ANALYTICAL INVESTIGATIONS OF THIN CYLINDRICAL PANEL SUBJECTED TO UNDER MECHANICAL LOADS

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Abstract

Shell structures have been widely used in pipelines, aerospace and marine structures, large dams, shell roofs, liquid-retaining structures and cooling towers. The weight reduction of the cylindrical panel can have a certain role in the general weight reduction of the vehicle and is a highly desirable goal. Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials.In this project, Static, linear buckling & linear layer analysis to determine the deformation, stress of the Thin cylindrical panel (with and without hole) . Layer stacking method carried out on cylindrical panel for 3, 6 and 9 layers for analysis of aluminum alloy 8011, CFRP ,glass fibre reinforced plastic material and FGM. 3Dmodeling done by the parametric software CATIA and analysis done in ANSYS software.

In this thesis, we are finding the stress on the thin cylindrical panel (with and without hole) with conventional and composite materials. Furthermore we are conducting the linear layer analysis at different geometries.

1. INTRODUCTION

Various fields of engineering such as civil, mechanical, aerospace and nuclear engineering fields the thin walled cylindrical shells finds wider applications as primary structural members. The stiffened and unstiffened shells made up of metallic and laminated composite materials (large diameter to thickness ratio) are extensively used in underwater, surface, air and space vehicles as well as in construction of pressure vessels, storage vessels, storage bins and liquid storage tanks. The geometric imperfections due to manufacturing processes takes dominant role in decreasing the buckling load of cylindrical shells. Buckling is often viewed as the controlling failure mode of these structures due to its relatively small thickness of these structural members. It is therefore essential that the buckling strength of the thin shells along with knowledge of its buckling has been the subject of many researchers in both analytical and experimental investigations.

Composite structures are important in different areas of industry such as aero, marine aircrafts, ships, automotive and so on. Many of the structures experience blast loading during war or terrorist attack or accidental explosions. Response of composite structures subjected to explosion has been a field of intense activity of researchers in recent decades. So composite plates and shells form one of the basic elements of the structures, therefore, studying the blast response of such structures helps understanding and improving their blast resistance.

A Composite material (also called a composition material or shortened to composite, which is the common name) is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components.

Cylindrical Panel

The eigen frequencies and eigen modes of a thin isotropic cylindrical panel are calculated. The purpose of the analysis is to examine the performance of the MITC shell elements combined to point mass elements (PMASS).

The panel is supported with four springs attached to the corners of the plate. Thus, the panel is not fully constrained and a shift of 1.0 has to be applied in order to be able to solve the eigenvalue problem.

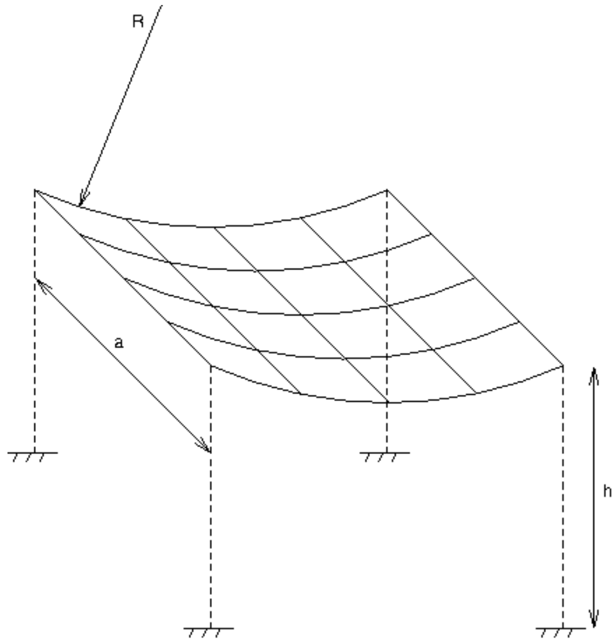


Fig : Curved panel model

FUNCTIONALLY GRADED MATERIALS (FGM)

Functionally Graded Materials (FGMs) are a group of inhomogeneous materials composed of two or more materials engineered to have continuously varying material properties along preferred directions. The FG materials are microscopically heterogeneous and are made from mixture of two or more materials that are appropriate to achieve the desired objectives. The overall material properties of the FGMs are unique and different from the individual material that forms it. The mechanical properties that vary continuously in the preferred directions are Young’s modulus, Poisson’s ratio, Shear Modulus and density etc.

2. LITERATURE REVIEW

Reza Haghi[1] In this paper, the behavior of composite structures against the explosive phenomenon has been investigated using finite element method. Some composite shells such as composite plates and hemispheres with different layer-upping have been investigated using LS-DYNA software. The blast loading is simulated by explosion's pressure versus time curves and is directly defined in LS-DYNA software. The Tsai-Wu failure criterion is used to predict the behavior of the composite structure.In this paper, the effect of layer-upping on the blast resistance of the structure is investigated. The results show that, hemisphere composite has better performance against the blast loading than plate and failure occur under greater load. Also it is shown that angle ply composite structures have good resistance in comparison with cross plies one.

Mahmoud Shariati[2] In this paper, the effects of the length, sector angle and different boundary conditions on the buckling load and post buckling behavior of CK20 cylindrical panels have been investigated using experimental and numerical methods. The experimental tests have been performed using the INSTRON 8802 servo hydraulic machine and for numerical analysis. Abaqus finite element package has been used. The numerical results are in good agreement with the experimental tests.

M. Shariati [3] The effects of the length, sector angle and different boundary conditions on the buckling load and post buckling behavior of cylindrical panels have been investigated using experimental and numerical methods. The experimental tests have been performed using a servo hydraulic machine and for numerical analysis, Abaqus finite element package has been used. The numerical results are in good agreement with the experimental tests

Y. Venkata Narayana[4] The Laminated cylindrical shells are being used in submarine, underground mines, aerospace applications and other civil engineering applications. Thin cylindrical shells and panels are more prone to fail in buckling rather than material failure. In this present study linear and non-linear buckling analysis of GFRP cylindrical shells under axial compression is carried out using general purpose finite element program (ANSYS).

Nonlinear buckling analysis involves the determination of the equilibrium path (or load-deflection curve) upto the limit point load by using the NewtonRaphson approach. Limit point loads evaluated for geometric imperfection magnitudes shows an excellent agreement with experimental results. The influence of composite cylindrical shell thickness, radius variation on buckling load and buckling mode has also investigated. Present study finds direct application to investigate the effect of geometric imperfections on other advanced grid stiffened structures.

Farbod Alijani[5] The present literature review focuses on geometrically non linear free and forced vibrations of shells made of traditional and advanced materials. Flat and imperfect plates and membranes are excluded. Closed shells and curved panels made of isotropic, laminated composite, piezoelectric, functionally graded and hyperelastic materials are reviewed and great attention is given to non linear vibrations of shells subjected to normal and in plane excitations. Theoretical, numerical and experimental studies dealing with particular dynamical problems involving parametric vibrations, stability, dynamic buckling, non stationary vibrations and chaotic vibrations are also addressed. Moreover, several original aspects of non linear vibrations of shells and panels.

Dr. Adnan N. Jamel[6] The present work is an attempt to investigate the vibrations characteristics and effect of static stresses and deformation in partially pressurized thick cylindrical shells, such as the gun barrels. The method used cover analytical investigation developed to determine static stresses and deformation along the thick cylindrical shell using LAME'S equation. The numerical investigation is developed using the finite element method with axisymmetric element (Plane 42) four nodes to determine the static response and solid element (Solid 45) eight nodes for vibration analysis by using the ANSYS package. The obtained results show a good agreement with the other investigators. It's found that the natural frequency of the selected models almost equal (150. Hz) and these results indicate that the frequency of powder gasses pressure more than (150 Hz) to be far away from resonance phenomena.

