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Buckling Analysis of Laminated Composite Plate Using FE Method

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Abstract: This study investigates the use of finite element analysis to composite plate structures. The major purpose of this research is to use FEA techniques to evaluate the buckling behavior of composite plates. FEA simulation and CAD modeling are both possible with the help of ANSYS APDL. It has been determined that carbon composite is a material and that the individual plates may take on either a hexahedral or a quadrilateral geometry. The buckling load of the plate is determined by applying the structural loads on it. The FEA is performed for all permutations, which include changing the h/b ratio from 0.08 to 0.16 and then from 0.16 to 0.24. The buckling load is determined by the eigenvalues and is different for each h/b ratio. According to FEA predictions, increasing the h/b ratio increases the buckling load. The findings of this study suggest that finite element analysis (FEA) may be utilized to enhance the design of composite structures subjected to a wide range of loading scenarios.
Keywords: Composite plates, FEA

I. INTRODUCTION

Composite plates, made from bonded materials like fibers or laminates, are multi-layered structures that are robust and lightweight. The performance of a composite plate may be optimized for a given application by selecting the materials used in the plate depending on their desired attributes, like strength, stiffness, & durability[1].

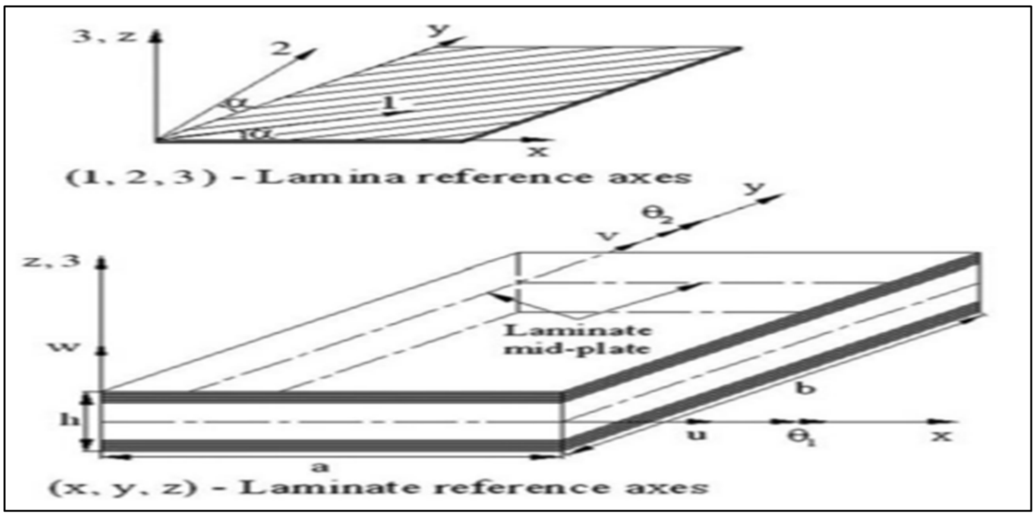

Figure 1: Composite plate

Composite plates have several applications; only some of them include the shipping, vehicle, aircraft, and sports equipment industries. Aerospace manufacturers often employ composite plates for fuselage and wing construction among other structural uses. Their strength and low weight make them ideal for usage in car body panels, hoods, and other structural components. Boat hulls, decks, and other marine parts that are often exposed to salt water often make use of composite plates due to their durability and corrosion resistance.

The Benefits of Composites Included [2]:

1) Compared to its individual fiber/particle and matrix, the strength to weight ratio of composite material is very high.
2) In comparison to its individual parts, composite materials have a high degree of stiffness.

3) Due to the excellent damping qualities of composite materials, vibration amplitude has become lessened as compared to conventional materials.
4) Increased wear resistance lengthens the life of the composite construction.
5) By adding graphite fibers, for instance, composite materials' electrical conductivity can be improved.
6) The design of composite materials can be flexible.
7) The poor thermal conductivity of many composite materials makes them advantageous for applications.
8) Compared to other materials, composites are frequently more enduring and demand fewer maintenance tasks over time.

LIST OF ABBREVIATIONS:

Abbreviations	Full Forms
FEM	Finite Element Method
FSDT	First Order Sher Deformation
SMA	Shape Memory Alloy
TSDT	Tignometric Shear Deformation Theory

II. LITERATURE REVIEW

Teter et al. [2016] analyzed the vibrational characteristics of composite materials made up of various lignocelluloses, while Savin et al. (2016) performed tests to determine the rotor's modal analysis. They discovered how material structures affected natural modes[3].

Eslami et al. [2017] ‘s big rectangular composite plates' mode forms, natural frequencies, and buckling behaviour were predicted using FEA and compared to results from a Rayleigh-Ritz approato of modelling vibrations. Clamping and simple support were used as boundary conditions for the plate. It was determined that as the aspect ratio drops below 0.25, inherent frequencies of plate convergence[4].

Shrigandhi et al. [2011] used FEA to perform a modal study on composite sandwich panels. Utilizing finite element & harmonic balance techniques, the researcher analyzed the vibrations of a composite laminated plate. In comparison to the h-version of identical finite element techniques, the hierarchical finite element method needs a much less number of degrees of freedom[5].

Wang et al. [2020] Effects of free vibration of laminated and sandwich composite laminated plates were investigated, with a focus on the role of higher-order facet shell components. As a result of their investigation, they concluded that, for composite laminates, there is little to choose between First Order Shear Deformation Theory and Higher Order Shear Deformation Theory. On the other hand, sandwich panels have a significant frequency differential that rises with laminate thickness [6].

Huihui et al. [2019] carried out research to determine the vibrational characteristics of woven fiber laminated composite plates when subjected to hygrothermal conditions. The governing equation employed in this study was FSDT. Experiments were performed with both freely supported and clamped-supported boundaries. Both experimental and analytical studies demonstrated that 4 sides clamped (CCCC) boundary conditions had greater vibration frequencies than simply supported owing to clamping impacts & improved elastic rigidities limitations [7].

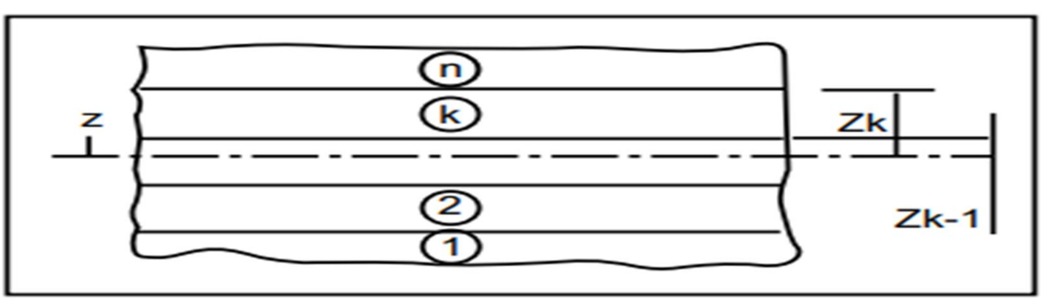

Figure 2: Geometry of n layered laminate [7]

Zhaoji et al. [2022] performed free and forced vibration experiments utilizing experimental setup to analyze the vibrational properties of a carbon fiber-reinforced polymer composite containing numerous carbon nanotubes. It was determined that after incorporating carbon nanotubes into a composite, a decreased natural frequency was detected. On the other hand, the damping properties of composite improved following the inclusion of carbon nanotubes [8].

