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Impact Analysis of Composite Shells

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Abstract: An investigation has been conducted into the deformation characteristics of cylindrical and spherical composite shells. These structures consist of a flexible core placed between two composite face sheets. The analysis employs an advanced theory of sandwich structures with flexible cores, focusing on cylindrical and spherical geometries. The behavior of the cylindrical sandwich shell is comprehensively described using a high-order sandwich shell theory. This theory effectively captures nonlinear distortions within the cross-sectional plane of the flexible core, as well as variations in its height. Notably, the model does not make any assumptions regarding the displacement distribution of core components. In this particular study, stress and displacement characteristics of the flexible core are derived through a three-dimensional elasticity solution. The face sheets, on the other hand, are modelled using classical shell theory. To validate the results of the high-order solution, a comparison is drawn between the closed-form solution (developed for simply supported boundary conditions) and outcomes obtained from a commercial finite element method. This verification process involves both cylindrical and spherical configurations. Furthermore, the investigation explores the influence of physical and geometrical parameters on the behaviors of cylindrical and spherical sandwich shells. Therefore, study extends to conducting impact analyses through ANSYS software and a comparison of modelling techniques utilizing CATIA also practical testing, specifically focusing on two-layer and three-layer cylindrical and spherical shells.

Keyword: Impact analysis cylindrical and spherical sandwich shells, CATIA, Ansys, Bending test composite material glass fiber. Deformation characteristics, Cylindrical and spherical sandwich shells, Flexible core, Composite face sheets, Advanced theory of sandwich structures, Nonlinear distortions, Cross-sectional plane, Variational principles.

1.1 Introduction

Fiberglass Reinforced Plastic (FRP), commonly referred to as fiberglass, constitutes a type of thermoset plastic resin that experiences fortification through the incorporation of glass fibers. Plastic resin materials are categorized into two distinct classes: thermosets and thermoplastics. Within this resin system, the characteristics pertaining to chemical, electrical, and thermal attributes are determined. The inclusion of fibers imparts attributes such as strength, dimensional stability, and resistance to elevated temperatures. Additionally, additives play a role in establishing coloration, defining surface texture, and influencing a range of properties encompassing aspects like weather resistance and flame retardancy.

The processing of FRP composites is characterized by intricate chemical interactions, culminating in the attainment of their ultimate properties. A myriad of factors contributes to the final properties, encompassing the specific type, quantity, and composition of both the resin systems and reinforcement materials. Furthermore, the incorporation of additives introduces a significant variable that substantially impacts the properties exhibited by the FRP composite.

Fig: 1.1 Glass fiber

1.2 Aim of the project

Keeping in view on aim of the project, following objectives are framed.

The project objectives are:

- To develop computational model of response of fiber-glass composite under impact load using finite element method.
- To verify the computational model with impact experiment.
- To analyze the behavior of fiber-glass composite under various impact load using the above computational model

1.3Scope of the project

This research will analyze fiber glass reinforced polymers that have been exposed to impact using the finite element approach (FEM). A laboratory impact check will yield the experimental consequences. An experiment might be used to verify the FEM. A digital evaluation of the impact take a look at might be executed the use of the Algor finite element algorithm.

1.4 Impact Tests

Composite materials, such as fiberglass, possess notably high strength relative to their weight. This quality finds practical applications in aviation, where it contributes to improved fuel efficiency by reducing overall aircraft weight. In the realm of composite design, the compressive strength plays a vital role and is subject to rigorous testing. Yet, evaluating compressive strength presents challenges, leading to the adoption of diverse testing methods. A prominent approach involves the ASTM standard, which combines impact loading with compression testing.

