mm ²)	Strain
KEVLAR	2.60512	165.583	0.001479

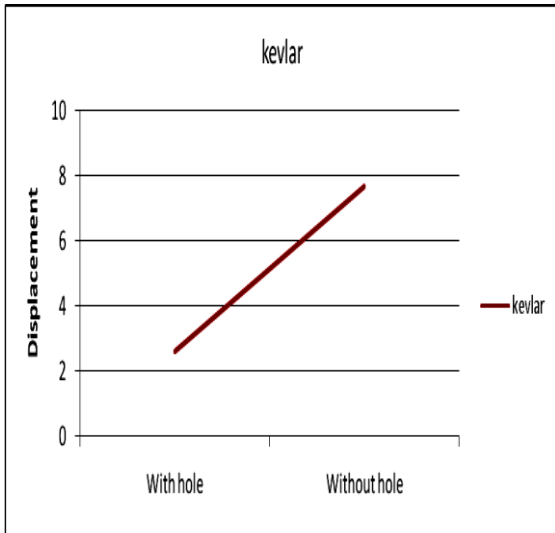


Figure 25. By observing the above graph, the displacement is increasing for without hole and is more.

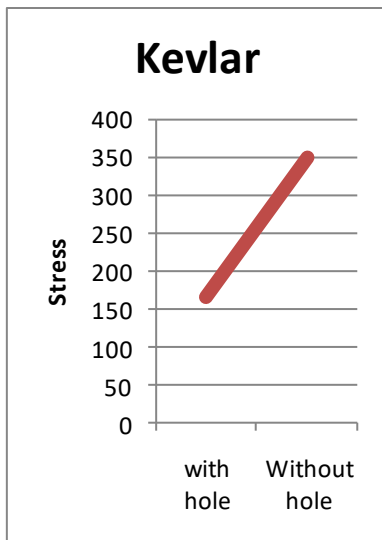


Figure 26. By observing the above graph, the stress is increasing for without hole and is more.

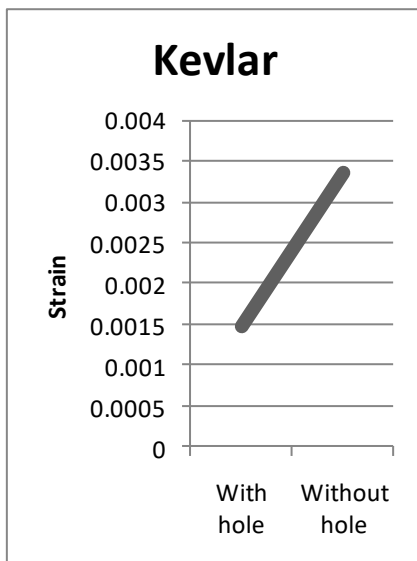


Figure 27. By observing the above graph, the strain is increasing for without hole and is more.

TABLE 7. SHELL ELEMENT

		Displacement(mm)	Stress(N/mm ²)	Strain
Kevlar	5 layers	0.755432	7.43135	0.668E- ⁰⁴
	11 layers	0.945379	7.39653	0.859E- ⁰⁴

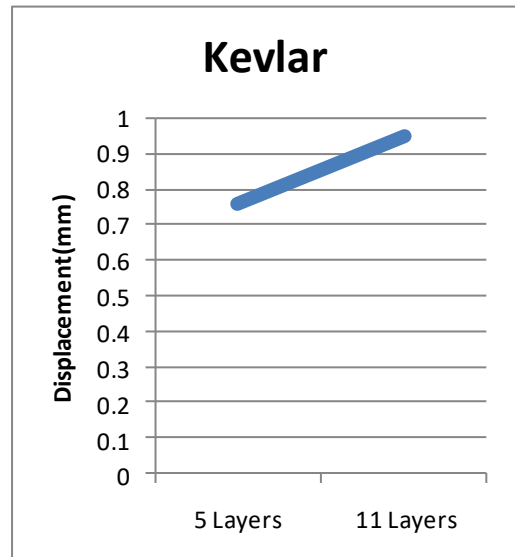


Figure 28. By observing the above graph, the displacement is increasing for 11 layers

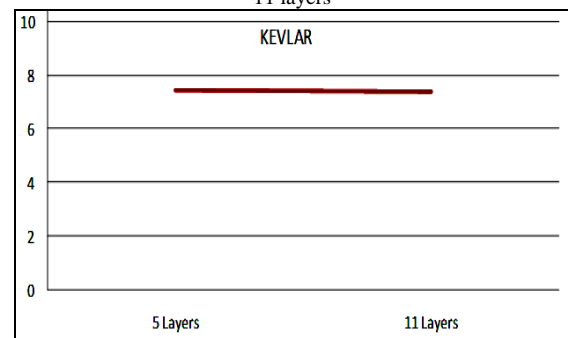


Figure 29. By observing the above graph, the stress is almost same for 5 layers and 11 layers.