Jiang et. al. [2018] Utilized FEM (finite element method) software ANSYS, they determined the natural frequencies & mode shapes of laminated cantilever boxed beams exposed to both uniform or asymmetric stiffness at their peripheries, as seen in Fig. 2.2 [9].

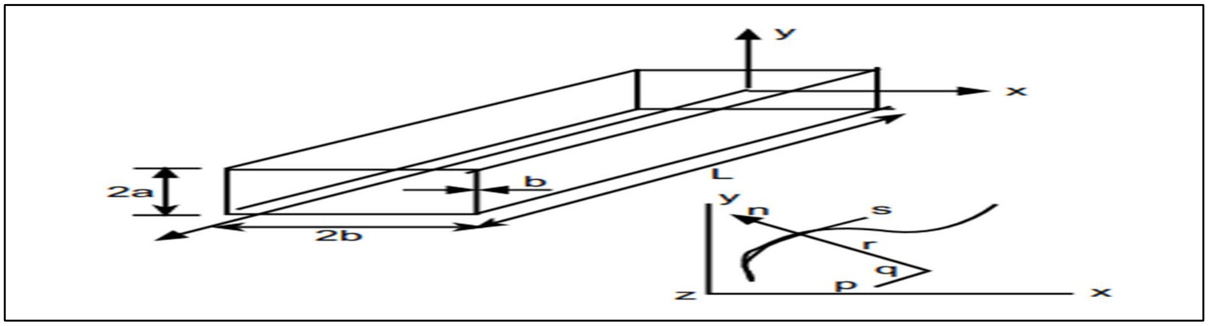

Figure 3: Geometry of the beam

Sun et al. [2022] employed finite element analysis to find out how a composite laminated plate vibrates. The greater the concentration of fibers in the plate's middle part, the greater the buckling stress and natural frequencies. If more fibers are focused on the plate's exterior, critical buckling stress will rise [10].

Chang et al. [2020] Using the finite difference approach, we calculated the vibration characteristics of both symmetric and angle-ply laminated composite plates. It was determined that the orientation of fibers in an angle-ply laminated plate had a significant influence on the natural frequencies of the plate. Nevertheless, the largest natural frequency response was found when fibers were oriented at 45 degrees [11].

III. OBJECTIVE

The purpose of this study is to use Finite Element Method to Conduct structural analysis and assess the Buckling behaviour of composite plates. The CAD modelling and FEA simulation are conducted using ANSYS APDL. From the FEA analysis, the eigenvalue buckling load is determined for different combinations of h/b ratio. The h/b ratio taken for the analysis is .08, .16, and .24.

IV. METHODOLOGY

This section discusses the comprehensive processes involved.

A. Modelling of Plate

The methodology involves modeling of the plate with an area tool. The model of the plate is developed using key points, and lines and added to form area. In total, 10 layers are created with 5mm thickness each. The developed model of the composite plate is shown in Figure 4.

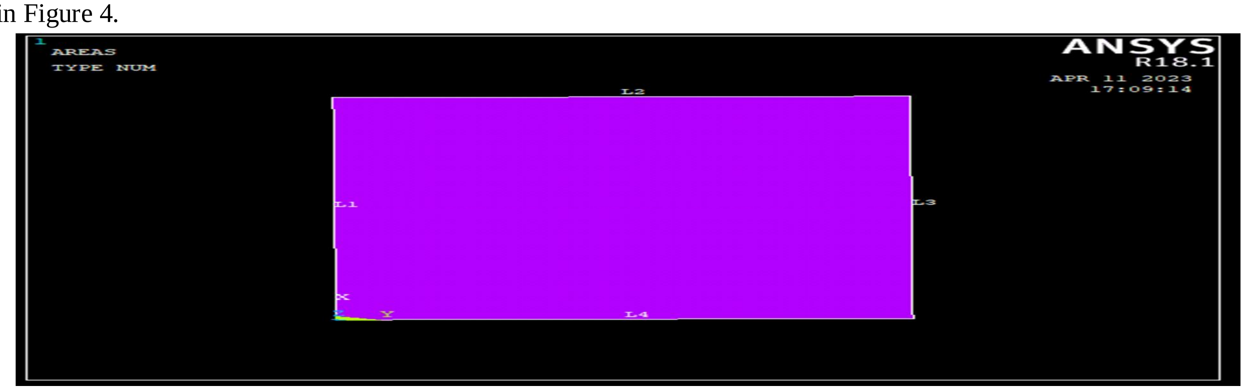

Figure 4: CAD model of composite plate

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B. Material Property Definition

LINEAR ORTHOTROPIC PROPERTIES FOR COMPOSITE MATERIAL

YOUNG'S MODULUS(GPa)			POISSION RATIO			RIGIDITY MODULUS(GPa)		
E1	E23	E13	µ12	µ23	µ13	G12	G23	G13
13200	2200	2200	0.365	0.464	0.726	820	430	430

Figure 5: Material property definition of carbon composite

C. Element Definition

The material definition is given for composite plate. The material definition is done for carbon composite. The material is the orthotropic type and is shown in Figure 5 above. The plate's mesh is made up of hexahedral and quadrilateral elements. Figure 6 depicts the composite plate mesh model.