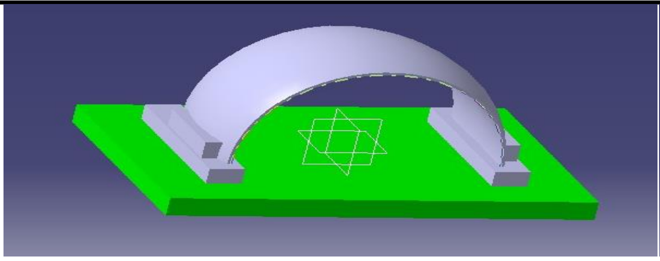
Impact analysis emerges as a valuable tool for foreseeing potential outcomes stemming from proposed alterations. It holds particular significance in evaluating pivotal decisions, offering insights into potential damages. By identifying issues in advance, it empowers the formulation of proactive contingency plans, enhancing the efficiency of project management. The realm of impact tests encompasses various approaches.

2. REVIEW OF LITERATURE

1. Reis, Paulo NB, Carlos ACP Coelho, and Fábio VP Navalho [1]. "Impact response of composite sandwich cylindrical shells. These theory gives a brief idea of cylindrical shell by changing geometrical layers
2. Yi Zou, Shah Huda, and Yiqi Yang [2] investigated the homes of polypropylene-based laminates made from complete and chopped wheat straws (WS), along with their tensile electricity, flexural electricity, impact strength, and sound soaking up capacities (PP).
3. P. Tyhreepopnatkul, N. Kaerkitcha, and N. Athipongarporn [3] have all investigated mechanical homes, inclusive of tensile power, impact energy, and thermo gravimetric evaluation. (TGA). The altered fibre in laminates fashioned of polycarbonate composites with pineapple leaf fibre (PALF) has been diagnosed by way of exam utilising Fourier transform infrared spectroscopy (FTIR).
4. Y-Xu, S. Kawata, K. Hosoi, K. Kawai, and S. Kuroda [4] using the salinized-kenaf polystyrene composites. The contact between the kenaf fibre and matrix can be stepped forward through treating the fibre with a polymeric coupling agent. With the DMA effects, the improved fibre composites demonstrated a regular garage modulus and a lower loss detail.
5. Byoung-Ho Lee, Hyun-Joong Kim, and Woong-Ryeol Yu[5] examined the development of long, spasmodic natural fiber progressed polypropylene bio composites and their mechanical houses.

3 DESIGN IN 3D CATIA MODELING

CATIA offers two main types of models: Solid For these there are two different workbenches you can use: Part design exclusively for solid modeling as shown in(Fig3.1toFig3.4)



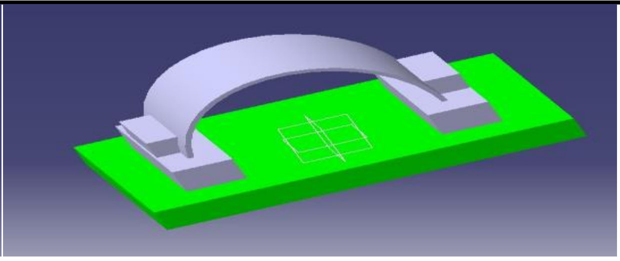
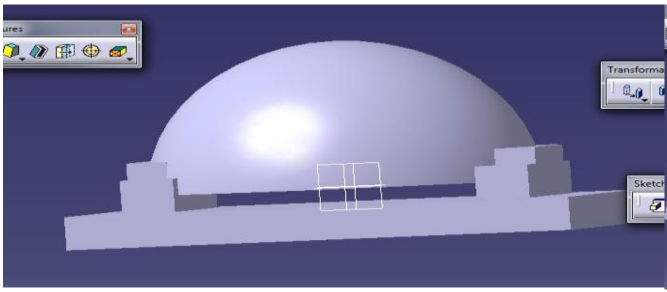


Fig: 3.1 2 mm cylindrical composite shell CATIA 3D model. Fig: 3.2, 3 mm cylindrical composite shell CATIA 3D model.