Khamlichi et al. [7] studied analytically, about the effect of localized axisymmetric initial imperfections on the critical load of thin elastic cylindrical shell subjected to axial compression. Schneider (2006) discussed about the effect of local axisymmetric concave and convex axisymmetric ring shaped imperfection patterns on buckling strength of cylindrical shell under axial compression and one of the conclusion was that as width of imperfection increases buckling strength increases whereas as depth of imperfection increases buckling strength decreases.

Prabu et al. [8]carried out parametric study about the effect of dent dimensions and its orientations on the buckling strength of short stainless steel cylindrical shells under uniform axial compressive force load condition and it was concluded that circumferential dents have more dominant effect than longitudinal dents in reducing the buckling strength of cylindrical shells.

3. MATERIALS AND METHODS

In this project Materials used for cylindrical shell panel analysis are Aluminum alloy 8011, Carbon fiber, glass fiber and FGM.

MEHANICAL PROPERTIES OF MATERIALS:

Materials	**Young's modulus(Mpa)**	**Tensile strength(Mpa)**	**Poisson's ratio**	**Density(kg/mm3)**
Aluminum alloy 8011	69000	490	0.31	0.00000271
CFRP	228000	3900	0.30	0.00000020
E-Glass fiber	72000	3441	0.21	0.0000024

CFRP

In fiber reinforced composites, fiberglass is the "workhorse" of the industry. It is used in many applications and is very competitive with traditional materials such as wood, metal, and concrete. Fiberglass products are strong, lightweight, non-conductive, and the raw material costs of fiberglass are very low.In applications where there is a premium for increased strength, lower weight, or for cosmetics, then other more expensive reinforcing fibers are used in the FRP composite.

E- Glass fiber

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fibers are therefore used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fiber-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), also popularly known as "fiberglass". This material contains little or no air or gas, is more dense, and is a much poorer thermal insulator than is glass wool.

Functionally Graded Materials (FGMs)

Functionally Graded Materials (FGMs) are a group of inhomogeneous materials composed of two or more materials engineered to have continuously varying material properties along preferred directions. The FG materials are microscopically heterogeneous and are made from mixture of two or more materials that are appropriate to achieve the desired objectives. The overall material properties of the FGMs are unique and different from the individual material that forms it. The mechanical properties that vary continuously in the preferred directions are Young's modulus, Poisson's ratio, Shear Modulus and density etc.

MATERIAL PROPERTY CALCULATIONS FOR FGM

For Young's Modulus

For k=2; z=1

$E(Z)=(Et-Eb)(z/h+1/2)^K+Eb$

For k=2;z=-1

$E(Z)=(Et-Eb)(z/h+1/2)^K+Eb$

For Densities

For k=2;z=1

$\rho(Z)=(\rho t-\rho b)(z/h+1/2)^K+\rho b$

Material Properties

For Young's Modulus

Material properties

Top material: ceramic (ET=380000MPa)

Bottom material: Aluminum (Eb=69000 MPa)

Table. Functionally graded material properties (aluminum alloy 8011 and ceramic) for k=2

Layer number(z)	Young's modulus E (MPa)	Density ρ (Kg/m3)	Poisson ratio υ
5	220880	5536	0.31
4	320720	4830	0.309
3	445520	4164	0.308
2	595280	3702	0.307
1	770000	3307	0.306
-1	96080	2812	0.304
-2	71120	2711	0.303
-3	71120	2711	0.302
-4	96080	2812	0.301
-5	146000	2383	0.3

4.MODELING AND ANALYSIS

Solid Works (stylized as SOLIDWORKS) is a strong modeling computer-aided layout (CAD) and laptop-aided engineering (CAE) computer application that runs on Microsoft Windows. Solid Works is published with the aid of Dassault Systems.