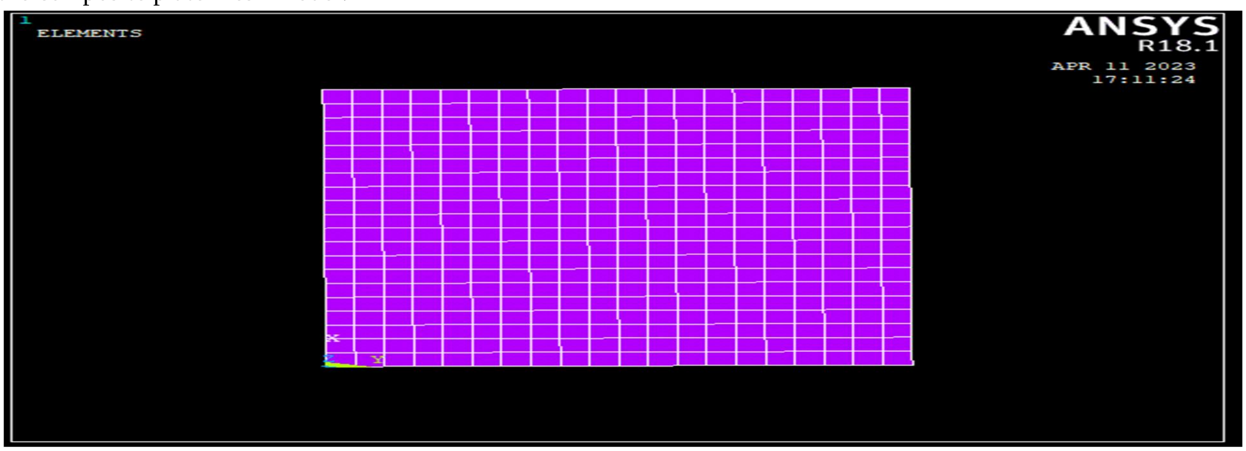

Figure 6: Meshed model of plate

1) Stack up definition

The composite material is made up of a variety of laminates. For each laminate and the various design combinations, including h/b.16, h/b.08, and h/b.24, thickness and orientation angles are specified.

There Are a total of ten distinct layers that have been specified, each of which has a predetermined thickness value (0.8 mm, 0.4 mm, & 1.2 mm), as well as a certain orientation angle. (00 and 900). Figure 7 depicts the structural orientation of a variety of laminates in their various forms.

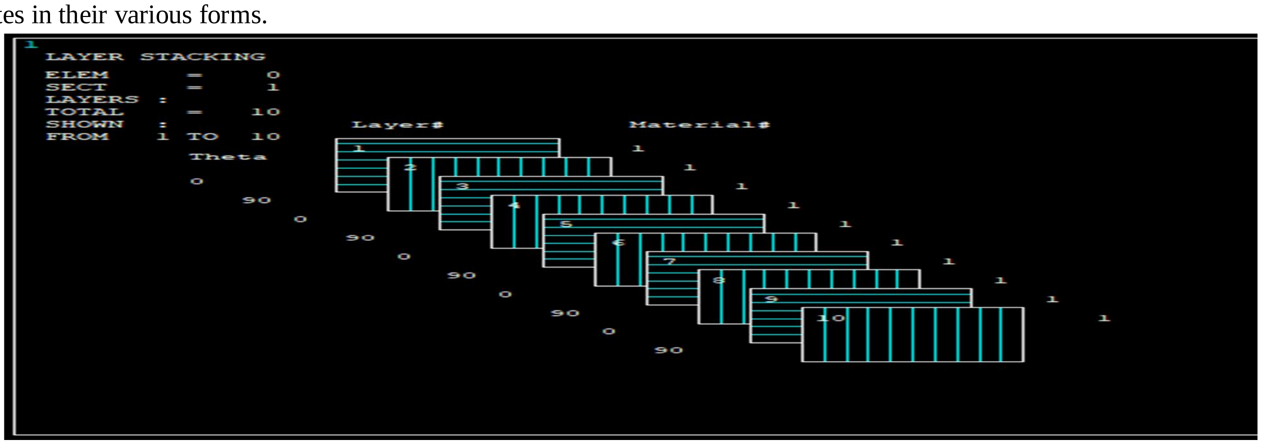

Figure 7: Different laminas with orientation

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D. Loads and Boundary Conditions

The structural loads are applied on a plate to determine the buckling load. The initial load of 1N is applied on the top right and bottom right key point of the composite plate. The left line of the composite plate is applied with fixed support. The simulation is executed once loads and boundaries are applied to the structure. In the process, the matrix is created and assembled to form a global stiffness matrix.

E. Solution

Upon specifying the loads and boundary conditions, the simulation is executed by selecting the "solve" icon. During the process of solving, the matrix of stiffness for the element is formulated and the outcomes are interpolated for the complete length of the element's edge using nodal outcomes.

V. RESULTS AND DISCUSSION

The present study involves the utilization of carbon composite material for conducting structural analysis to determine the xy shear stress, 1st principal stress, and xy shear elastic strain. The analysis is carried out for varying h/b ratios of .08, .16, and .24.

A. h/b Ratio of .08

A structural investigation was conducted on a rectangular plate constructed from carbon composite material, featuring a h/b ratio of 0.08. The plot of shear stress in the xy direction is derived through FEA of a rectangular plate. The maximum xy shear stress is observed to occur at the corners of the plate, where a magnitude of 4.33 MPa is obtained.

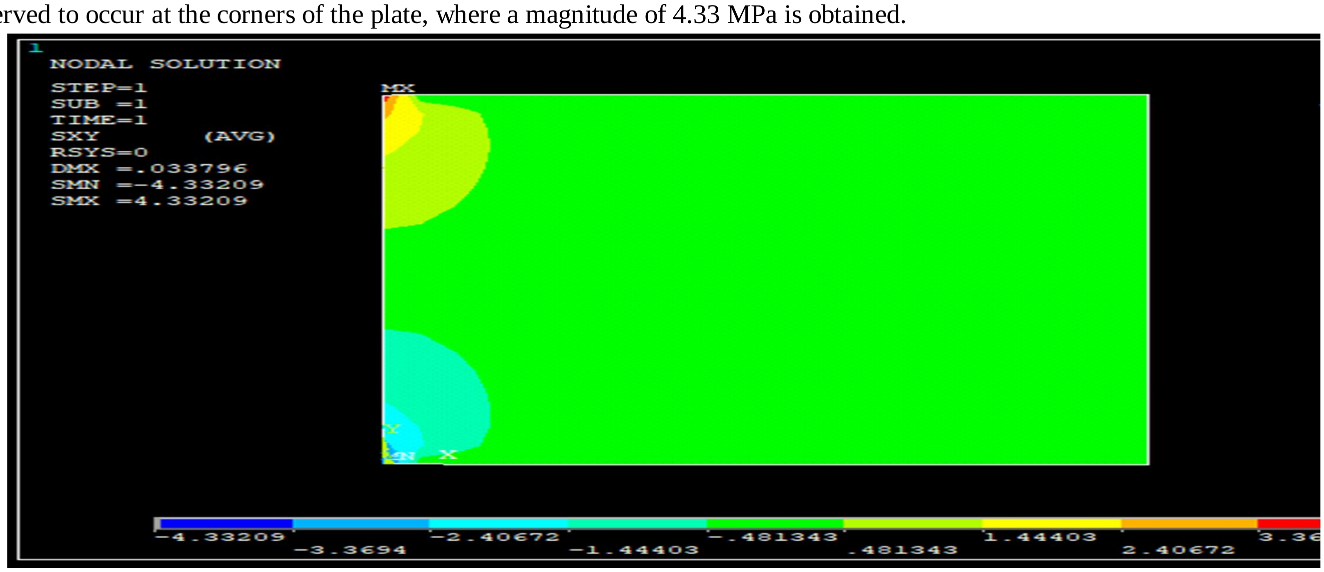

Figure 8: xy shear stress for h/b .08 value and Carbon Composite Material

The primary stress magnitude is determined for the composite material plate. The location of the maximum principal stress is found in close proximity to the boundary subjected to fixed support boundary conditions. The analysis yielded a maximum principal stress of 4.418MPa. The uniformity of principal stress is observed in various regions of the plate, where the magnitude of said stress approximates 2.45MPa.

