Comparative Study on Buckling Behaviour of Polymer Composite Shells with Metallic Shells for Under Water Vessels by FEA

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Abstract: This investigation was focused on comparing the performance of polymer composite shells with metallic shells of an underwater vessel which operates at a depth of 800 m with effective length of 1000 mm and inner diameter of 250 mm using ANSYS software. For the buckling pressure of 8MPa, Hish strength steel (HY 80), Titanium alloy, Glass epoxy and Carbon epoxy materials were examined. The results showed 39.46% and 36.33% weight reduction in carbon epoxy and glass epoxy respectively when compared to high strength steel.

KEYWORDS: Underwater vessel, Critical buckling pressure, Polymer composite shells, Hydrostatic pressure, FEA, Stress stiffness matrix

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INTRODUCTION:

Underwater vessels gained significance in last few years with the developments in the ocean science and underwater projects, when they dive deep in to water the hydrostatic pressure on them will increase and they suffer buckling. Materials used for underwater vessels must be capable of withstanding high external pressure with good resistance to corrosion, good acoustic absorption high strength to weight ratio.

Fiber reinforced polymer composites can improve the depth and range of operation due to their less weight. These materials can be moulded into required shapes due to their formability and withstand heavy loads because of their high structural stability.

STRUCTURE OF PAPER

The paper is organized as follows: In Section 1, the introduction of the paper is provided along with the structure, important terms, objectives. In Section 2 we discuss related work. In Section 3 tells us about the methodology and the process description. Section 4 tells us results and concludes the paper with acknowledgement and references.

OBJECTIVES

The objective of this project is to calculate the Critical Buckling pressure of underwater vessels and compare the performances of polymer composites shells with metallic shells using FEA.

RELATED WORK

There are numerous works that have been done related to structure and buckling behaviour of polymer composite shells.

Smith [1] has identified the areas of uncertainties in the behavior of polymer composites including failure when subjected to compressive stress.

Carvelli[2] has recommended a procedure for numerical buckling analysis of underwater vessel based on experimental studies under deep sea environment of a complete vehicle composed of cylinder, cones and hemispherical components.

Massager [3] Optimized buckling capacity of thin cylindrical vessels using Genetic Algorithm and recommended ± 55^0 oriented based on the study considering 30, 45, 60,75, 90 orientations for polymer composites.

Ross [4]Proposed glass/polyester for underwater vessel based on the influence of operating environment and material properties on their structural stability.

MODELING OF SPECIMEN

The 3-D cylindrical shell of underwater vessel has a length of 1000 mm, inner diameter of 250 mm and a thickness of T for the critical buckling pressure (CBP) of 8MPa as shown in figure 1. Material properties considered for the analysis are listed in Table 1 and Table 2. For metallic shells isotropic material properties of elastic modulus and poisson's ratios were considered and for polymer composite shells orthotropic material properties of elastic modulus, poisson's ratios and shear modulus are considered.

MESHING OF MODELS

The models are meshed in ANSYS using ANSYS shell elements like SHELL63 for the metallic shells and SHELL 99 for the polymer composite shells which are shone in the figure 2. A shell element has six degrees of freedom at each node.

BOUNDARY CONDITIONS

Both the ends of the cylinder are constrained in all six degrees of freedom (i.e. Translation in x, y, z directions and rotation in x, y, z axis). A load of external pressure of 1Mpa was applied on the outer surface of the shell as shown in figure 3.