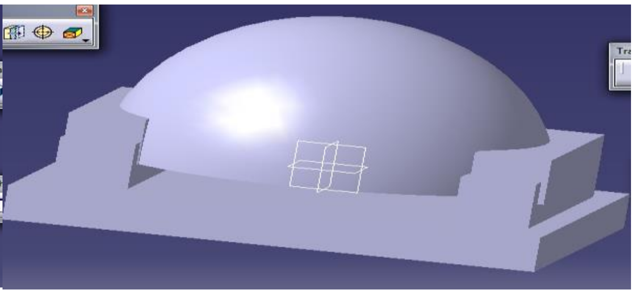


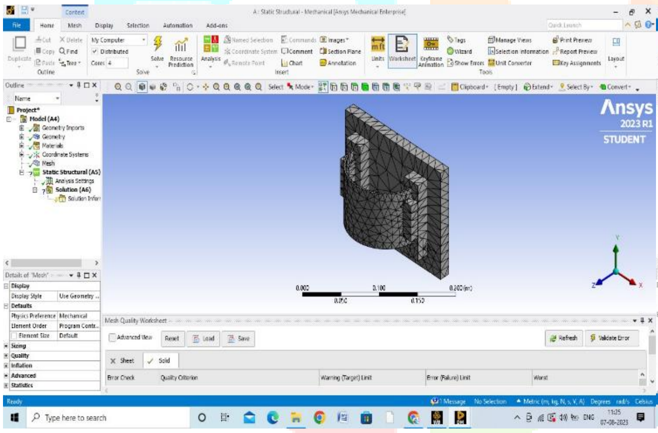
Fig: 3.3, 2 mm spherical composite shell CATIA 3D model. Fig: 3.4, 3 mm spherical composite shell CATIA 3D model.

4 ANALYSIS

4.1 Introduction to Finite Element Method

The finite element method (FEM) is a popular method for numerically solving differential equations arising in engineering and mathematical modeling as shown in(Fig4.1toFig4.16)

4.2 Impact analysis (2 mm) cylindrical composite shell



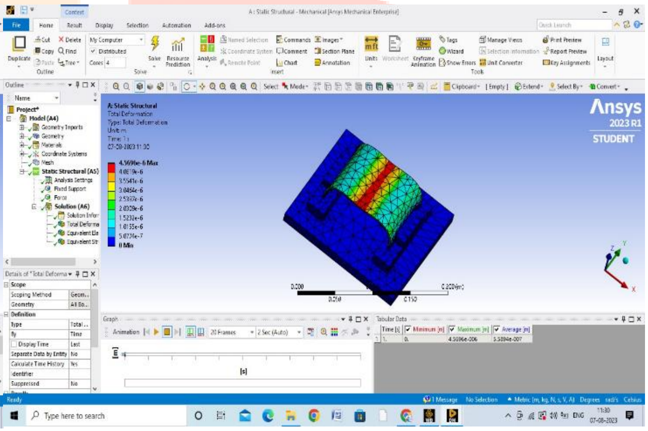
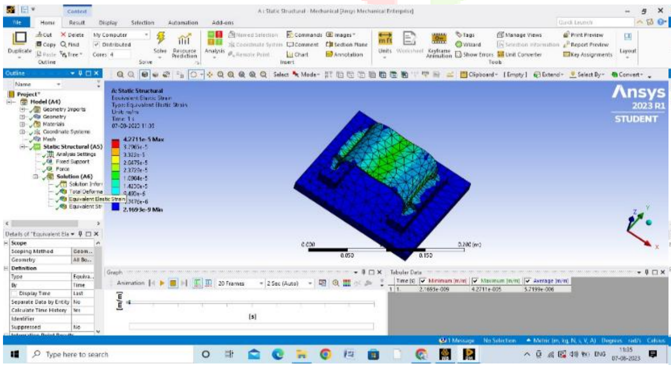


Fig: 4.1 Meshing cylindrical composite shell Fig: 4.2 Deformation cylindrical composite shell