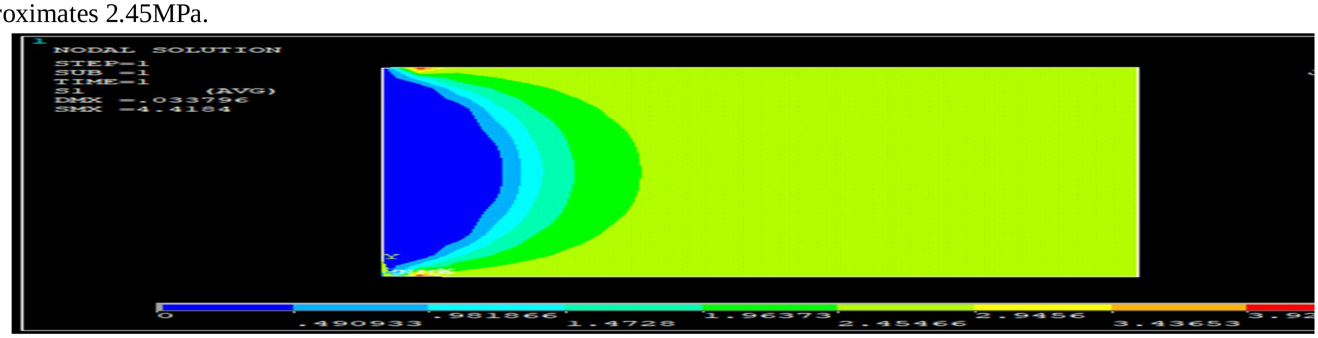

Figure 9: 1^{st} principal stress for h/b .08 value and Carbon Composite Material

The elastic strain of shear in the xy direction has been determined for a plate with a h/b ratio of 0.08 and composed of carbon composite material, as depicted in Figure 10. The analysis yielded a maximum xy shear strain of .005283mm/mm.

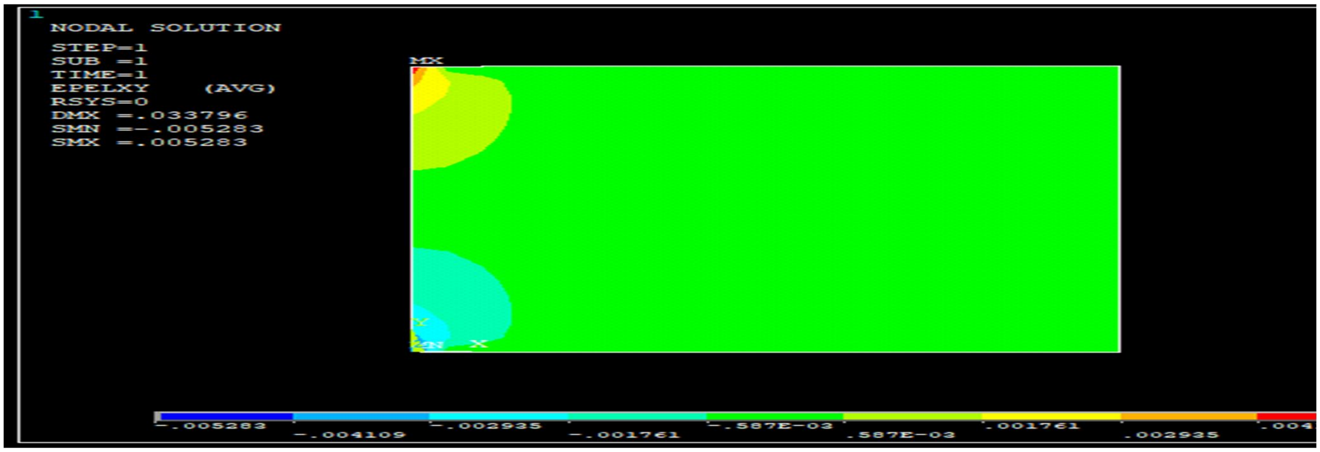

Figure 10: xy shear elastic strain for h/b .08 value and Carbon Composite Material

B. h/b .16

A structural analysis was performed on a rectangular plate made of carbon composite material with a h/b ratio of 0.16. The plot of shear stress in the xy direction is derived through FEA of a rectangular plate. The maximum xy shear stress is observed at corners of plate, where the magnitude of maximum shear stress value is 2.111 MPa.

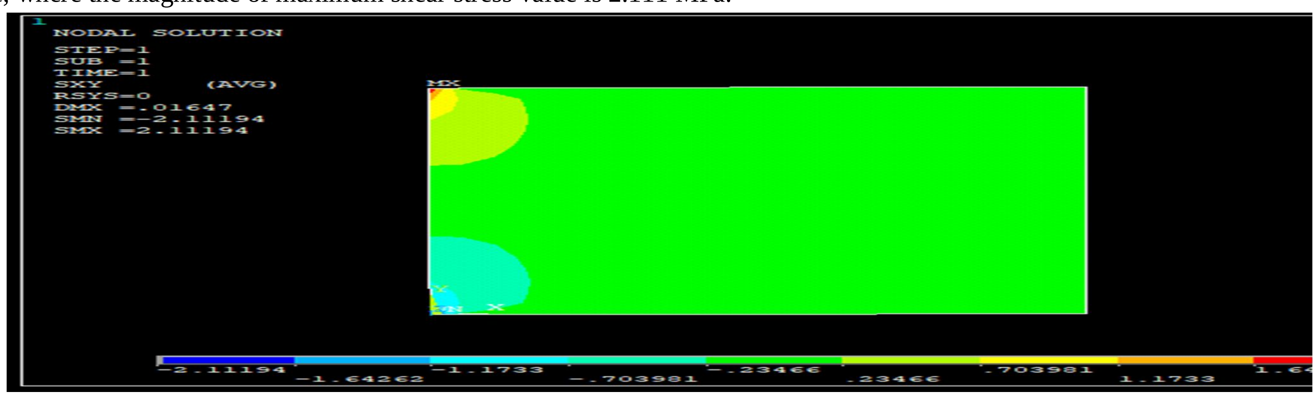

Figure 11: xy shear stress for h/b .16 value and Carbon Composite Material

The plate composed of a composite material with a h/b ratio of 0.16 yields value of first principal stress. The location of maximum principal stress is in proximity to the boundary subjected to fixed support boundary conditions. The analysis yielded a maximum principal stress of 2.28 megapascals. The uniformity of principal stress is observed in various regions of the plate, where the magnitude of principal stress approximates 1.269MPa.