3D model cylindrical panel without hole

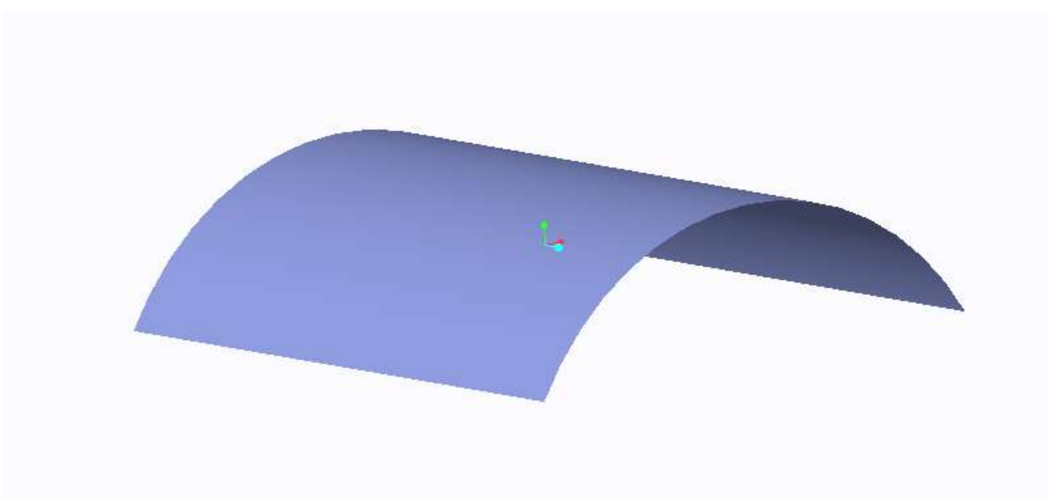


Fig : 3D model

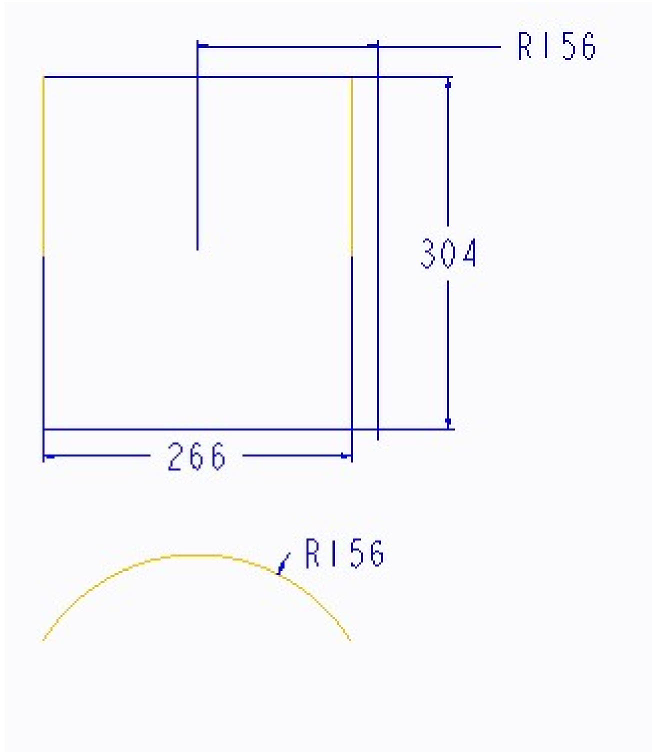


Fig : 2D model

3D model cylindrical panel with hole

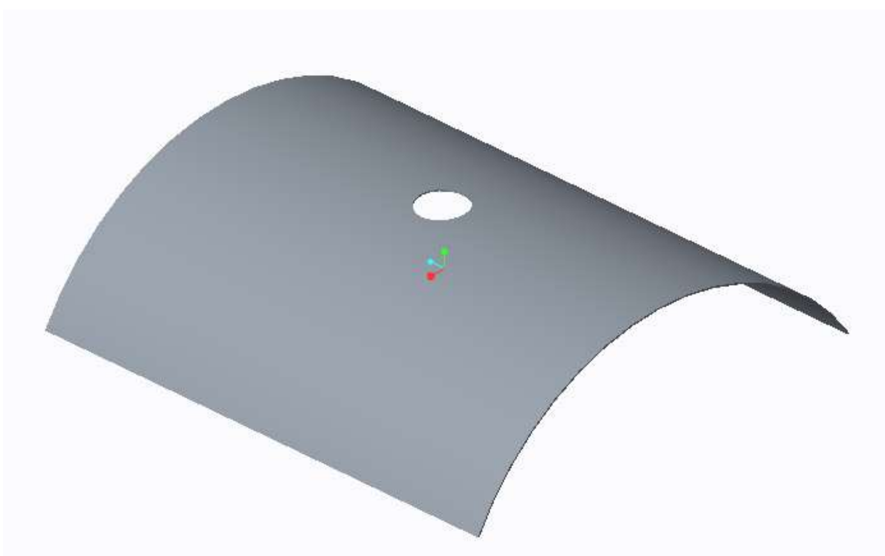


Fig : 3D model cylindrical panel with hole

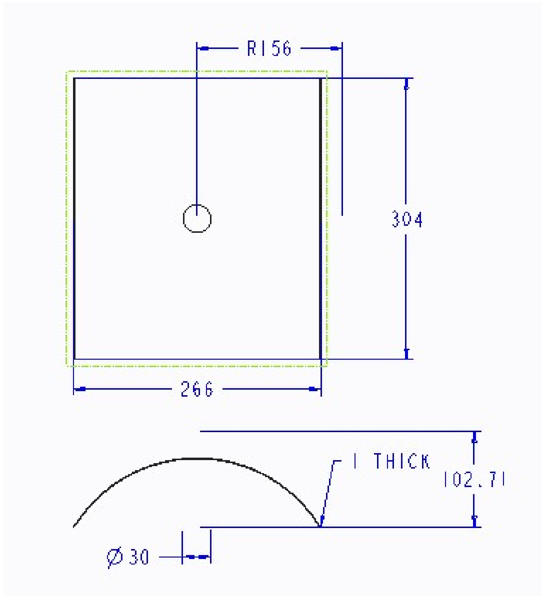


Fig : 2D model cylindrical panel with hole

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

Static Analysis - Used to determine displacements, stresses, etc. under static loading conditions. ANSYS can compute both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

Eigenvalue buckling is generally used to estimate the critical buckling loads of stiff structures (classical eigenvalue buckling). Stiff structures carry their design loads primarily by axial or membrane action, rather than by bending action. Their response usually involves very little deformation prior to buckling.

Generic Steps to Solving any Problem in ANSYS

Like solving any problem analytically, you need to define (1) your solution domain, (2) the physical model, (3) boundary conditions and (4) the physical properties. You then solve the problem and present the results. In numerical methods, the main difference is an extra step called mesh generation. This is the step that divides the complex model into small elements that become solvable in an otherwise too complex situation. Below describes the processes in terminology slightly more attune to the software.

5. STATIC ANALYSIS OF CYLINDRICAL THIN PANEL

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes. Static analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time.