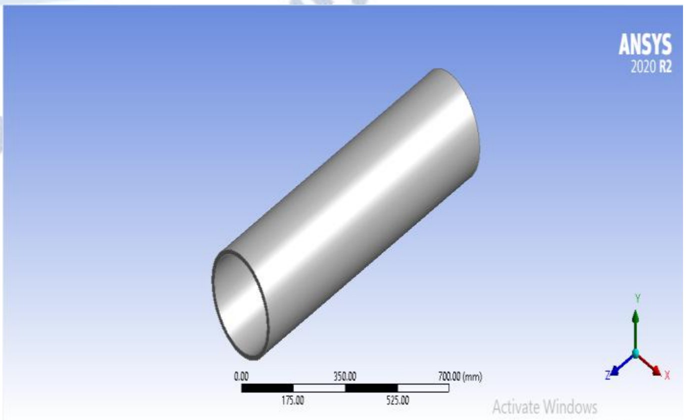

Figure 1: Cylindrical shell Model

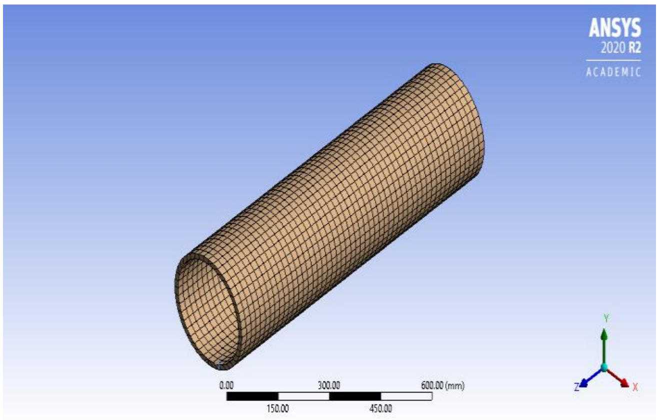

Figure 2: Mesh

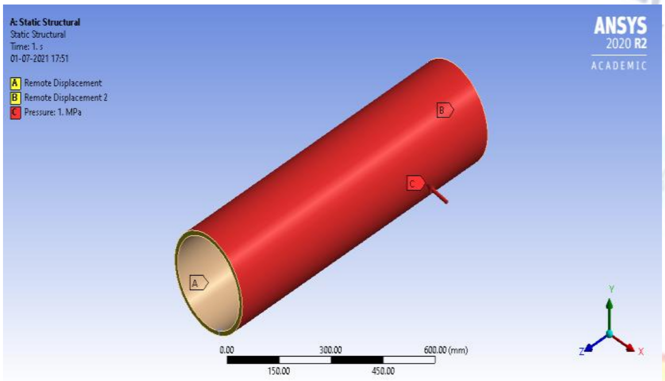

Figure 3: Boundary condition for underwater vessel model

Material	Density (Kg/m³)	Young's modulus(GPa)	Poisson's Ratio
High Strength Steel HY 100	7850	207	0.29
Titanium Alloy	4400	119	0.32

Table 1: Material properties of metallic shells

Material	Glass Epoxy	Carbon Epoxy
Density	1700	1600
Young's modulus (GPa) E_1	45.6	162
E_2	16.2	15.1
E_3	16.2	15.1
Poisson's ratio u_{12}	0.27	0.283
u_{23}	0.49	0.492
u_{13}	0.278	0.34
Shear modulus(Gpa) G_{12}	5.83	5.70
G_{23}	5.83	5.70
G_{13}	5.78	5.40

Table 2: Material properties of composite shells

FINITE ELEMENT ANALYSIS

Finite element analysis was conducted to find the buckling loads and post buckling behavior of the shells. In ANSYS linear buckling analysis is performed in two steps. At first Pre-buckling stress of the structure is calculated, in second step by consideringthe pre-buckling stress stiffness matrix [s] eigenvalue buckling problem is solved which is in the form of [K] + ◎$_i$[S]) {◎} $_i$ = {0}. (1)

Where [K] = Stiffness matrix

[S] = Stress stiffness matrix

◎ = ith eigenvalue

i = ith Eigen vector of displacements

Once the Eigenvalues are predicted the critical buckling load is calculated from below equation (2).

P_{cr} = ◎ * P_a

Where P_{cr} is critical buckling pressure.

P_a is applied pressure.

The Block Lanczos method is used because it is more accurate and with least computational time, the thickness of the shells is varied till the critical buckling pressure of 8MPa is reached for all materials as shown in table 3.

Material	Thickness (mm)
High Strength Steel HY 100	9
Titanium Alloy	11
Glass Epoxy	25.6
Carbon Epoxy	25.8