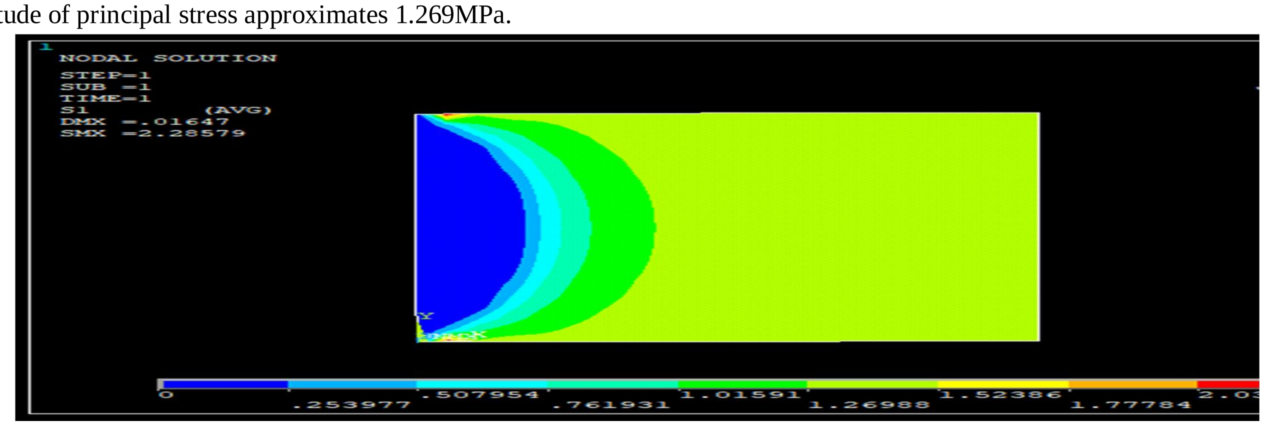

Figure 12: 1st principal stress for h/b .16 value and Carbon Composite Material

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The elastic strain of shear in the xy direction has been derived for a plate with a h/b ratio of .16 and composed of carbon composite material, as illustrated in Figure 13. The analysis yielded a maximum xy shear strain of .002576mm/mm

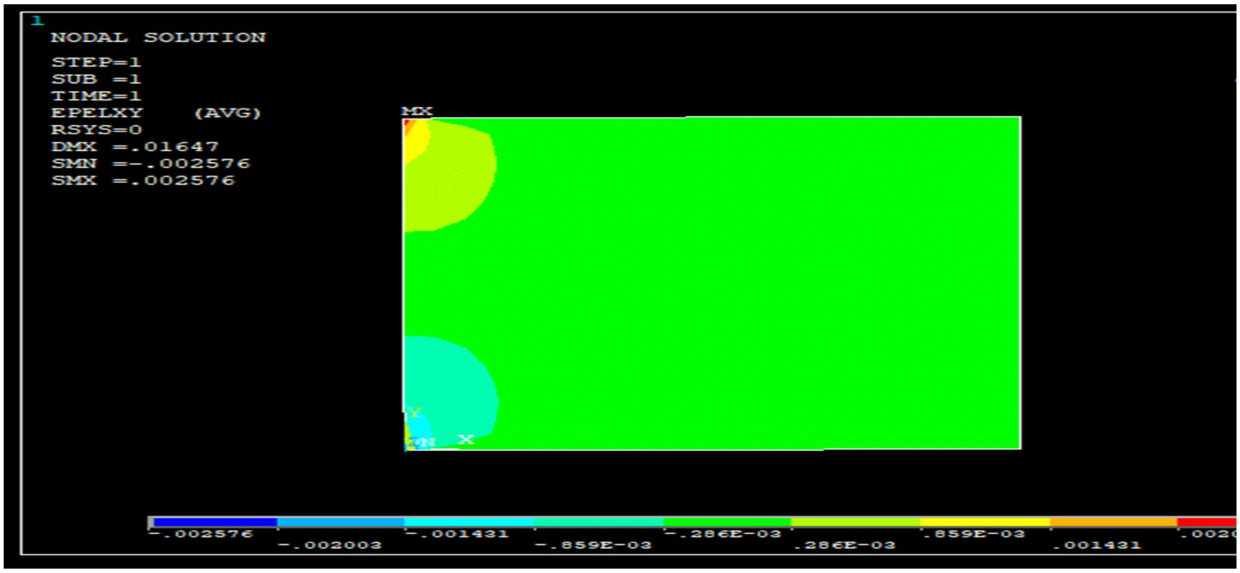

Figure 13: xy shear elastic strain for h/b .16 value and Carbon Composite Material

C. h/b .24

A study was conducted to analyze the structure of a rectangular plate made of carbon composite material, featuring a h/b ratio of 0.24. The plot depicting the shear stress in the xy direction is derived through FEA of a rectangular plate. The maximum xy shear stress is observed to occur at the corners of plate. The magnitude of this maximum shear stress value is 1.375 MPa.