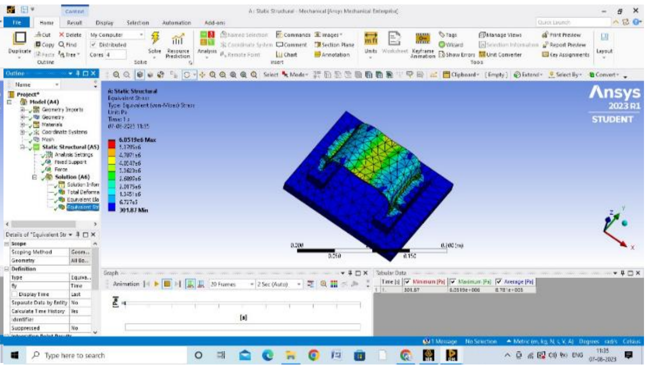


Fig: 4.3 Strain cylindrical composite shell Fig: 4.4 Stress cylindrical composite shell

4.3 Impact analysis (3 mm) cylindrical composite shell

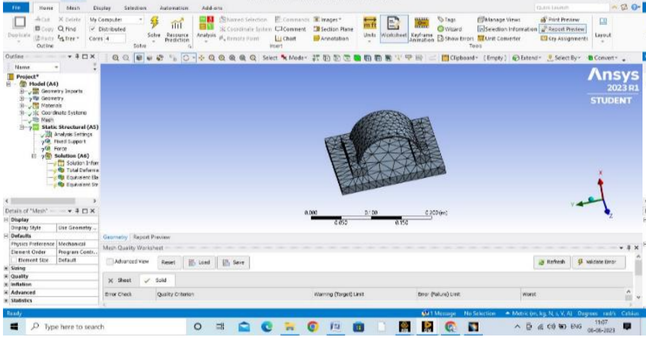


Fig: 4.5 Meshing cylindrical composite shell

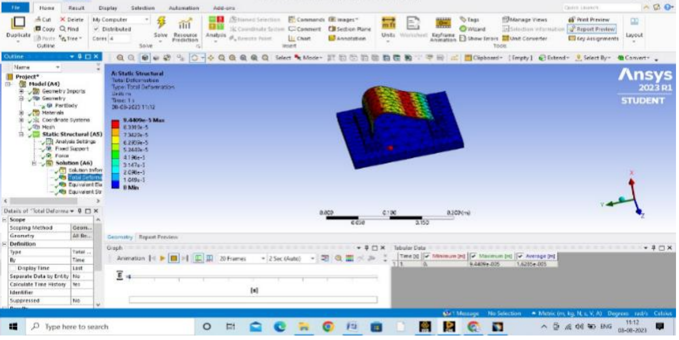


Fig:4.6 Deformation cylindrical composite shell

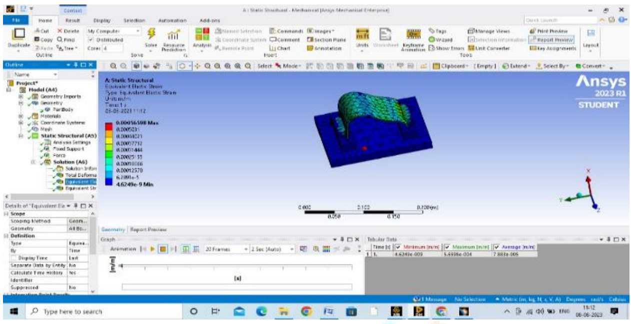


Fig: 4.7 Strain cylindrical composite shell

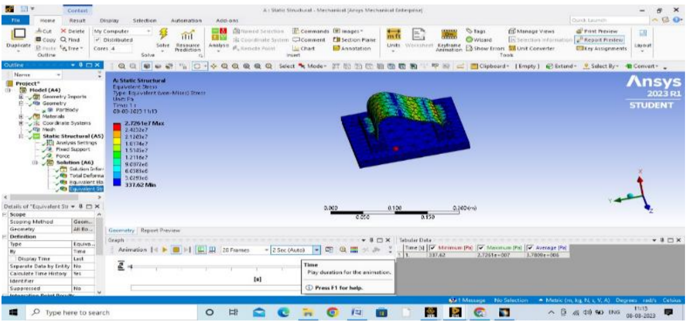


Fig: 4.8 Stress cylindrical composite shell

4.4 Impact analysis (2mm) spherical composite shell

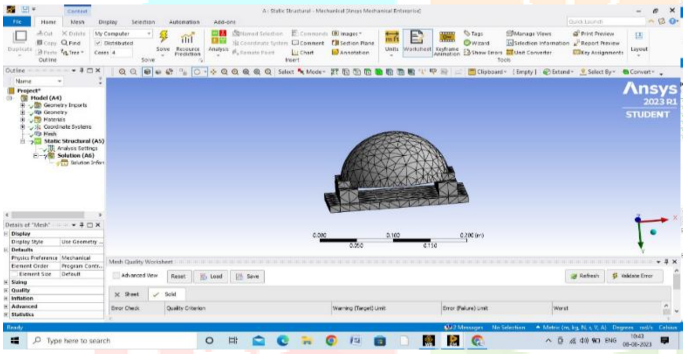


Fig: 4.9 Meshing spherical composite shell

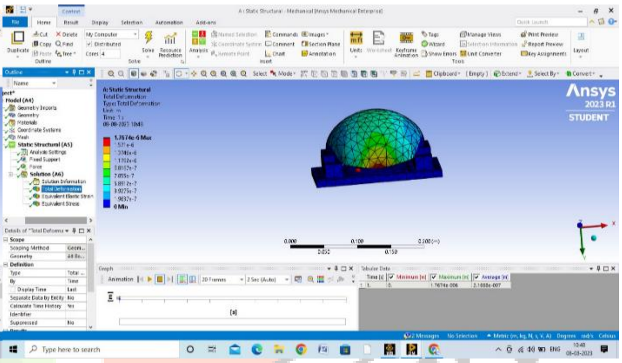


Fig: 4.10 Deformation spherical composite shell

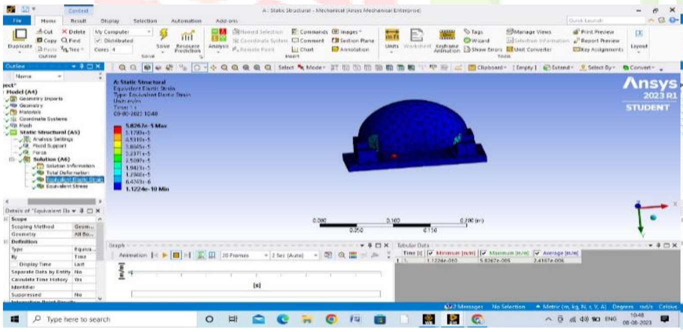


Fig: 4.11 Strain spherical composite shell

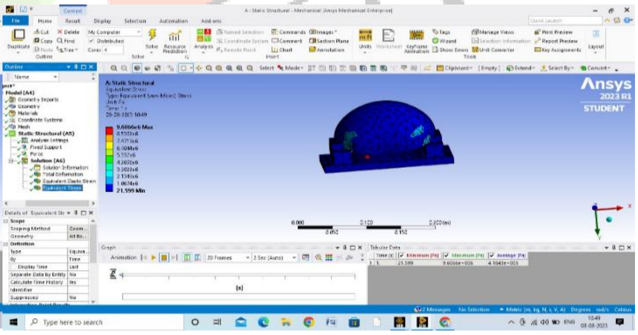


Fig: 4.12 Stress spherical composite shell

4.5 Impact analysis (3 mm) spherical composite shell

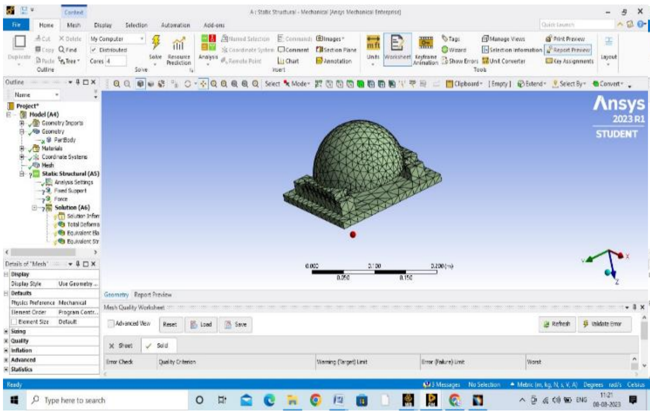


Fig: 4.13 Meshing spherical composite shell

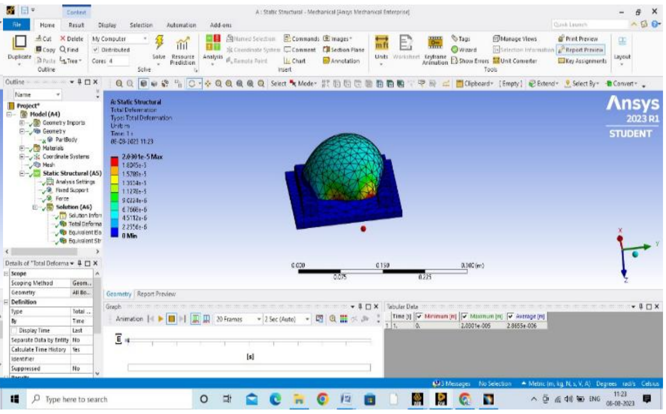


Fig: 4.14 Deformation spherical composite shell

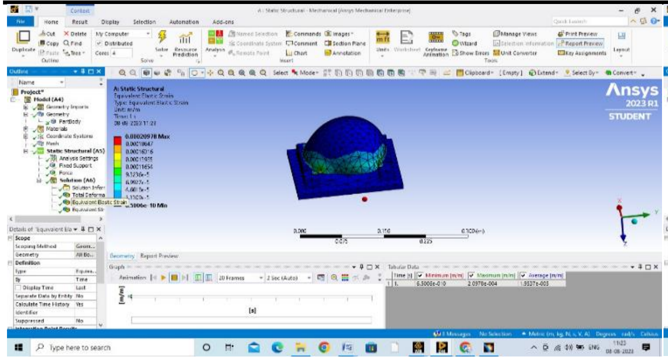


Fig: 4.15 Strain spherical composite shell

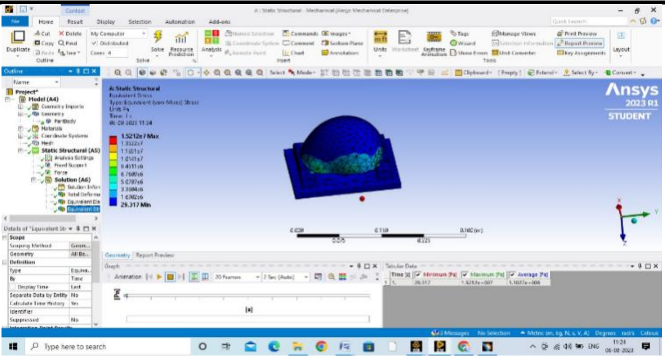


Fig: 4.16 Stress spherical composite shell

5. EXPERIMENT ANALYSIS COMPOSITE SHELL

