

Analysis of Composite Cylindrical Shell with and Without Cut-out Section

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Abstract— The objective of this study is to analyse the composite cylindrical shell with and without cutout by applying axial load on Aramid fiber reinforced polymer (AFRP) and Basalt fiber reinforced polymer (BFRP) shell. The Static and Eigen value buckling analysis is done on shell model. The circular, elliptical and rectangle cutouts are considered on cylindrical shell. The compressive stress, deformation, buckling load of each case for cylindrical shell is obtained from ANSYS software. As Fiber reinforced composite materials are more efficient and reliable structures because of their high strength and specific modulus compared to other metallic materials. Stress increases for shell with cutout when compared to the shell without a cutout. The responses of composite shells with cutouts are obtained using geometrically nonlinear FEM software, carried by ANSYS. Composite cylindrical shells are often subjected to defects and damage from both in-service and manufacturing events. Finite element models are also used by many researchers to characterize the behaviour of cylindrical shell considering different types of material and geometrical imperfections. The buckling load value is maximum in circular cutout and minimum in the without cutout. Different changes in the material properties are used here to analyse the static and buckling behaviour of composite shells.

Keywords: Cylindrical Shell, Cutouts, Ansys, Composite, Buckling Analysis, FEM

I. INTRODUCTION

In many industrial applications, shells are equipped with openings of various shapes, sizes and locations within the lateral surface. Nowadays the usages of composite cylindrical shell are gradually increased in many engineering fields. These composite materials provide a number of distinctive design features because of the inherent tailoring properties, including lower weight, high performance, extended service life, and less system maintenance. Submarines, the underground pipeline industry, and the aerospace industry all make extensive use of the composite cylindrical shells. The constant need for lightweight, energy-efficient structures has recently driven structural engineers into the field of structural optimization (specifically, stiffened shell configurations), along with the use of unconventional materials like fiber-reinforced composite (due to their high stiffness or strength to weight ratios). Throughout their useful lives, these shell constructions are subject to compressive loads. There is little existing research estimating the effects of a cutout on the buckling load of a cylindrical shell using analytical techniques because cutout geometry is arbitrary and the resulting complexity of the local membrane stress distribution around the cutout makes prediction difficult. To ensure the integrity of these cylindrical laminated composite shells throughout their service life, a thorough understanding of

their buckling reaction is required. The theoretical limit load for geometry and loading can be significantly reduced for shells with only minor variations. When designing these buildings and during their service lives, it is important to examine how these flaws may affect their ability to transport loads and overall safety. Numerous researchers also employ finite element models to describe the behaviour of cylindrical shells while taking into account various material kinds and geometrical flaws. To explore the buckling and post-buckling response of a large number of cylindrical steel thin-shell prototypes with structural openings, computational models were created that adhere to numerical evaluation methodologies prescribed by current European guidelines for shell buckling.

Although the shell must be stiffened around the opening in order for the applied forces to pass through, the local stress situation right next to the opening is typically the most crucial for the shell. The wall experiences vertical compressive stresses when the shell is filled with stored product, and considerations of buckling under axial compression regulate the wall thickness. The stability of each configuration was studied using each of the analysis procedures identified by the European rules for shell buckling in order to examine behavioural changes in the buckling strength regime of the response that are caused by parametric variations in the cutout (i.e. shape, size, position, and number) (EN 1993-1-6:2007). If the axial compression of the cylindrical shell is homogeneous, it will buckle in a way that is symmetrical to the axis of the cylinder. The energy approach can be used to determine the critical value of the compressive force per unit length of the shell edge.

Regarding the resolution of real-world design issues, FEM's applications are virtually endless. FEA has been the de facto method for solving structural engineering issues in recent years. The automobile and aerospace industries are two sectors that extensively rely on this technology. Manufacturers must rely on this strategy in order to maintain their competitiveness as a result of the requirement to meet the high demands for quicker, stronger, more efficient, and lightweight automobiles and aircraft. Aramid fibers, short for aromatic polyamide, is a type of strong and heat-resistant synthetic fibres. They are utilised for ballistic-rated body armour fabric and ballistic composites in aerospace and military applications. A composite material made of rigid polymer resin and unidirectional basalt fibres is known as a basalt fibers. Natural volcanic basalt rocks are melted at a temperature of around 1400 °C to create basalt fibres. The main objective of the study is to evaluate the stress, deformations and buckling load in cylindrical shell with different cutouts and without cutout by Ansys software. The analysis are done with the use of finite element models. Results and conclusions are determined from the analysis are listed above.

II. OBJECTIVES OF THE PRESENT WORK

The main objective of this work includes the following:

- To carry out static analysis of composite cylindrical shell with and without cutout.
- To study the buckling behaviour of composite cylindrical shell with and without cutout.
- To know the behaviour of the shell with change in the material properties.
- To study the parameters such as stress concentrations, buckling load and deformations.