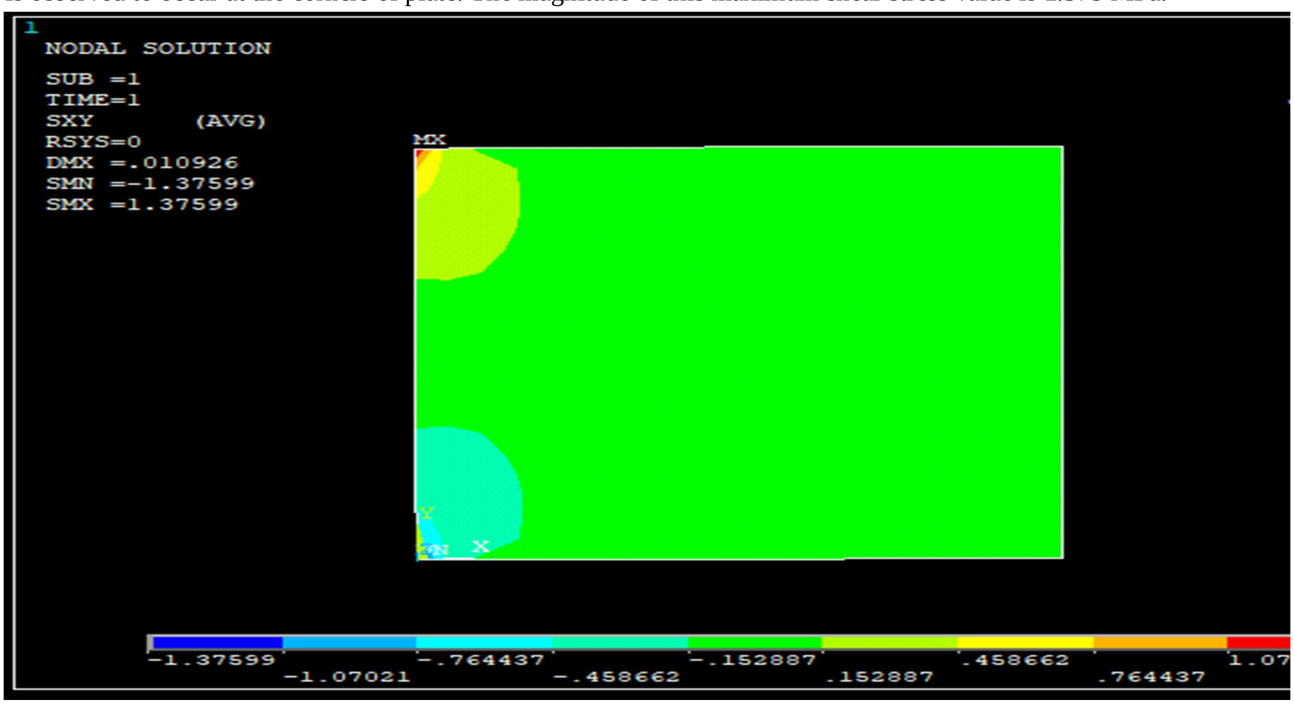

Figure 14: xy shear stress for h/b .24 value and Carbon Composite Material

The first principal stress value has been determined for a composite material plate with a ratio of height to width of 0.24. The location of maximum principal stress is in proximity to boundary subjected to fixed support boundary conditions. The analysis yielded a maximum principal stress of 1.562MPa. The uniformity of principal stress is observed in various regions of the plate, where the magnitude of principal stress approximates 0.868MPa.

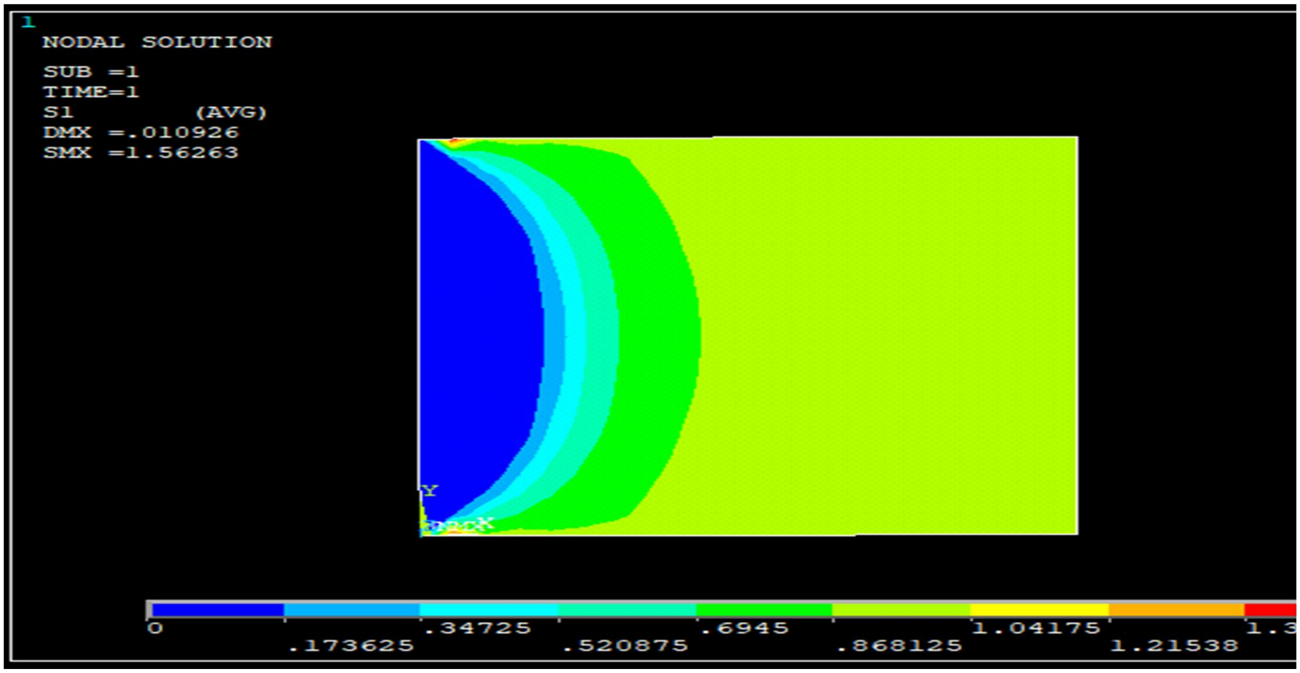

Figure 15: 1st principal stress for h/b .24 value and Carbon Composite Material

The elastic strain caused by xy shear is determined for a plate with a h/b ratio of .24 and composed of carbon composite material, as illustrated in Figure 16. The analysis yielded a maximum xy shear strain of .001678mm/mm.

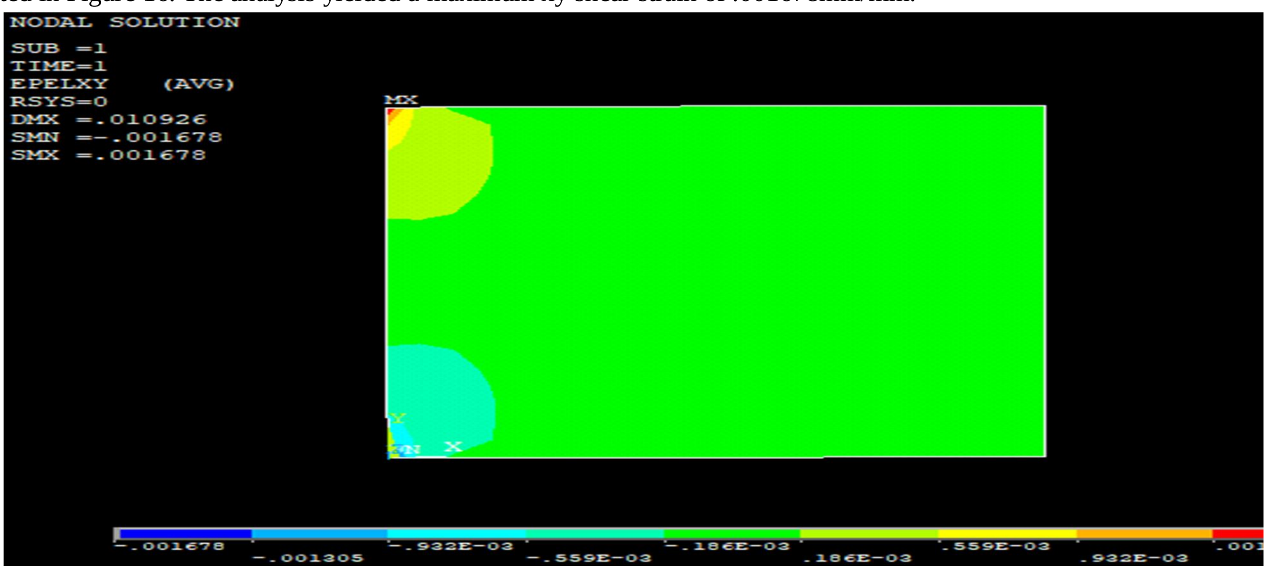

Figure 16: xy shear elastic strain for h/b .24 value and Carbon Composite Material

D. Comparative ***Studies***

The comparative studies are performed between different design of h/b i.e. .08, .16 and .24.