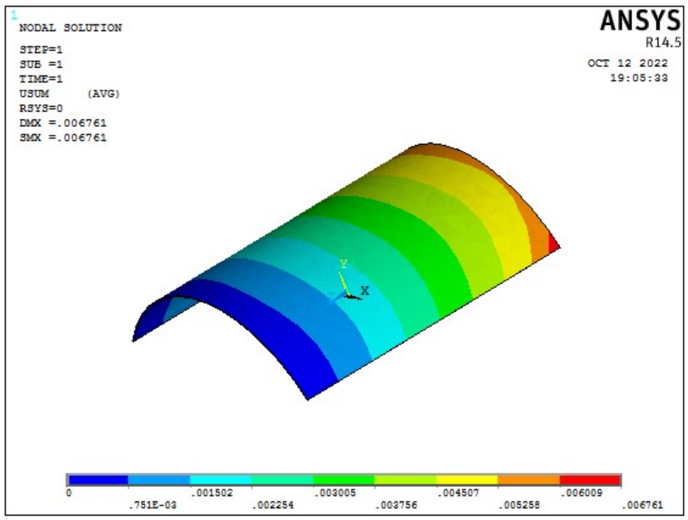


Figure: Total deformation for E GLASS fiber

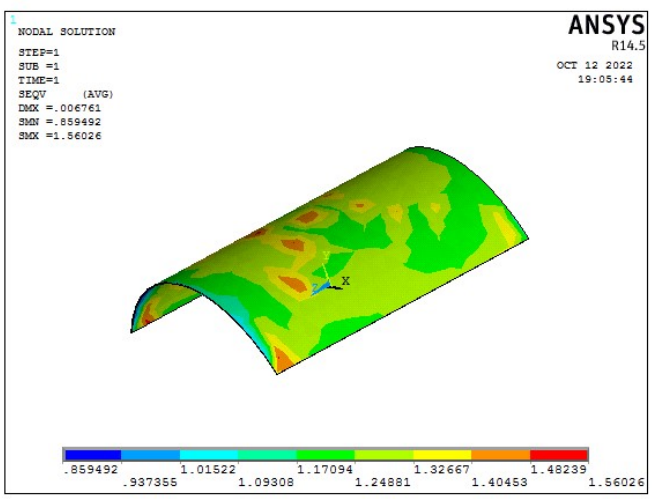


Figure: Equivalent stress for E GLASS fiber

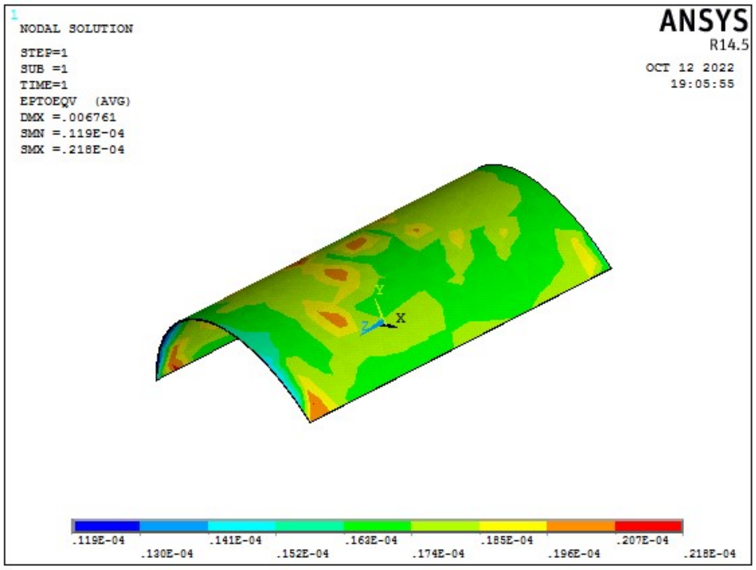


Figure: Equivalent strain for E GLASS fiber

CASE: 2 WITH HOLE

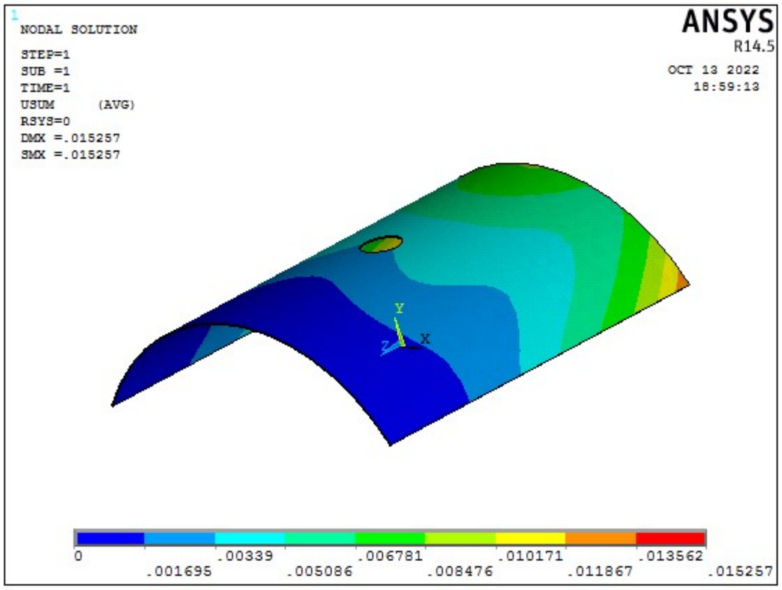


Figure: Displacement for E-glass fiber

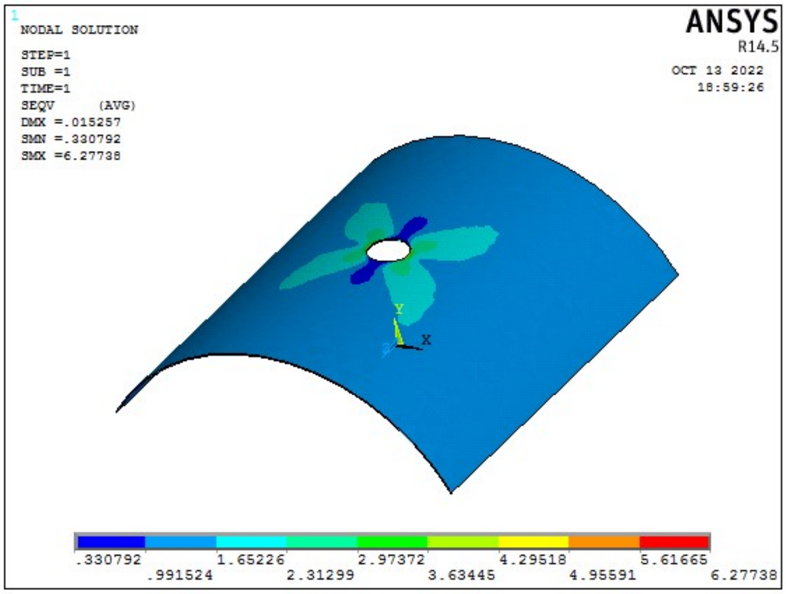


Figure: Equivalent stress for E-glass fiber

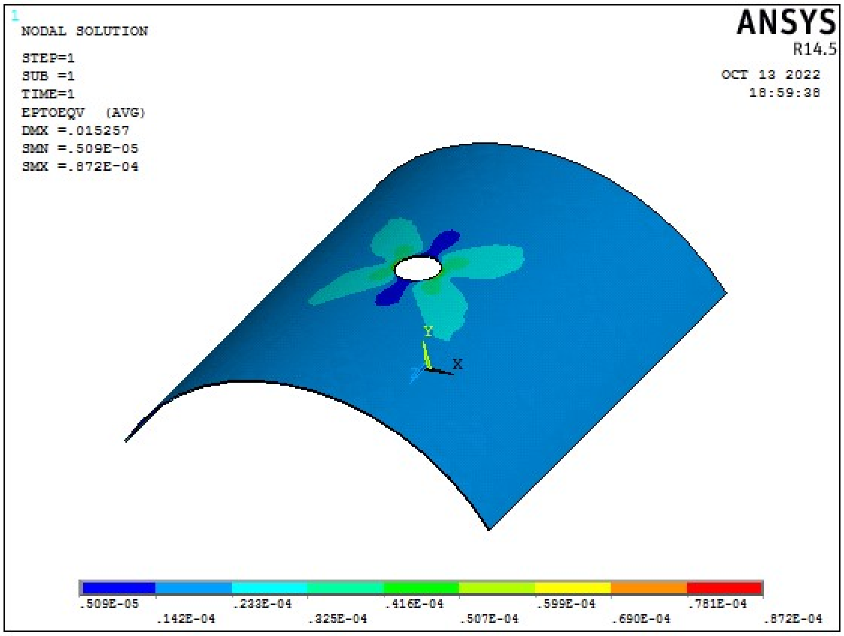
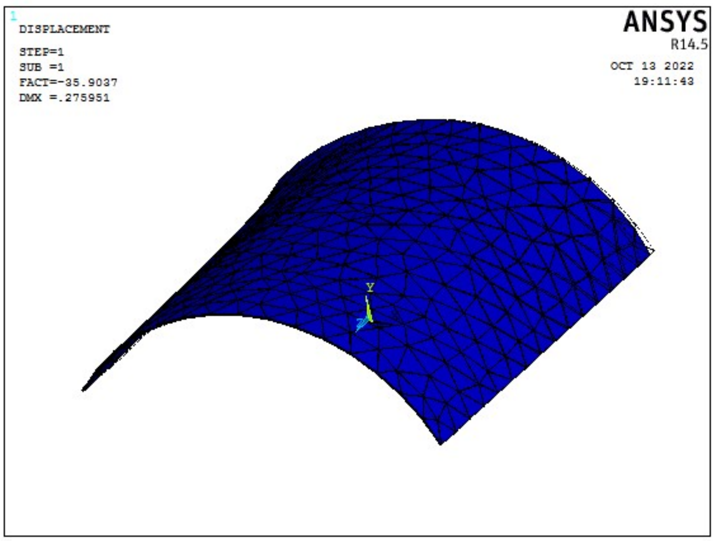


Figure: Equivalent strain for E-glass fiber

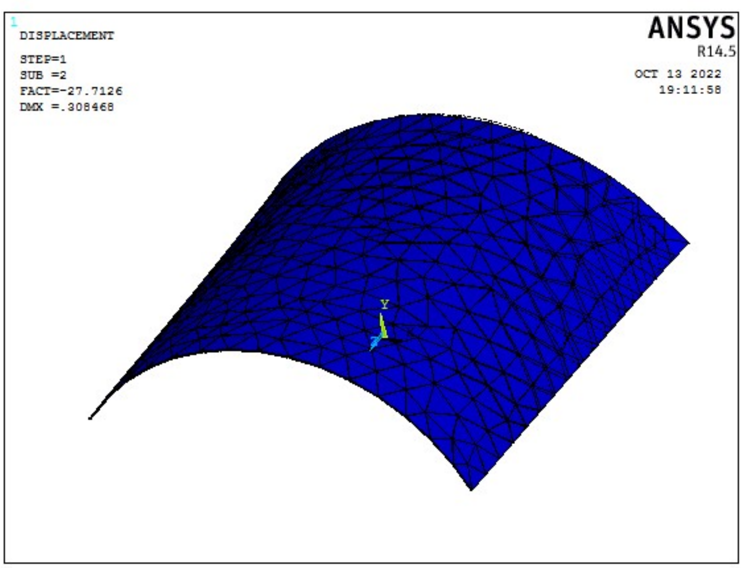
LINEAR-BUCKLING ANALYSIS OF THIN CYLINDRICAL PANEL

First, consider a linear-buckling analysis (also called eigenvalue-based buckling analysis), which is in many ways similar to modal analysis. Linear buckling is the most common type of analysis and is easy to execute, but it is limited in the results it can provide. Linear-buckling analysis calculates buckling load magnitudes that cause buckling and associated buckling modes. FEA programs provide calculations of a large number of buckling modes and the associated buckling-load factors (BLF). The BLF is expressed by a number which the applied load must be multiplied by (or divided — depending on the particular FEA package) to obtain the buckling-load magnitude.The buckling mode presents the shape the structure assumes when it buckles in a particular mode, but says nothing about the numerical values of the displacements or stresses. The numerical values can be displayed, but are merely relative. This is in close analogy to modal analysis, which calculates the natural frequency and provides qualitative information on the modes of vibration (modal shapes), but not on the actual magnitude of displacements.

