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Sandwich Structure Bending Analysis using Finite Element Analysis

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Abstract: Many commercial packages use sandwich composite materials, and this search takes advantage of ANSYS software to evaluate their bending behaviors. FEM gives a good understanding of material behavior with the exposure of outdoor forces. The construction of the sandwich production that accounts for its many layers, as well as for the characteristic features of the materials used is an important aspect of this examination. Many commercial packages use sandwich composite materials, and this search takes advantage of ANSYS software to evaluate their bending behaviors. FEM gives a good understanding of material behavior with exposure to outdoor forces. The construction of the sandwich production that accounts for its many layers, as well as for the characteristic features of the materials used is an important aspect of this examination.

Keywords: Sandwich composites, Numerical analysis, Structural Response, Finite Element Method.

Introduction

Composite materials, in particular sandwich structures, play a pivotal function in numerous commercial sectors, along with aerospace, car, shipbuilding, and the production of lightweight but strong materials (Ma et al. 2021)(Oladele et al. 2020). These systems are composed of multiple layers with awesome residences, offering an most excellent mixture of low weight, high power, and stiffness (Ng et al. 2022)(Aldeen et al 2023). Effective design and optimization of such structures, however, necessitate a complete analysis in their mechanical conduct (Khan et al. 2020)(Liu et al. 2020). Finite element simulation software like ANSYS has end up important for this motive. As a robust and extensively followed device, ANSYS facilitates the modeling and evaluation of complex1 systems, presenting targeted insights into cloth behavior under diverse1 loading and environmental conditions (Qi et al. 2021)(Chen et al. 2018)(Bhashyam, 2002). Gauchía et al. (2017) talk the importance of optimizing automobile shape designs to stability automobile stiffness and weight, that are vital elements for automobile approval and performance. They propose coupling finite element technique (FEM) software like ANSYS with MatLab for optimization, leveraging MatLab's pre-carried out and user-defined algorithms. This integration lets in for computerized, person-free optimization of complicated vehicle systems, as verified through a bus structure case have a look at. The goal is to optimize weight and torsional stiffness by way of adjusting beam thickness whilst minimizing weight. Genetic algorithms have been decided on for the optimization, as they are effective for multidimensional international searches with a couple of local minima. The evaluation is performed the use of ANSYS, which can be programmed in Parametric Design Language (APDL) for parametric modeling, enabling automatic optimization with out consumer intervention. This technique is designed to improve car dynamics, which includes managing, rollover stability, and lateral grip. Al-Abboodi et al. (2024) evaluated the mechanical homes of a steel glass alloy (Fe49.7, Cr17.1, Mn1.9, Mo7.4, W1.6, B15.2, C3.8, Si2.4) prepared with the aid of spark plasma sintering (SPS) the use of a 3-factor bending apparatus. The look at centered on samples with macro-scale pass-sections, presenting regular take a look at dimensions and well-managed sample sizes. Sharp notches, with radii 3 times smaller than in previous studies, had been created the usage of a wire saw. The notch fracture toughness and Young's modulus were measured as 231 GPa and four.91 MPa·m^$^{1/2}$, respectively. Vickers indentation and flexure exams for Young's modulus have been constant, but the indentation fracture longevity was 49.9% decrease than that acquired through flexure assessments. The micro-scale mechanical belongings assessment approach developed in this observe is applicable to samples with specific compositions or manufacturing methods. Mansoora et al. (2020) investigated the vibration analysis of rotors, focusing on the impact of unbalancing forces that can result in crack initiation and increase in the rotor shaft. To predict cracking, vibration parameters and the presence of capacity cracks have been studied analytically and numerically the use of a custom-advanced ANSYS code. The rotor, supported via journal bearings, had its stiffness and damping coefficients calculated analytically after which applied to the vibration version. The numerical outcomes had been as compared with analytical solutions, displaying appropriate agreement with a maximum errors of seven.31% for the critical pace. The have a look at located that because the crack depth accelerated, each the orbit size and response also multiplied, while the important pace reduced. Wahrhaftig et al. (2023) studied the minimum layout bending second of concrete narrow columns the use of a device of equal stiffness. The method simplifies non-prismatic factors by means of changing them right into a prismatic system with equal bending stiffness. Numerical simulations, thinking about loading, concrete's modulus of elasticity adjustments, and cracking, showed that the equivalent stiffness method decreased the trouble complexity. Due to concrete creep, the maximum moment within the equivalent device became found to be 2.94 instances lower than in the unique machine. Mobark et al. (2023) carried out an experimental and numerical look at the compelled vibration of nano Al2O3 cantilever beams with holes and cracks. The have a look at recognized the impact of Al2O3 concentrations (0% 1% 3%, 4%) on beam morphology and vibration traits. Results showed that crack and hole depth increased with higher records loading, and nanoparticle dispersion stepped forward damping with the aid of enhancing electricity dissipation. Future paintings should use Power Spectral Density (PSD) for structural reaction analysis rather than time records loading. Aldriasawi et al. (2024) studied the impact of floor remedy on Fe-based totally amorphous coatings. Vacuum heat remedies at 670°C and 770°C have been applied, displaying a Vickers hardness of 755, desirable wear resistance, and compressive residual stresses of −55 MPa. Combined vacuum warmness treatment and sandblasting improved compressive stress by means of 122%, lowering wear quantity by using 30%. However, remedy at 770°C negatively impacted the coating’s residences. This examine makes a speciality of the bending evaluation of sandwich structures the use of the finite element1 technique (FEM) within ANSYS. The primary objective is to research the mechanical response of sandwich structures1 beneath bending masses, considering the configuration and material1 homes of every layer. The analysis targets to assess stresses, ordinary deformations, and layer-specific1 deformations, which are vital for designing and optimizing sandwich structures for various commercial 1applications. Moreover, this research contributes to advancing the 1understanding of composite materials and numerical1 analysis strategies. The findings offer practical insights for reinforcing the performance and sturdiness of industrial1 merchandise, underscoring the significance1 of sandwich structures in engineering1 innovation.