Table 5.1: Carbon composite results

Design type	h/b .08	h/b .16	h/b .24
Shear stress (Mpa)	4.332	2.1111	1.375
Principal stress (Mpa)	4.418	2.285	1.562
Elastic strain(mm/mm)	0.00528	0.00257	0.00167

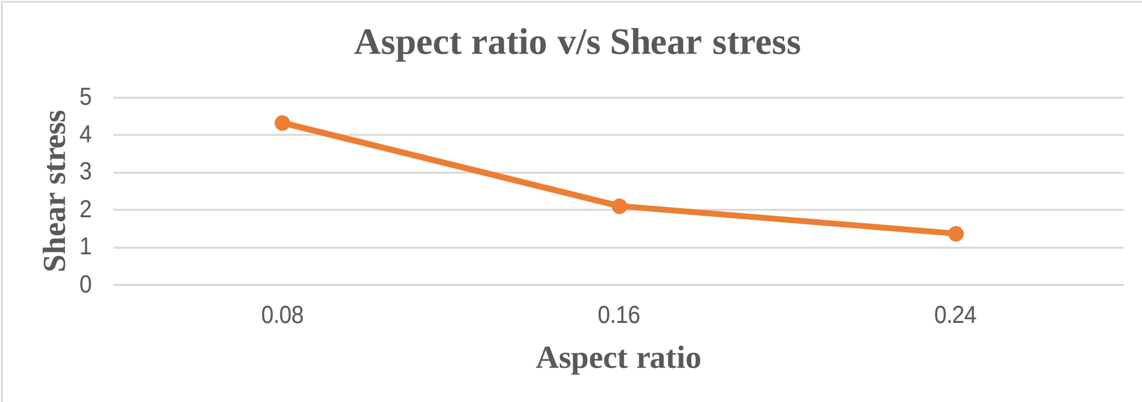

Figure 17: Shear stress of carbon composite plate

The comparison plot of shear stress indicates that an increase in laminate thickness results in a reduction of the shear stress induced on the plate, as illustrated in Figure 17. The plate with a ratio of h/b equal to 0.24 yields the minimum shear stress.

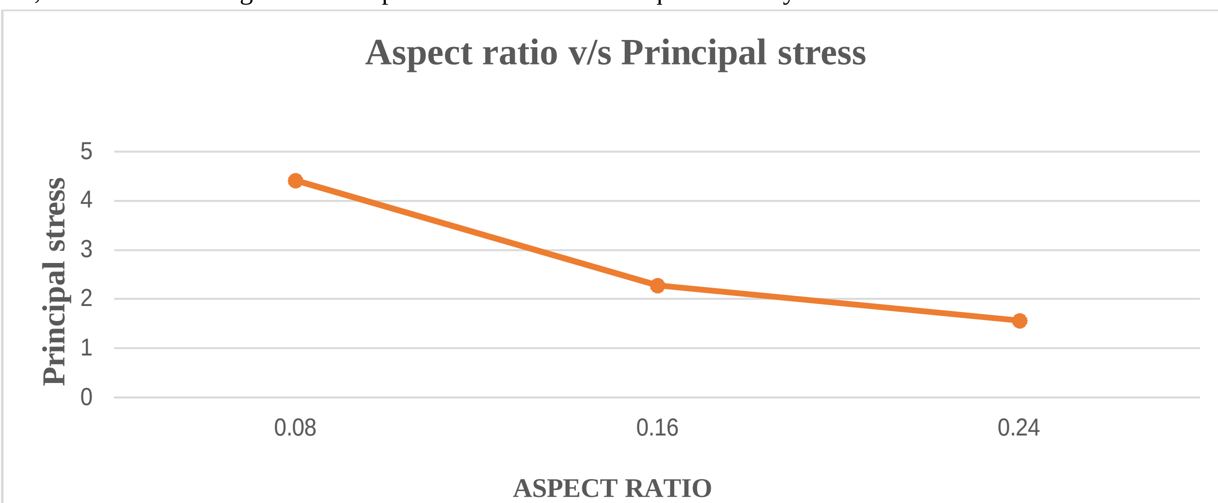

Figure 18: Principal stress of carbon composite plate

Figure 18 shows a comparison plot of primary stress, which demonstrates that main stress imposed on plate decreases as laminate thickness increases. The plate's h/b ratio of .24 yields the minimum principal stress. The plate exhibiting a h/b ratio of .24 also demonstrates minimal elastic strain.

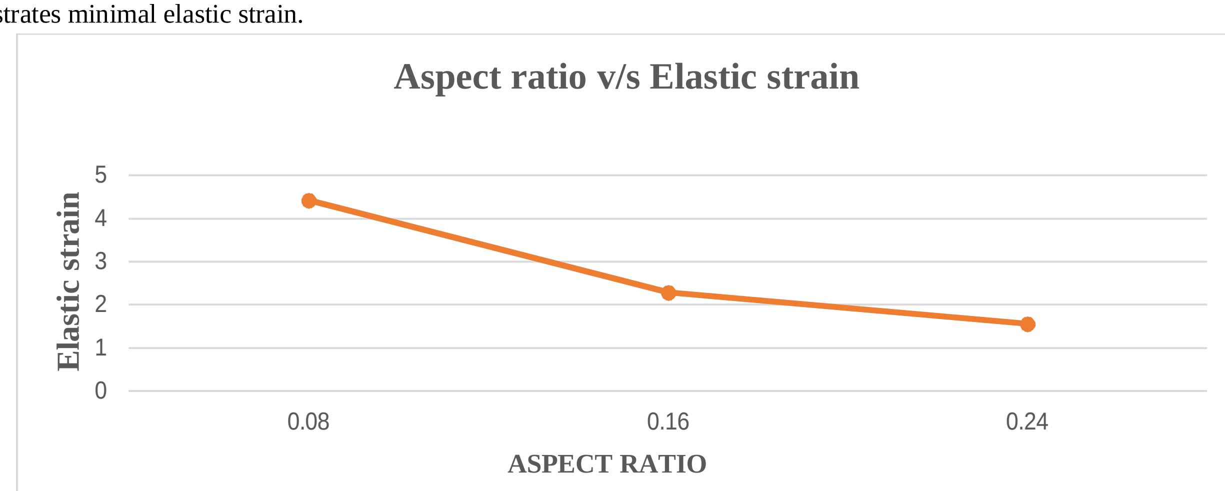

Figure 19: Elastic strain of carbon composite plate

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F. Buckling Analysis

The buckling analysis is conducted on plate using ANSYS APDL for composite material and h/b ratio of .08, .16 and .24. For determining buckling load, th91e FEA analysis is conducted at 1 N load. The Eigen value buckling value is determined.