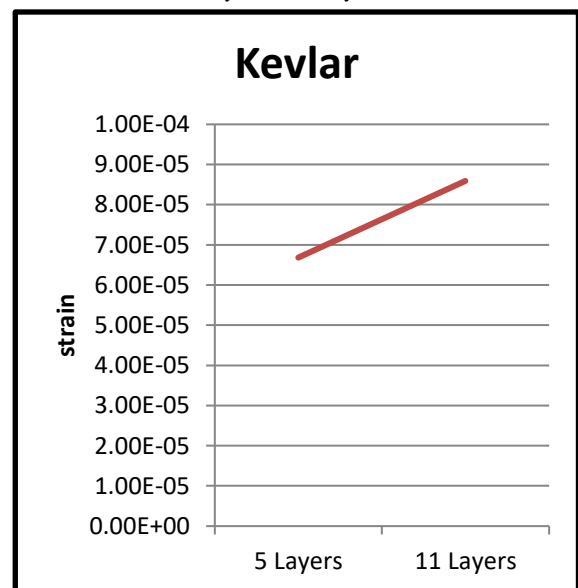


Figure 30. By observing the above graph, the strain is increasing for 11 layers

TABLE 8. Buckling Analysis

	First Set		Second Set		Third Set	
	DISP (mm)	FACTO R	DISP (mm)	FACTO R	DISP (mm)	FACTO R
Kevlar	1.02738	26142.2	1.11873	10771.2	1.12145	14913.9

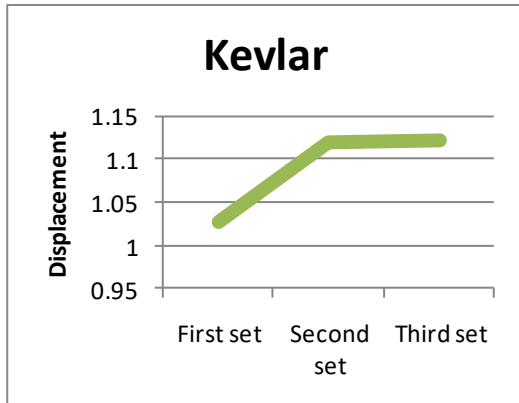


Figure 31. First Set Displacement

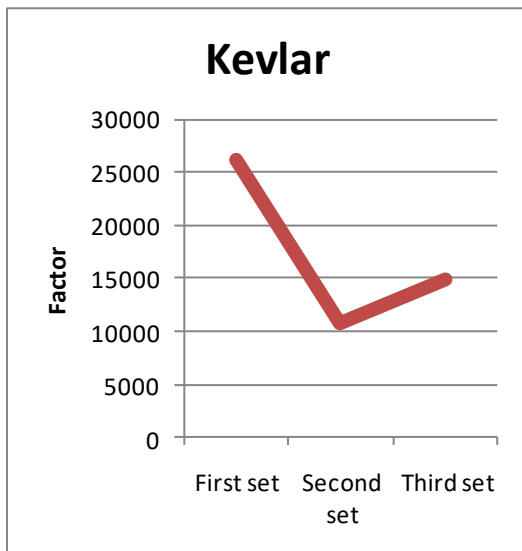


Figure 32. First set and Third set

By observing the above graph, the buckling factor is more for First set less in second set and moderate in third set.

VIII. CONCLUSION

The static and buckling analysis is done to determine the stress and deformation fields in a thin laminated-composite

cylindrical shell with an elliptical head without cutout and with cutout using Kevlar composite is presented. However, 5 and 11 layers are used as layer stacking for composite of kevlar materials. By observing the structural analysis results, the stress values are decreased for vessel with hole than the vessel without hole and the stresses and displacements are within the range of permissible values for Kevlar material. The maximum displacement is 1.43482mm and minimum displacement is 0.159425mm and the stress is almost same for 5 layers and 11 layers. By observing obtained data, the displacement is increasing for 11 layers the strain is increasing for 11 layers, the strain is increasing for without hole and is more, the displacement is increasing for without hole and is more, the displacement is increasing for without hole and is more.

IX. REFERENCES

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Dr. Viswa Mohan Pedagopu has vast experience in both teaching and industry. He has worked in central government, private universities in India and abroad. He has many national and international publications with double blinded peer reviewed, UGC approved and Scopus indexed reputed journals. He attended many conferences in national and international conferences in India and abroad. He is an editor, guest editor, and reviewer for many journals. His research interests not limited to but in Computer Integrated Manufacturing, CAPP, advanced manufacturing technologies and flexible manufacturing systems. He has fellow and senior membership in many outstanding institutions like ASME, CSME, MCS, IACSET, FIE, IAEME, FIRAJ and MISTE.