Software Setup

CAD Model

In order to simulate the sandwich panel's 3-factor bending test, a floor package model turned into first made with Design Modeler software program after which imported into ANSYS. The Design Modeler become applied to precisely design the faces and construct the layers of the composite materials. The mechanical meshing methodology in ANSYS Workbench become selected, employing a aggregate of tetrahedral and hexahedral factors to improve accuracy and computational efficiency (Aldriasawi et al. 2024)(Abdelhussien et al. 2023)(Abdelhussien et al. 2024).

The studies applied the SOLID186 detail from the ANSYS detail collection, characterized by 20 nodes and especially designed for modeling elastic substances. This element kind facilitated correct simulation of deformations and mechanical responses below carried out hundreds.

Mechanical properties

Both Table 1 and Table 2 detail the mechanical traits of the materials that made up the sandwich panels that have been part of this studies.

Table 1. Mechanical Characteristics of Materials

Materials	Density (Kgm^{-3})	Young's Modulus (Pa)	Poisson's Ratio
Aluminium	2770	7.1E+10	0.33
E-Glass	2600	7.3E+10	0.22
Polyurethane	192	6.61E+07	0.316
Resin Epoxy	1160	3.78E+09	0.35

Table 2. Mechanical Characteristics of Carbon Fibers

Mechanical Properties	Density (Kgm^{-3})	Young's Modulus (Pa)			Poissons Ratio		
Direction	1800	X	Y	Z	XY	YZ	XZ
Carb. Fiber		2.3E+11	2.3E+10	2.3E+10	0.2	0.4	0.2

Geometry

After making the surface bundle model in Design Modeler, it turned into imported into ANSYS. The design of the composite faces and layers become performed the usage of ANSYS Composite PrepPost (ACP) (Bhashyam, 2002).

Figure 1. Mesh implementation on a Sandwich Panel

In order to acquire particular simulations with the FEM, meshing is an crucial a part of ANSYS. Depending at the form of element, the mesh will have exclusive factors with one-of-a-kind varieties of nodes that represent the shape of the geometry. The finite detail approach simplifies numerical resolution by decreasing the countless levels of freedom of a continuous item to a restricted range through making use of the calculation precept to a finite range of factors after which interpolating the results across the whole shape.