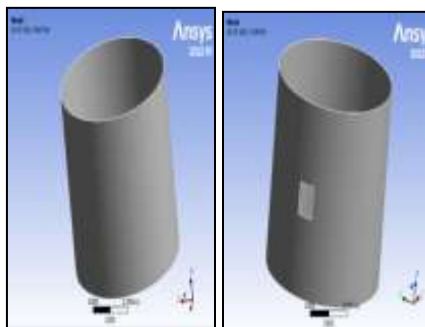
III. MODEL DESCRIPTION

In the present study 8 different models of composite shell which is having radius of 150 mm, thickness is 1.25mm and length is 300mm is used. AFRP (Aramid fiber reinforced polymer) and BFRP (Basalt fiber reinforced polymer) are used for the analysis. The end supporting condition were provided fixed. Load is applied on top as compressive force such as 1500 N. In AFRP, Young's modulus 7.05×10^{10} Pa, Bulk modulus 2.48×10^{10} Pa, Shear modulus 3.42×10^{10} Pa. In BFRP, Young's modulus 8.9×10^{10} Pa, Bulk modulus 4.94×10^{10} Pa and Shear modulus 3.70×10^{10} Pa. The same amount of Area (approximately) is removed in all cutouts. In circular cutout, circle radius 25.25mm, In elliptical cutout, minor axis 20.8mm and major axis 30.7mm. In rectangular cutout, length 50mm and breadth 40mm. The shell was modelled in Ansys software with and without cutout sections.

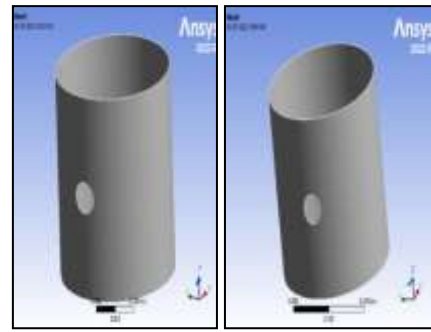
IV. MODELS CONSIDERED FOR ANALYSIS

Following 8 models are analysed by equivalent static and response buckling method using Ansys software.

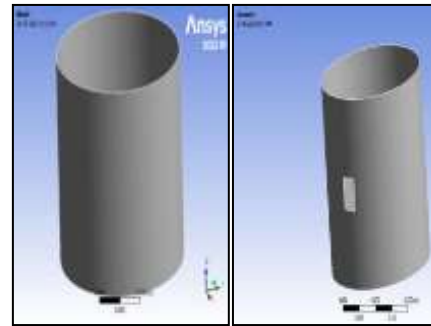
- Model 1: AFRP shell without cutout
- Model 2: AFRP shell with rectangular cutout at centre
- Model 3: AFRP shell with elliptical cutout at centre
- Model 4: AFRP shell with circular cutout at centre
- Model 5: BFRP shell without cutout
- Model 6: BFRP shell with rectangular cutout at centre
- Model 7: BFRP shell with elliptical cutout at centre
- Model 8: BFRP shell with circular cutout at centre



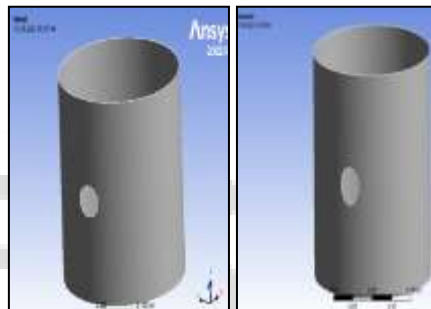
Model 1 and 2



Model 3 and 4



Model 5 and 6



Model 7 and 8

Fig. 1: Models

V. RESULTS AND DISCUSSION

The cylindrical shell is modeled for with and without cutouts. The mesh is generated and boundary conditions are applied. The loads are acting on meshed cylindrical shells. The stress, buckling load and deformation are obtained using ANSYS software for each case.

A. Static Analysis

The response of the structure to the applied external forces is determined using static analysis. Additionally, when the structure is susceptible to external displacements like different support settlements, the static analysis is carried out. In AFRP, deformation occurred in elliptical cutout is 0.09mm and deformation in without cutout is 0.053mm.