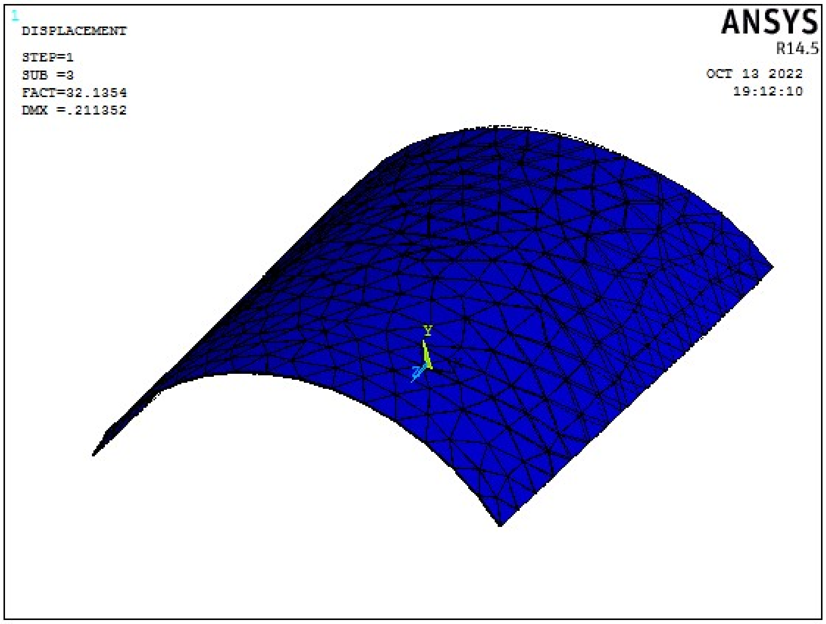
MODE 1



MODE 2



MODE 3



LINEAR LAYER ANALYSIS OF THIN CYLINDERICAL PANEL USING FGM

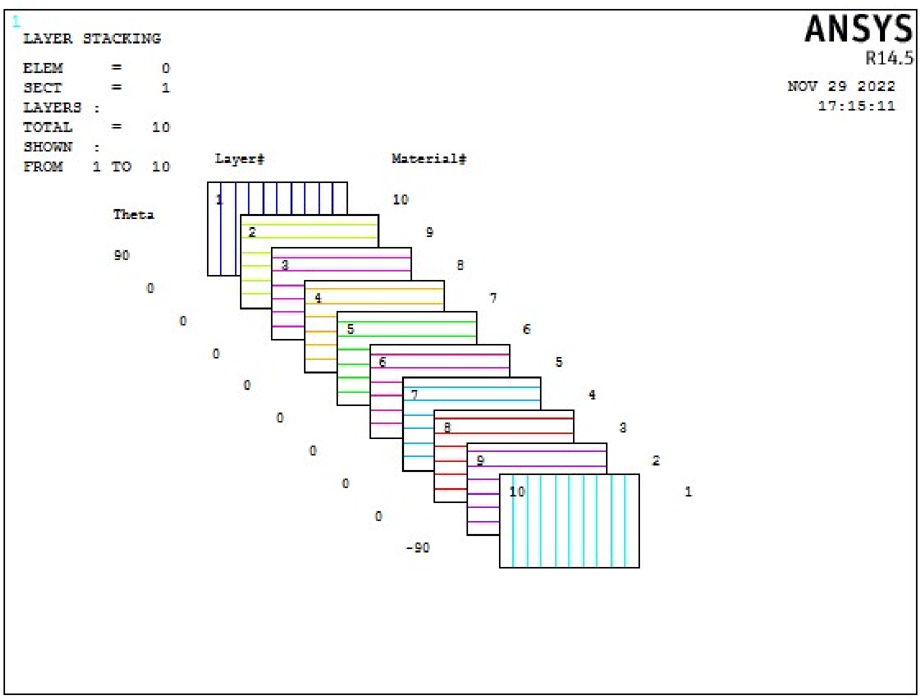


Figure: Layer stacking

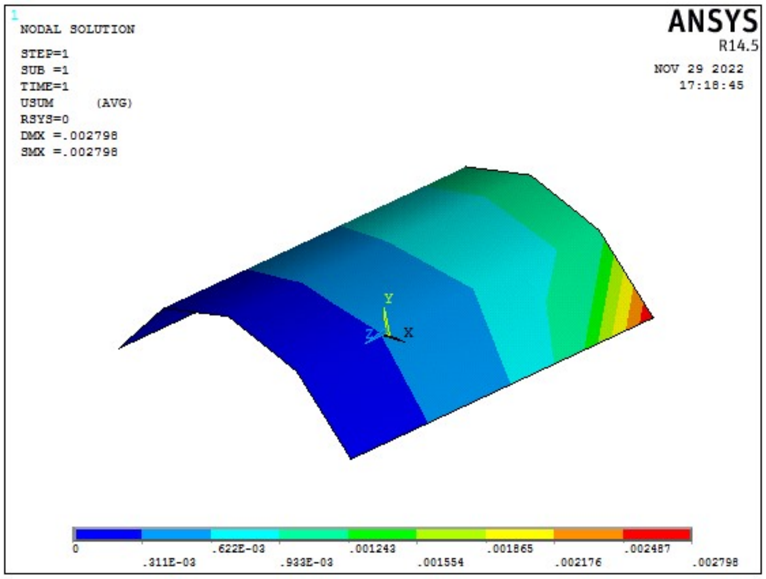


Figure: Displacement for FGM

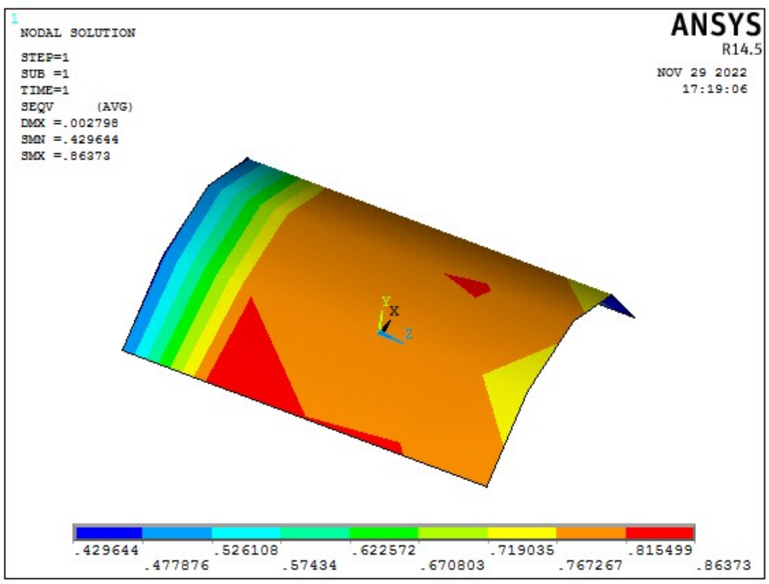


Figure: Equivalent stress for FGM

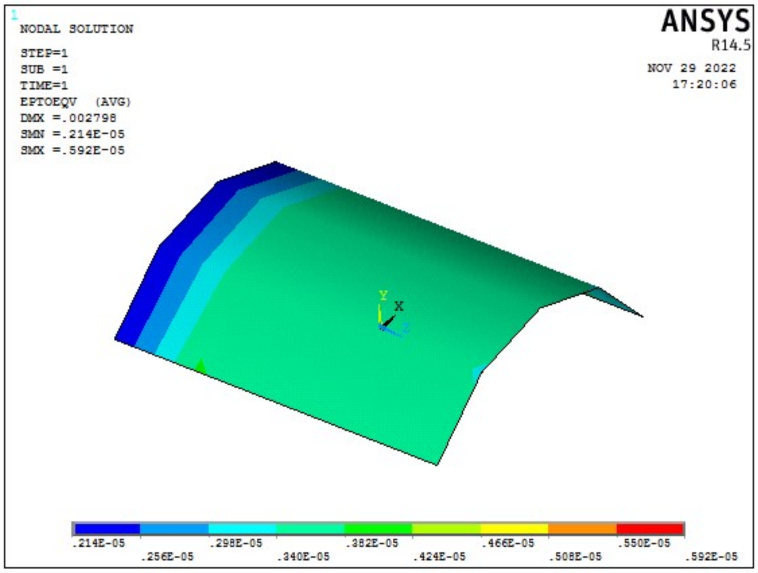
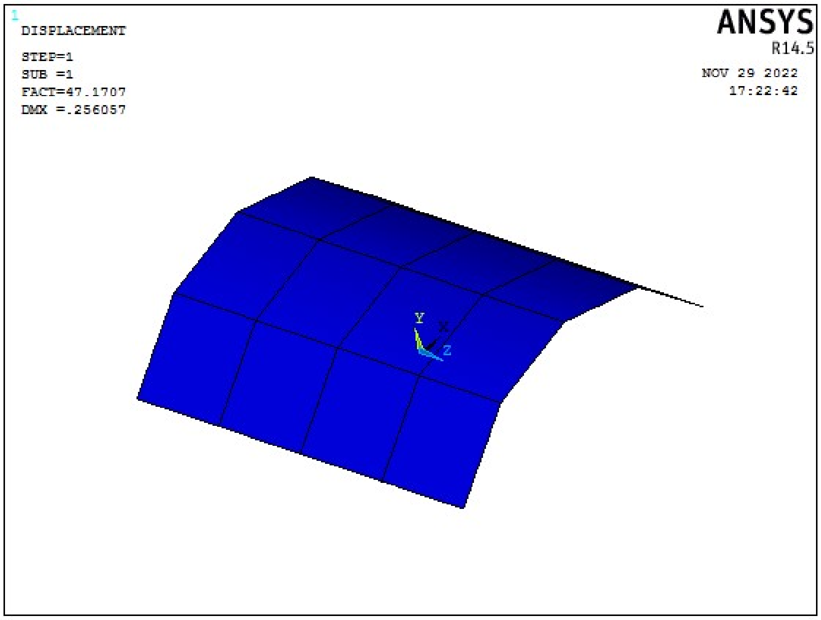


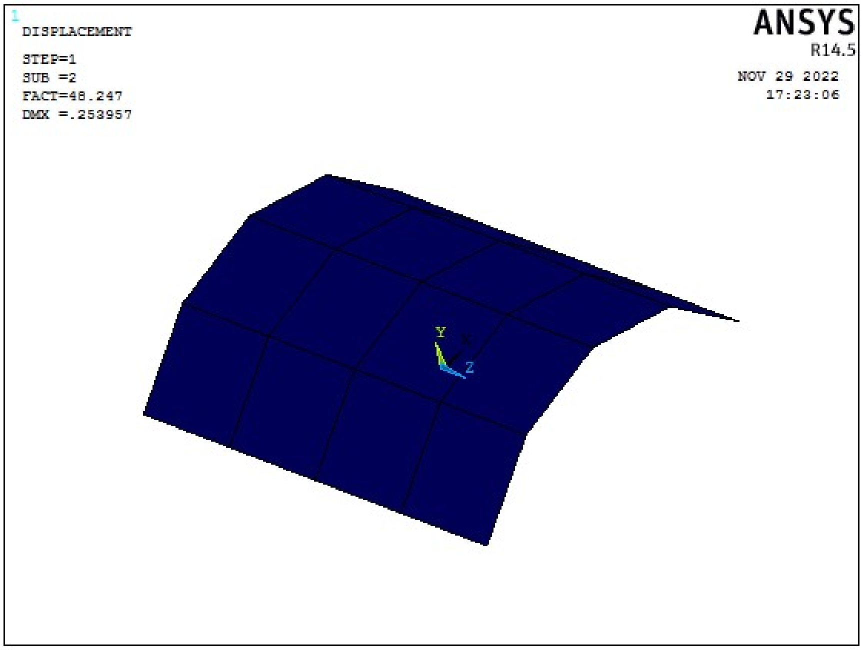
Figure: Equivalent strain for Carbon Fiber

BUCKLING ANALYSIS OF THIN CYLINDERICAL PANEL USING FGM