Boundary Conditions

In both times, the boundary conditions hired in this investigation were carried out in the same way:

1. Constraints on Degrees of Freedom (DOF): Displacements in the X, Y, and Z axes (UX, UY, UZ) were constrained at nodes along the beam's edges. This shows that nodes on those edges had been confined from displacement or deformation in those guidelines.

2. Application of Bending Force (F): The bending force turned into exerted at the midpoint of the beam. An outside force changed into exerted on the beam's core to duplicate actual bending conditions.

These boundary situations are hired to simulate realistic scenarios in which the beam is constant at its extremities and is subjected to a bending load at the center. They allow the simulation of the stresses and deformations that the beam undergoes beneath those occasions, which aids within the evaluation of its overall performance and the optimization of its design. The deformations, stresses, and reactions of the beam can be as it should be determined via numerical simulation by means of imposing those boundary situations and the perfect bending force, as illustrated in Figure 2.

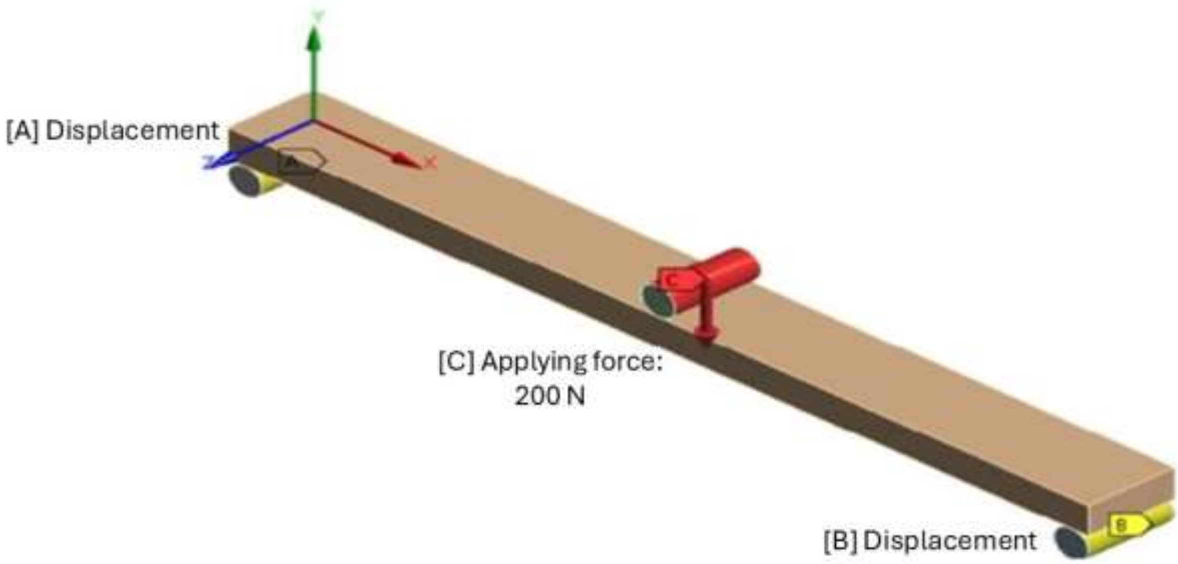

Figure 2. Selection of boundary situations and force zones.

Results and discussion

By comparing the results for various foam thicknesses, we can quantify how those variances have an effect on the shape's performance and overall responsiveness. Finding the most appropriate foam thickness for the composite shape in terms of weight-to-tension ratio requires a complete assessment of the consequences, including deformations, stresses, displacements, and responses to applied forces. Several factors must be taken under consideration at the same time as studying the outcomes of varying foam thicknesses. There can be blessings to a thicker foam layer in phrases of effect resistance, thermal insulation, and soundproofing. Nevertheless, this could bring about a sizeable boom in the shape's typical weight, which may be a concern in packages in which lightweighting is important.