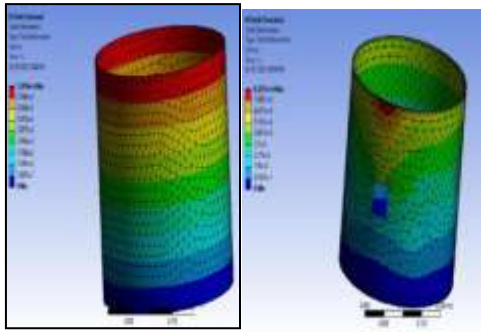


Fig. 2: Deformations in without and rectangle cutout

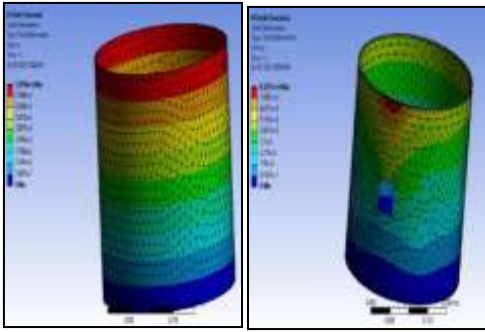


Fig. 3: Deformations in elliptical and circular cutout

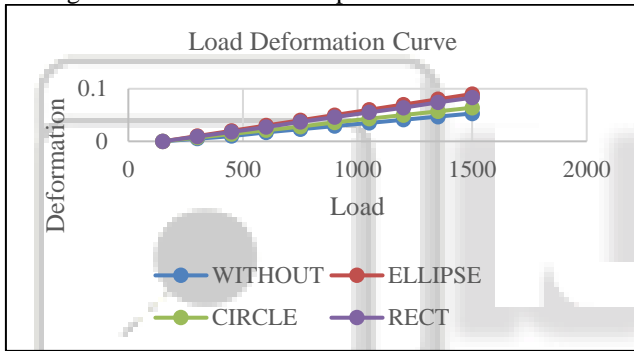


Fig. 4: Load deformation curve in AFRP shell

In BFRP, deformation occurred in elliptical cutout is 0.077mm and deformation in without cutout is 0.042mm.

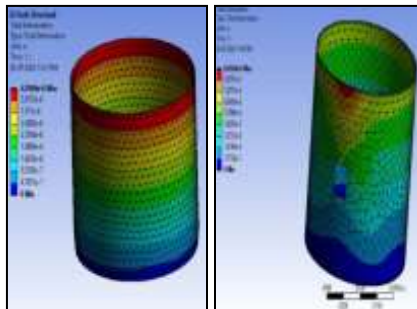


Fig. 5: Deformations in without and rectangular cutout

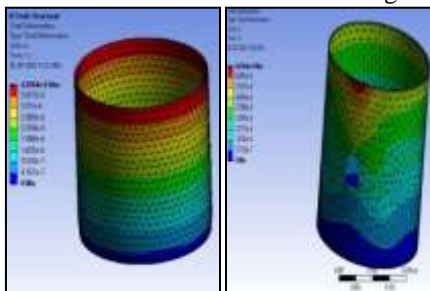


Fig. 6: Deformations in elliptical and circular cutout

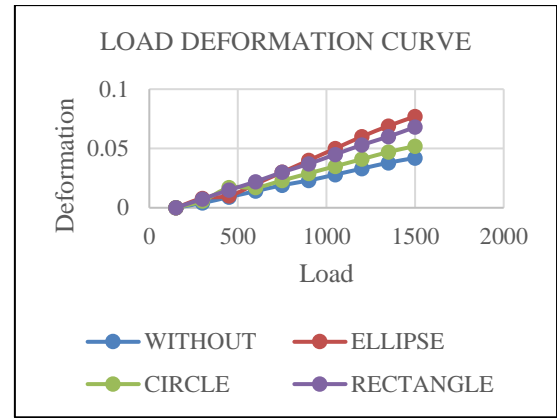


Fig. 7: Load deformation curve in BFRP shell

The basic comparison of different cutouts in AFRP and BFRP material is shown here in “Fig.4” and “Fig.7”. Highest deformation has been observed in MODEL 3 and least in MODEL 6. Also, lowest deformation observed in MODEL 1 and less in MODEL 5.

B. Buckling analysis

Buckling in general is the state of geometric instability of the structure induced by the in-plane thermal/mechanical forces. For some cases, this localized buckling is followed by a stable buckling response near the cutout, which is indicated by the fact that additional load can be applied to the shell before it exhibits overall collapse. Numerous buckling modes and their related buckling load factors can be calculated using FEA algorithms.

The influence of cutouts and the buckling behaviour is shown in “Fig.10” and “Fig.13” respectively. MODEL 4 and MODEL 8 offers high buckling load.