MODE 1



MODE2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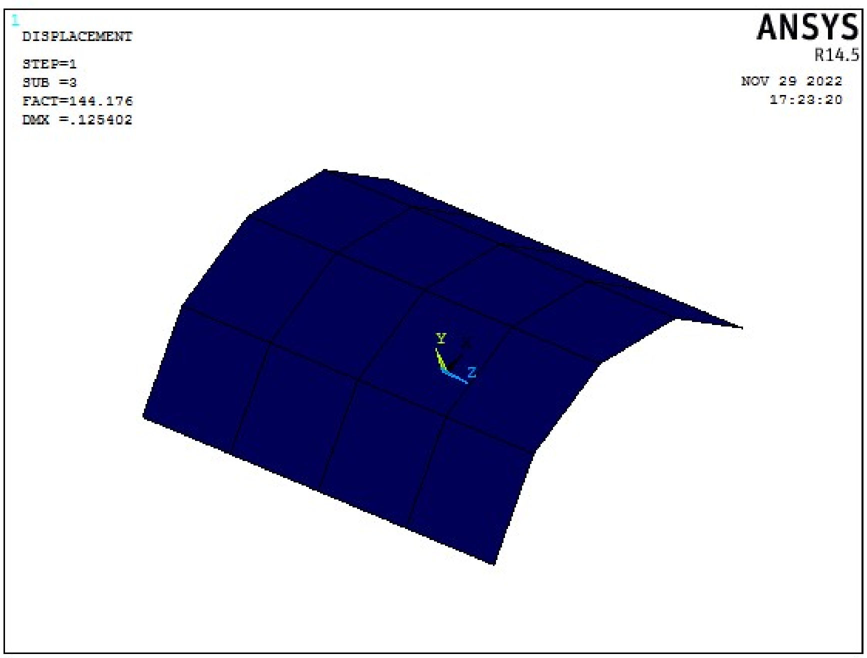
MODE 3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NOV 29 2022
17:23:20
Y
Z

6.RESULTS AND DISCUSSIONS

Table: Static Analysis Results

CASES	MATERIAL	DISPLCEMENT (mm)	STRESS(Mpa)	strain
Without hole	**Aluminum alloy 8011**	0.007007	1.592	0.23e-04
	Carbon fiber	0.0211	1.613	0.71e-04
	E-glass fiber	0.006761	1.560	0.21e-04
With hole	**Aluminum alloy 8011**	0.01596	6.274	0.911e-04
	Carbon fiber	0.004515	6.342	0.27e-04
	E-glass fiber	0.01527	6.272	0.87e-04