However, a shape's ordinary weight can be reduced through a smaller foam thickness, which may be fantastic for applications that prioritize light-weight. Nevertheless, this can compromise the shape's usual strength and tension, specially while subjected to extreme constraints or giant pressures.

It is imperative to gain an ideal equilibrium among the thickness of froth and the particular structural necessities. This can also necessitate compromises, as an intermediate foam thickness can offer a excellent equilibrium between structural pressure, impact resistance, and lightweight. The results of this evaluation can provide treasured insights for the layout and optimization of systems that make use of sandwich composite substances, thereby improving the sturdiness and performance of commercial merchandise.

Total displacement

The total displacement is measured for thicknesses ranging from 30 to 40 mm, thus making it possible to evaluate how this variation in thickness affects the overall behavior of the structure under load and contributes to determining the best configuration to optimize its performance.

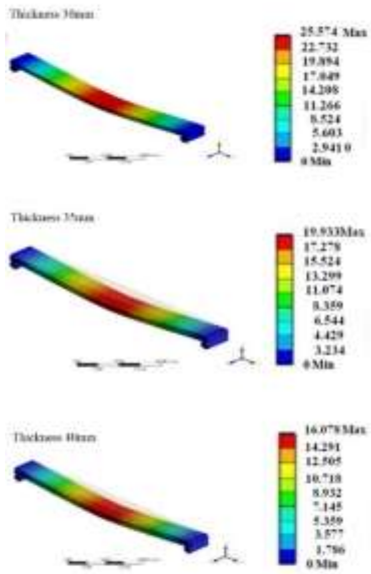

Figure 3. Total displacement [H: Static Structure; Unit: mm; Time: 5s]

Figure 3 shows the static structure with displacements of the type: total-Above/Below in mm with a holding time equal to 5 seconds. We can see that for the minimum thickness used of 30 mm, the final maximum displacement reaches a maximum value compared to the other thicknesses of 35 mm and 40 mm, with a value of 25.574 mm. By increasing the thickness of the sandwiches by an interval of 5 mm each time, we reduce the maximum displacement by almost a third of the maximum value for each increased thickness. Given that our panels exhibit curvilinear forms with two radii of curvature (internal and external) during operation, we can say that the external sides will be stretched and subjected to tensile forces, whereas the internal sides will be subjected to compressive forces. The foam inside will also be either compressed or stretched depending on its position within the panels. The 40 mm thickness is chosen due to its lowest maximal displacement many of the 3 thicknesses employed.

Equivalent elastic deformation

Figures 6 visually represent the equivalent elastic deformation concerning a thickness variation ranging from 30 to 40 mm. These graphical representations elucidate the variation in equivalent elastic deformation with differing thickness, yielding essential insights into the mechanical conduct of the structure below numerous loads and environmental conditions. Analyzing the tendencies illustrated in those figures allows a comprehensive understanding of the effect of thickness versions on the overall elastic deformation of the shape, thereby helping in the optimization and layout of sandwich structures for improved performance and durability throughout numerous commercial applications.