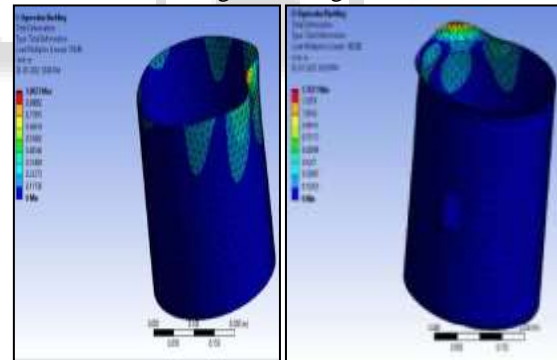


Fig. 8: Buckling modes of AFRP without and rectangular cutout

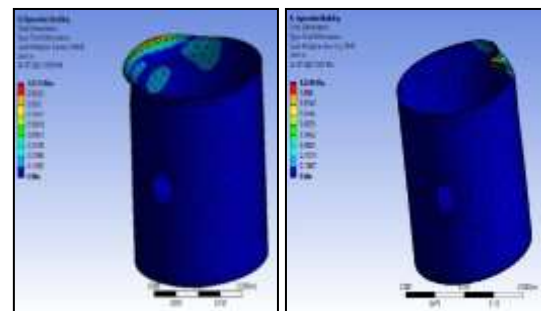


Fig. 9: Buckling modes of AFRP elliptical and circular cutout

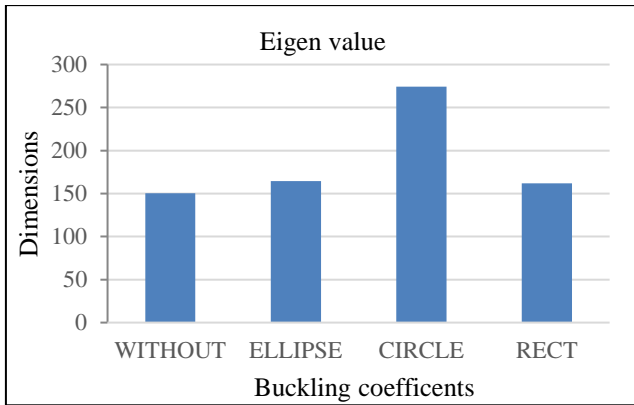


Fig. 10: Buckling modes of AFRP shell

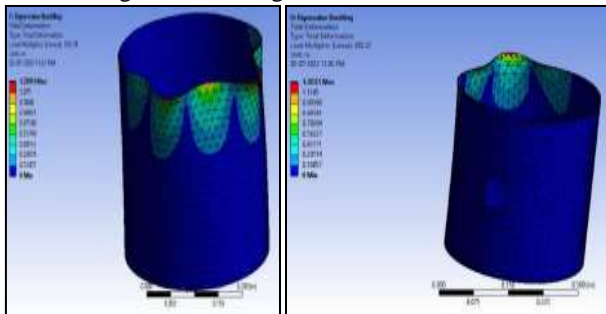


Fig. 11: Buckling modes of BFRP without and rectangular cutout

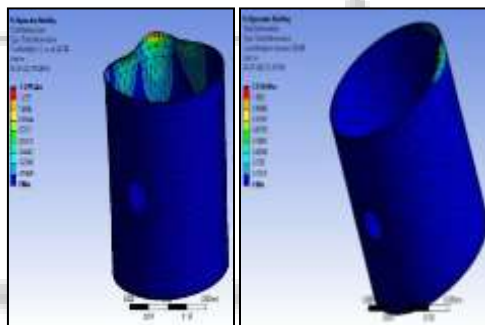


Fig. 12: Buckling modes of BFRP elliptical and circular cutout

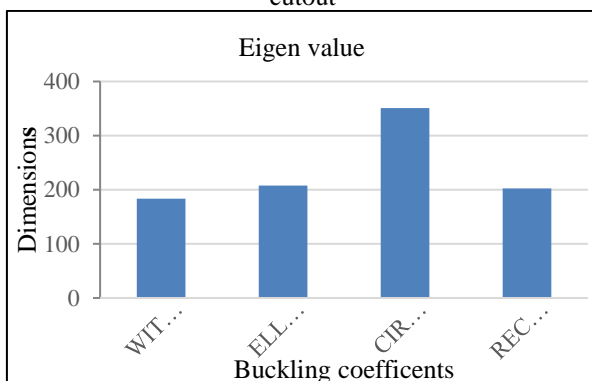


Fig. 13: Buckling modes of BFRP

VI. CONCLUSIONS

From the results obtained by the analysis, following conclusions are drawn.

- 1) The buckling load gets decreased for shell in without cutout when compared to with cutout.
- 2) Regarding cutout, buckling load is maximum for shell with circular cutout and minimum for without cutout.

- 3) Deformation is minimum for shell with without cutout and maximum for elliptical cutout.
- 4) Highest deformation occurred in AFRP shell than BFRP shell. So lowest deformation occurred in BFRP shell.
- 5) Buckling load is maximum in BFRP shell compared to AFRP shell. Therefore minimum buckling load occurred in AFRP shell.
- 6) From the study it can be concluded that BFRP material is better than AFRP.

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