Table: Buckling analysis results

Material	Without hole			With hole		
	Modes	**BLF**	**Displacement (mm)**	**Modes**	**BLF**	**Displacement (mm)**
Aluminum alloy 8011	**1**	35.20	0.28	1	26.06	0.27
	2	27.0556	0.31	2	26.50	0.32
	3	31.442	0.21	3	30.10	0.24
	4	42.42	0.18	4	38.88	0.21
	5	95.89	0.10	5	75.94	0.11
Carbon fiber	**1**	116.517	0.15	1	120.10	0.15
	2	89.52	0.17	2	88.20	0.17
	3	104.067	0.11	3	100.29	0.133
	4	140.397	0.10	4	129.62	0.11
	5	317.328	0.05	5	253.10	0.063
E-glass fiber	**1**	35.9037	0.77	1	36.47	0.27
	2	27.716	0.30	2	26.96	0.32
	3	32.134	0.21	3	30.402	0.24
	4	43.0525	0.106	4	39.11	0.21
	5	97.71	0.101	5	76.56	0.11

Table: linear layer stress analysis using FGM results

Condition	Total deformation (mm)	Stress (Mpa)	Strain
Without hole	0.002798	0.86373	5.9e-05
With hole	0.0074	5.17199	3.5e-04

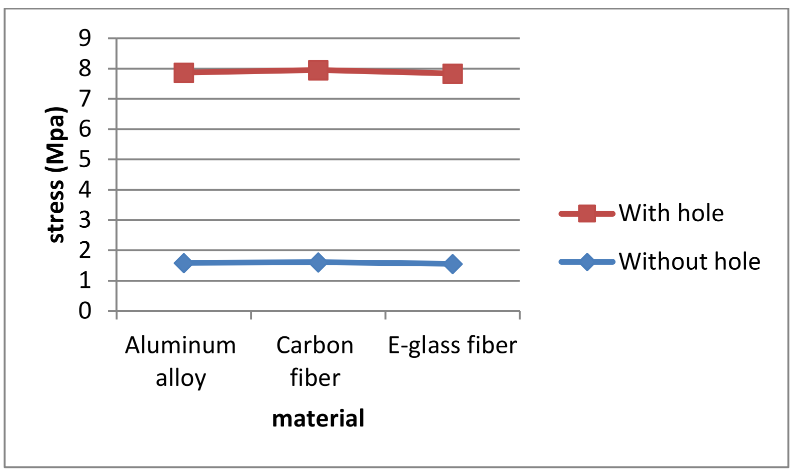
Table: linear layer Buckling analysis using FGM results

Conditions	Modes	BLF	Displacement (mm)
Without hole	**1**	47.17	0.2560
	2	48.24	0.2539
	3	144.176	0.12504
With hole	**1**	62.486	0.306771
	2	75.465	0.32952
	3	112.789	0.2015