5.1 cylindrical composite shell

Fig: 5.1 2 layers cylindrical composite shell

Fig: 5.2, 3 layers cylindrical composite shell

5.2 spherical composite shell

Fig: 5.3 2 layers spherical composite shell

Fig: 5.4, 3 layers spherical composite shell

The evaluation of compressive strength is a critical component in the characterization of composite materials, encompassing both cylindrical and spherical geometries. In the case of cylindrical specimens with a thickness of 2mm, an applied load of 533 N resulted in a maximal displacement of 440 mm. A corresponding cylindrical specimen with a 3mm thickness exhibited an applied load of 570 N, leading to a maximal displacement of 460 mm. Transitioning to spherical specimens, the 2mm-thick variant sustained an applied load of 873 N, resulting in a maximal displacement of 1120 mm. Contrasting this, the 3mm-thick spherical specimen withstood an applied load of 1801 N, yielding a maximal displacement of 1420 mm.

Upon careful comparison, it becomes evident that the spherical configuration outperforms the cylindrical counterparts in terms of strength and stiffness.

RESULT

Table 1: Impact Analysis: F= 870 kn

S. No	Thickness(mm)	Material Glass fiber	Deformation (10^3 mm)	Equivalent Strain (10^4)	Equivalent Stress M. Pa
1	2	Cylindrical	4.5696e-6	4.2711e-5	6.0519e+6
2	2	Spherical	1.7674e-6	5.8267e-5	9.6066e+6