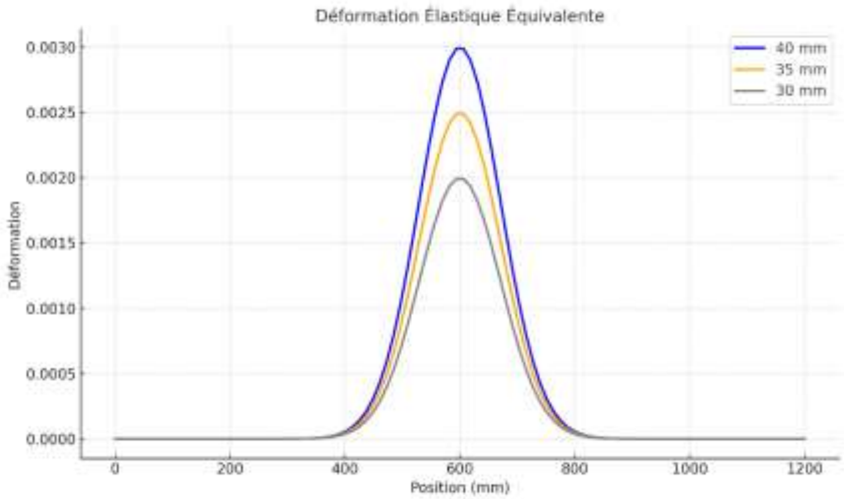

Figure 3. Equivalent elastic deformation

A simulation research turned into undertaken the use of ANSYS to study the impact of different foam thicknesses at the overall performance and reaction of a sandwich structure. Figure four illustrates the similar pressure values received following the utility of bending checks at the structure. The results indicated that the best equivalent pressure attained became 493.1 MPa within the 30 mm thick polyurethane foam, whereas the 35 mm thick polyurethane foam exhibited a most equivalent strain of 414.21 MPa. These findings underscore the importance of froth thickness in influencing the structural conduct and stress distribution within the sandwich structure under flexural loading.

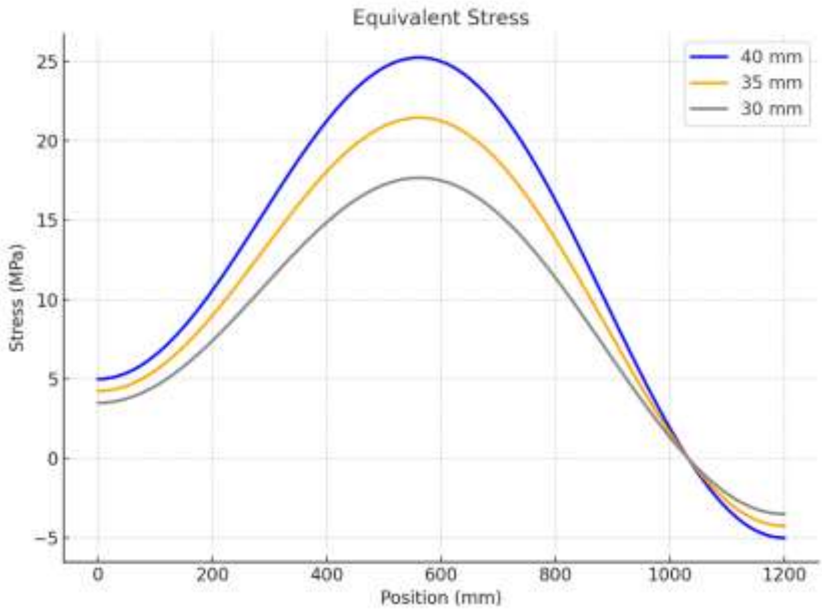

Figure 4. The equivalent stresses on a sandwich panel structure with distinctive foam thicknesses.

Conclusions

The effects received, along with equivalent stress, equal elastic deformation, and overall displacements, are presented in the accompanying figures. The bending analysis of the sandwich composite cloth changed into carried out the use of ANSYS software program, which effectively addressed the complexities associated with its behavior under loading situations. Precise finite detail modeling techniques have been applied, accounting for versions in the dimensions of the cloth layers. This method enabled a complete evaluation of deformations, stresses, and layer-particular responses.

References

Abdelhussein, A., Yang, G., Hussein, E. K., Li, L., & Mohamad, B. (2024). Investigation of fracture behavior and mechanical properties of epoxy composites supported with MWCNTs microscopically. Vibroengineering Procedia, 54, 193–201. https://doi.org/10.21595/vp.2024.23924

Abdelhussien, A., Yang, G., Hussein, E., Li, L., Al-Abboodi, H., & Mohamad, B. (2023). Analysis of the mechanical characteristics of date seed powder-based composite carbon fiber reinforced polymers. Facta Universitatis, Series: Mechanical Engineering, 0. Retrieved from http://casopisi.junis.ni.ac.rs/index.php/FUMechEng/article/view/11963

Al-Abboodi, H., Fan, H., Al-Bahrani, M., Abdelhussien, A., & Mohamad, B. (2024). Mechanical characteristics of nano-crystalline material in metallic glass formers. Facta

Universitatis-Series Mechanical Engineering, 22(2), 315–328. https://doi.org/10.22190/FUME230128016A