Graphs

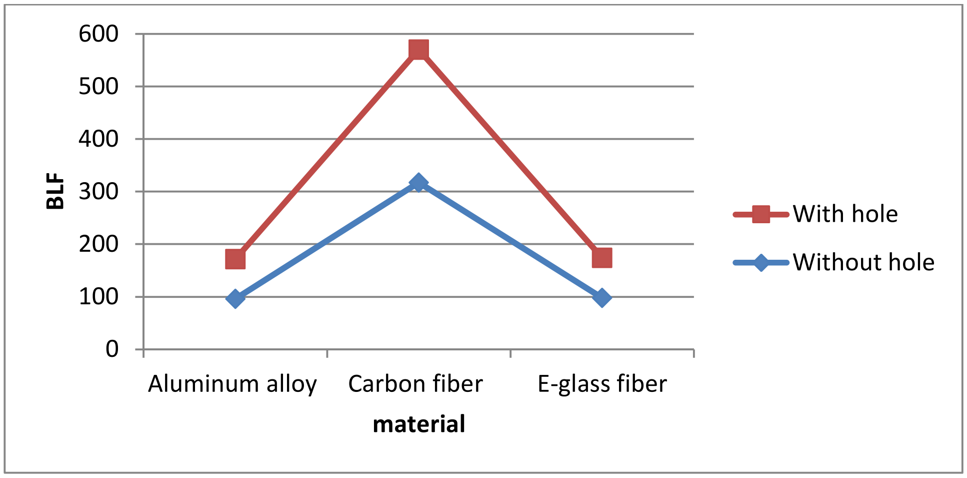
STATIC ANALYSIS RESULTS

Materials and cases Vs stress



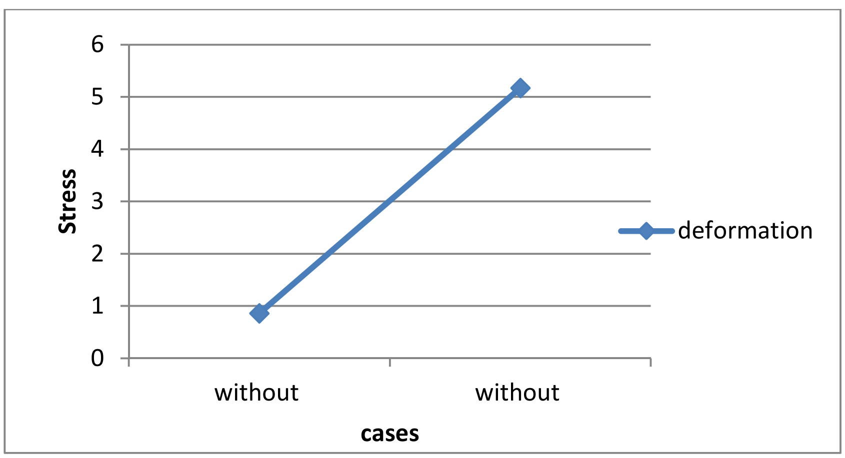
BUCKLING ANALYSIS

Materials and cases Vs BLF

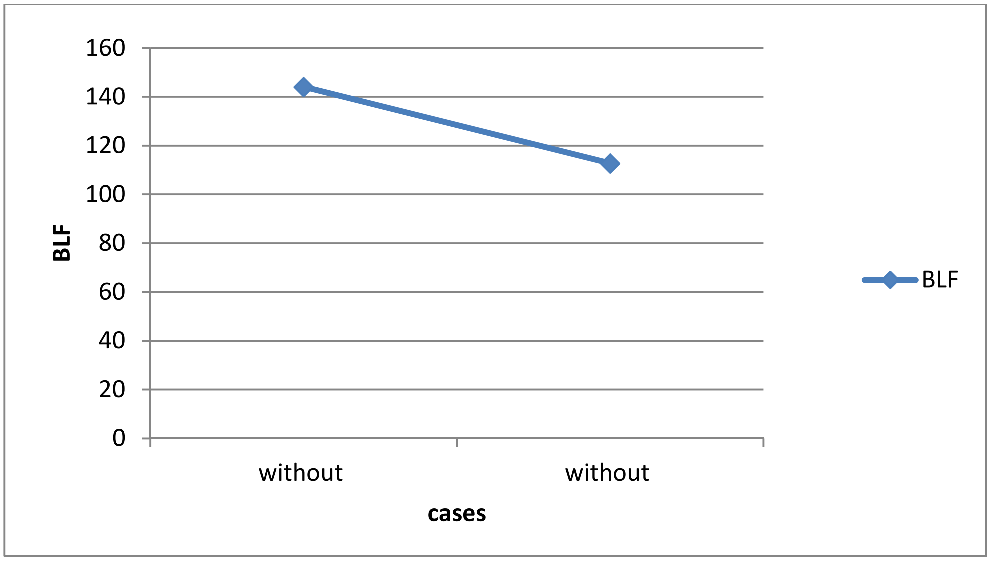


Linear layer static analysis using FGM graphs

Cases Vs Stress

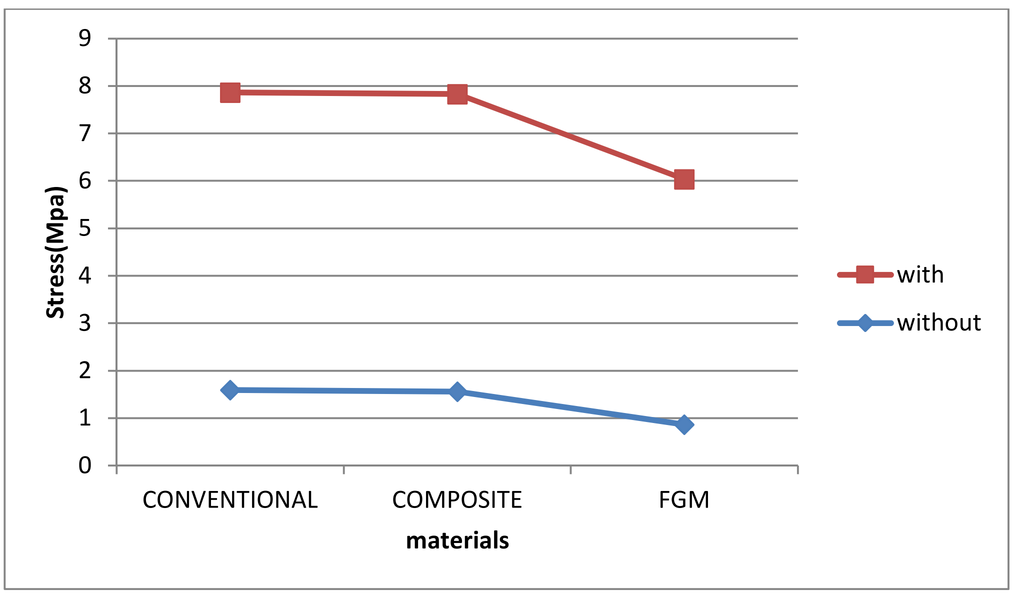


Cases Vs BLF

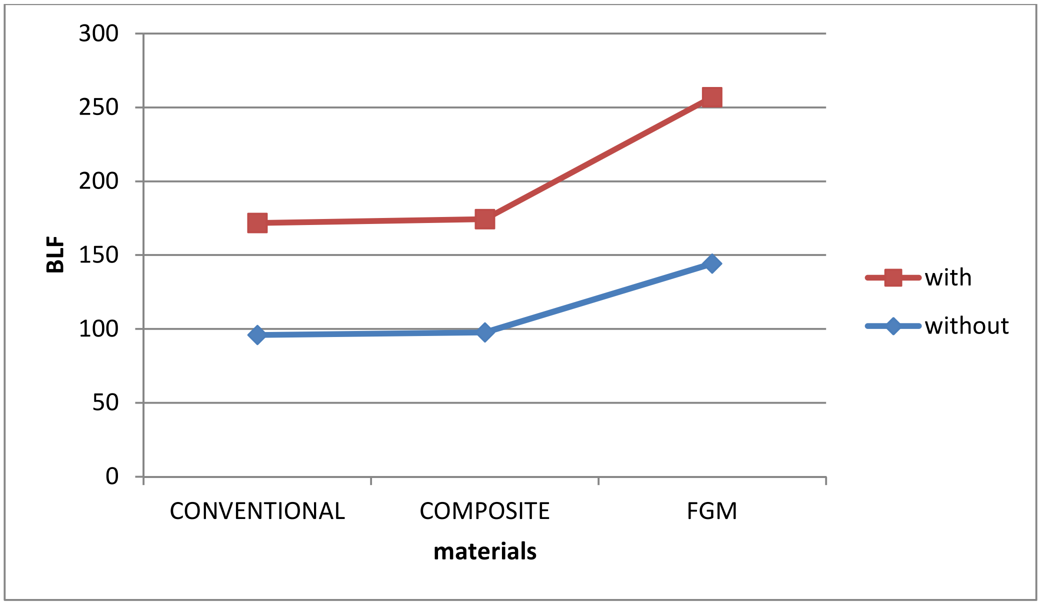


COMPARISON GRAPHS

Materials and cases Vs stress



Materials and cases Vs BLF



THEORETICAL CALCULATIONS

$$\sigma = \frac{pd}{2tE}$$

Where,

σ = stress (Mpa)
p=load (N)
d= diameter of thin cylindrical panel(mm)
t= thickness (mm)
E= Young's modulus

At material aluminum alloy 8011

$$\sigma = \frac{pd}{2tE}$$

$$\sigma = \frac{250 * 364}{2 * 1 * 69000}$$

σ =0.732mpa

At material Carbon fiber

$$\sigma = \frac{pd}{2tE}$$

$$\sigma = \frac{250 * 364}{2 * 1 * 228000}$$

σ =0.662mpa

At material Carbon fiber

$$\sigma = \frac{pd}{2tE}$$

$$\sigma = \frac{250 * 364}{2 * 1 * 72000}$$

σ =0.63mpa

At material FGM

$$\sigma = \frac{pd}{2tE}$$

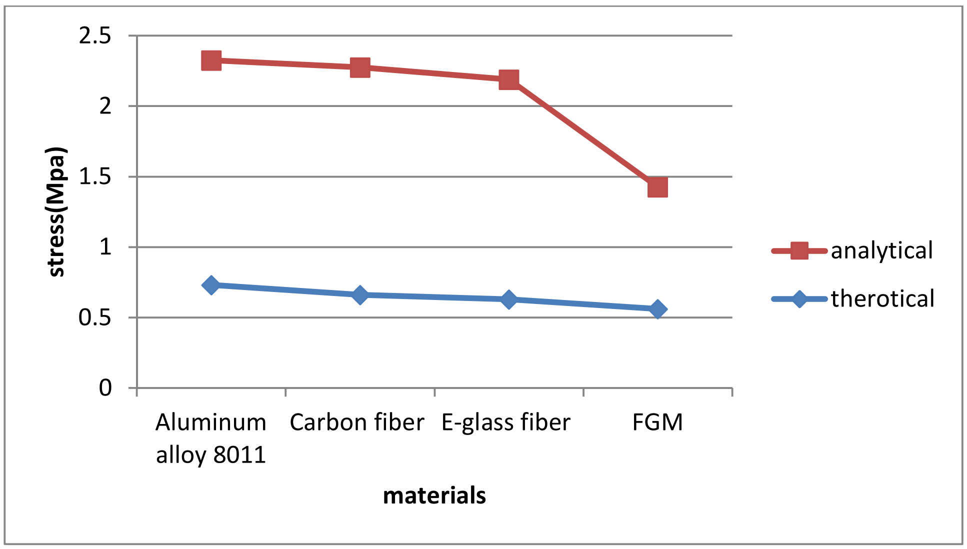
$$\sigma = \frac{250 * 364}{2 * 1 * 71120}$$

σ =0.562mpa

Theoretical results tables

Materials	Stress (Mpa)
Aluminum alloy 8011	0.732
Carbon fiber	0.662
E-glass fiber	0.63
FGM	0.562

Comparison graph of theoretical stress Vs analytical stress



7.CONCLUSION

In this project, Static, buckling & linear layer analysis to determine the deformation, stress of the cylindrical shell. Static, buckling and linear layer analysis of aluminum alloy 8011 , carbon fiber ,glass fiber reinforced plastic material and FGM at different case (with and without hole). 3D modeling done by the parametric software CATIA and analysis done in ANSYS software.

By observing the static analysis the deformation, stress and strain values are increases by increasing the loads. The stress values are less for E-glass fiber material when we compare the aluminum alloy 8011 and carbon fibre reinforced plastic material.

By observing the buckling analysis, the buckling factor more at carbon fiber material when we compare the aluminum alloy 8011 and glass fibre reinforced plastic material.

By observing the linear layer Static analysis, the stress value less at without hole when we compare them with hole.

By observing the linear layer buckling analysis, the buckling factor more at without hole when we compare them with hole.

From these above conclusions observed the better and suitable material and case of the thin cylindrical panel is without hole material is FGM.

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