3	3	Cylindrical	9.4409e-5	5.6598e-4	2.7261e+7
4	3	Spherical	2.0301e-5	2.0978e-4	1.5212e+7

Table 2: Experimental Impact Test

Names	Thickness (mm)	Ultimate load Applied (N)	Maximum Deformation (mm)
Cylindrical	2	533	440
Spherical	2	873	1120
Cylindrical	3	570	460
Spherical	3	1801	1420

CONCLUSION

Extensive impact testing was conducted on prototypes of both cylindrical and spherical composite structures, featuring thicknesses of 2mm and 3mm. The purpose was to assess and contrast their compressive strengths. The cylindrical composite specimen with a 2mm thickness displayed a discernible crack at a load of 533 N, accompanied by a maximal displacement of 440 mm. In contrast, the 3mm-thick cylindrical composite endured a higher load of 570 N, showcasing a maximal displacement of 460mm, thus surpassing the performance of the 2mm counterpart.

Shifting focus to the spherical composite prototypes, the 2mm-thick variant exhibited remarkable resilience, withstanding a peak load of 873 N and sustaining a maximal displacement of 1120mm. Notably, this performance exceeded that of the 3mm-thick spherical composite, which sustained a load of 1801 N but experienced a maximal displacement of 1420mm. Comparing the outcomes, the 2mm-thick spherical composite outperformed its 3mm counterpart, evidencing superior strength and stiffness.

This empirical analysis leads to several noteworthy conclusions: The 3mm-thick cylindrical composite showcases enhanced strength and stiffness in comparison to its 2mm equivalent. In the context of the comparison between spherical and cylindrical composite shells, the spherical configuration emerges as the superior option in terms of both strength and stiffness.

To delve into the technical aspects, CATIA V5 was employed to develop prototypes adhering to designated specifications. Subsequently, comprehensive analyses were executed utilizing ANSYS Workbench, subjecting the designs to varying impact and compressive loads. Finite Element Analysis (FEA) revealed minimal deformation, stress, and strain in the 2mm-thick spherical and 3mm-thick cylindrical prototypes. Remarkably, these structures exhibited lower stress levels compared to alternative composite materials and even steel.

In summation, the preponderance of evidence underscores the exceptional performance of the 2mm-thick spherical and 3mm-thick cylindrical composite prototypes. Their superior characteristics in terms of deformation and displacement render them optimal choices among the range of composite materials examined. This holistic assessment culminates in the determination that the 2mm spherical and 3mm cylindrical variants are indeed the most favorable choices, encapsulating both practical strength and structural integrity.

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