Table 3: Thickness of shells for 8MPa CBP

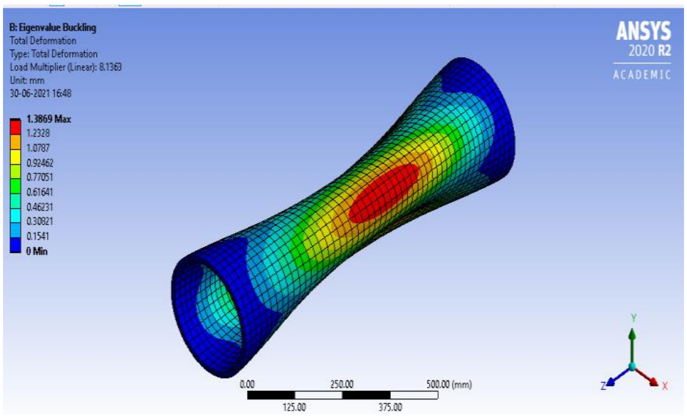

Figure 7:Shape of Carbon Epoxy under CBP of 8 MPa

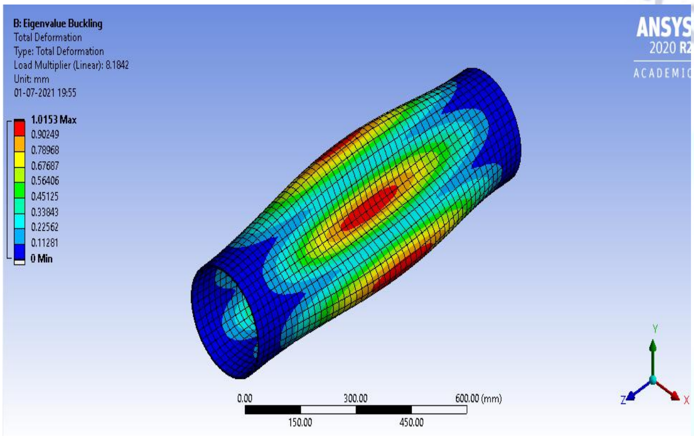

Figure 4: Shape of High strength steel under CBP of 8 MPa

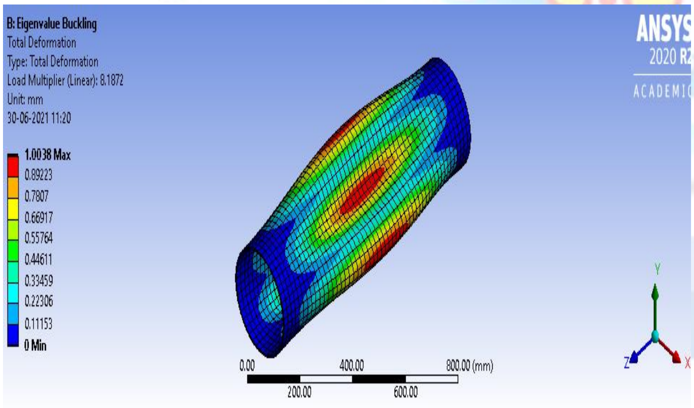

Figure 5: Shape of Titanium Alloy under CBP of 8 MPa

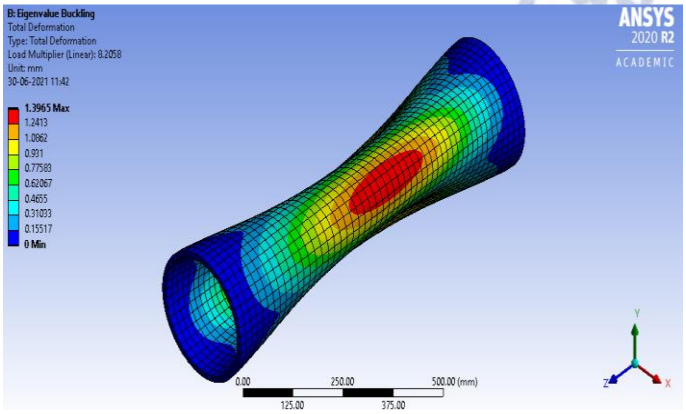

Figure 6: Shape of Glass Epoxy under CBP of 8 MPa

RESULTS AND CONCLUSION

Buckling behavior of polymer composite and metallic shells are investigated for underwater vessels of an operating depth of 800 m by analytical approach using ANSYS software. Different models with different thickness are calculated till the critical buckling pressure of 8 MPa is obtained figure 4 to 7 shows shapes of High strength steel HY 100, Titanium alloy, Glass and Corbon epoxy. The thickness of composite shells were found higher than metallic shells for CBP of 8MPa but due to their low density we see that weight of composite shells is less than metallic shells as shown in figures 8 and 9 respectively.

Based on the results following conclusions were arrived.

As compared to high strength steel there is 40% weight reduction in Carbon epoxy and similarly 37% in Glass epoxy for the critical buckling pressure of 8 MPa.

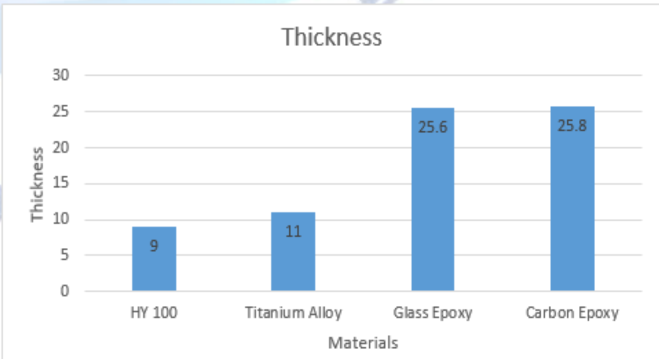

Figure 8: Thickness for CBP of 8 MPa verses Material

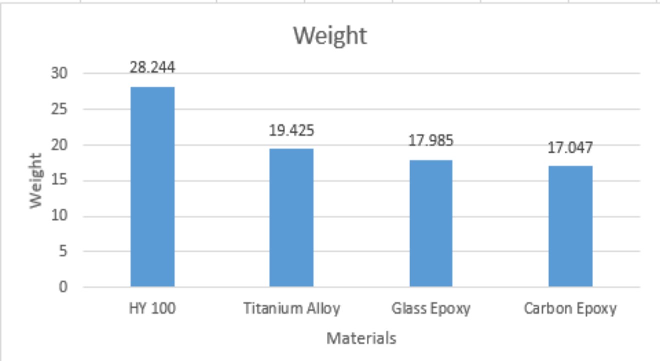

Figure 9: Weightfor CBP of 8 MPa verses Material

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