Aldeen, A., Mahdi, D., Zhongwei, C., Disher, I., & Mohamad, B. (2023). Effect of isothermal and isochronal aging on the microstructure and precipitate evolution in beta-quenched N36 Zirconium alloy. Facta Universitatis-Series Mechanical Engineering. https://doi.org/10.22190/FUME230405019A

Aldriasawi, S. K., Ameen, N. H., Fadheel, K. I., Anead, A. M., Mhabes, H. E., & Mohamad, B. (2024). An experimental artificial neural network model: Investigating and predicting effects of quenching process on residual stresses of AISI 1035 steel alloy. Journal of Harbin Institute of Technology (New Series), 31(5), 78–92. https://doi.org/10.11916/j.issn.1005-9113.2023090

Aldriasawi, S. K., Hasein, A. N., Anead, A. M., & Mohamad, B. (2024). Investigation the effect of surface treatment on the mechanical properties of coating. Pollack Periodica, 19(2), 138-145. https://doi.org/10.1556/606.2024.00955

Bhashyam, G. R. (2002). ANSYS mechanical—a powerful nonlinear simulation tool. Ansys, Inc., 1(1), 39.

Chen, X., & Liu, Y. (2018). Finite element modeling and simulation with ANSYS Workbench. CRC Press. https://doi.org/10.1201/9781351045872

Gauchía, B. L., Boada, M. J. L., Díaz, V., & Bennett, K. (2017). Integration of MATLAB and ANSYS for advanced analysis of vehicle structures. In MATLAB applications for the practical engineer. https://doi.org/10.5772/57390

Khan, T., Acar, V., Aydin, M. R., Hülagü, B., Akbulut, H., & Seydibeyoğlu, M. Ö. (2020). A review on recent advances in sandwich structures based on polyurethane foam cores. Polymer Composites, 41(6), 2355–2400. https://doi.org/10.1002/pc.25543

Liu, J., Tao, J., Li, F., & Zhao, Z. (2020). Flexural properties of a novel foam core sandwich structure reinforced by stiffeners. Construction and Building Materials, 235, 117475. https://doi.org/10.1016/j.conbuildmat.2019.117475

Ma, Q., Rejab, M. R. M., Siregar, J. P., & Guan, Z. (2021). A review of the recent trends on core structures and impact response of sandwich panels. Journal of Composite Materials, 55(18), 2513–2555. https://doi.org/10.1177/0021998321990734

Mansoora, H. I., Al-Shammari, M., & Al-Hamood, A. (Eds.). (2020). Theoretical analysis of the vibrations in gas turbine rotor. In IOP Conference Series: Materials Science and Engineering (Vol. 671, No. 1). IOP Publishing. https://doi.org/10.1088/1757-899X/671/1/012157

Mobark, H. F. H., Fahdel, E. Z., Hussein, M. T., & Mohamad, B. (2023). Experimental study of nano-composite materials on vibration responses. Diagnostyka, 24(3), Article 2023312. https://doi.org/10.29354/diag/171710

Ng, L. F., Subramaniam, K., & Mohd Ishak, N. (2022). An overview of the natural/synthetic fibre-reinforced metal-composite sandwich structures for potential applications in aerospace sectors. Advanced Composites in Aerospace Engineering Applications, 177–194. https://doi.org/10.1007/978-3-030-88192-4_9

Oladele, I. O., Omotosho, T. F., & Adediran, A. A. (2020). Polymer-based composites: An indispensable material for present and future applications. International Journal of Polymer Science, 2020, 1–12. https://doi.org/10.1155/2020/8834518

Qi, C., Jiang, F., & Yang, S. (2021). Advanced honeycomb designs for improving mechanical properties: A review. Composites Part B: Engineering, 227, 109393. https://doi.org/10.1016/j.compositesb.2021.109393

Wahrhaftig, A. de M., Plevris, V., Mohamad, B. A., & Pereira, D. L. (2023). Minimum design bending moment for systems of equivalent stiffness. Structures, 57, 105224. https://doi.org/10.1016/j.istruc.2023.105224.