The deformation obtained from FEA analysis of composite plate with h/b .08 is 1.77005mm as shown in figure 20. The buckling Load is determined for composite plate with h/b .08 which is found to be 167.43N.

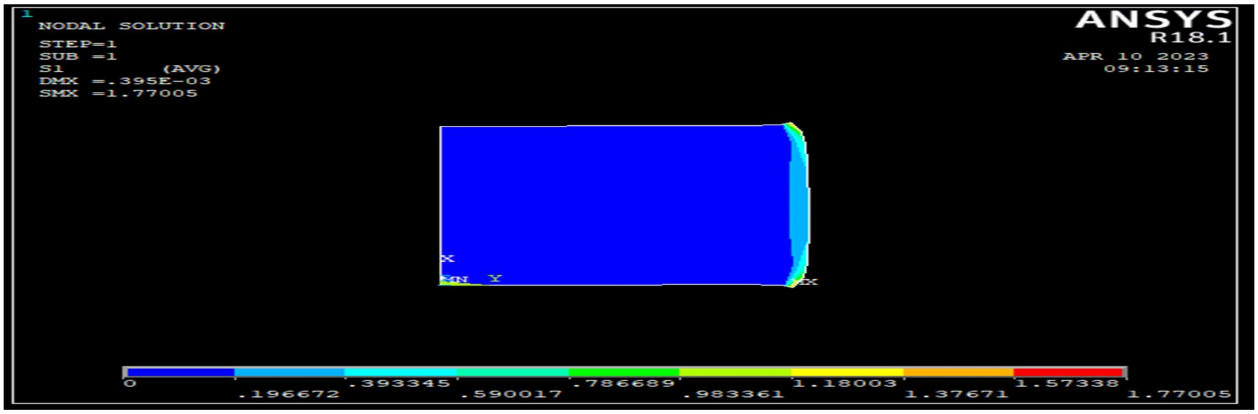


Figure 20: Deformation plot on plate for h/b .08

The deformation obtained from FEA analysis of composite plate with h/b .16 is 1.11723mm as shown in figure 21. The buckling is determined for composite plate with h/b .16 which is found to be 273.83N.

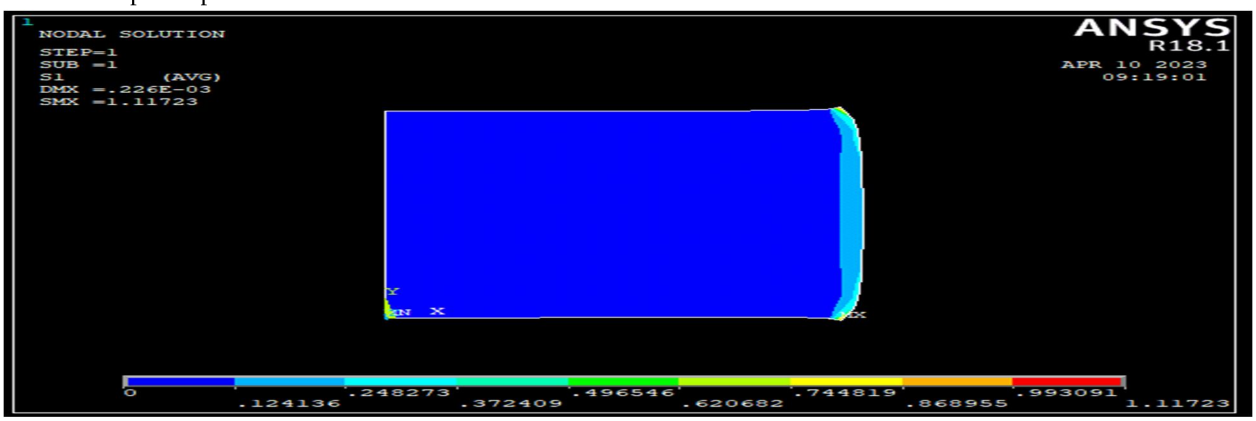


Figure 21: Deformation plot on plate for h/b .16

The deformation obtained from FEA analysis of composite plate with h/b .24 is .7492mm as shown in figure 22. The buckling is determined for composite plate with h/b .16 which is found to be 417.97N.

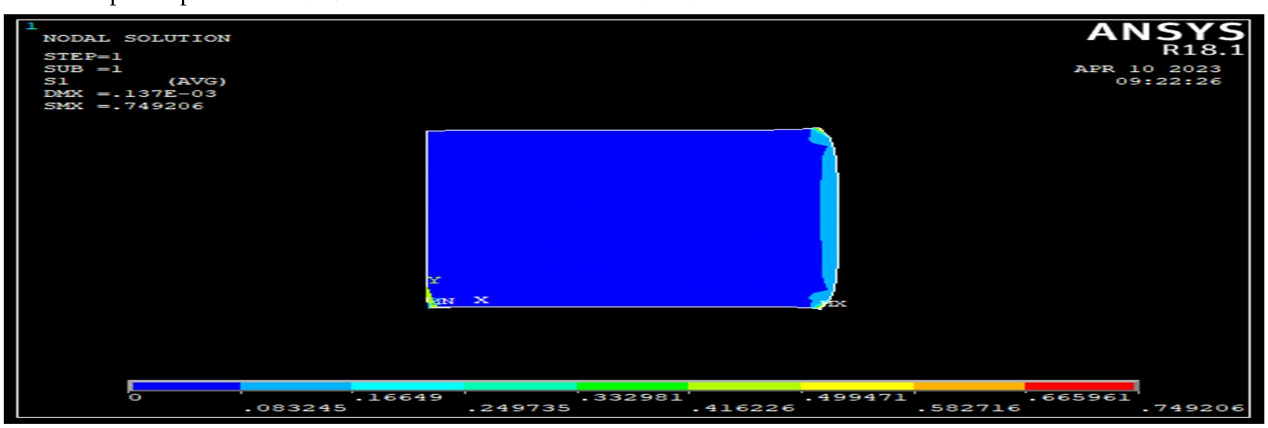


Figure 22: Deformation plot on plate for h/b .24

The deformation obtained from FEA analysis of composite plate with h/b .24 is .7492mm as shown in figure 22. The buckling is determined for composite plate with h/b .16 which is found to be 417.97N.

The effect of aspect ratio on buckling load and deformation is shown in fig. 23 and 24 below.

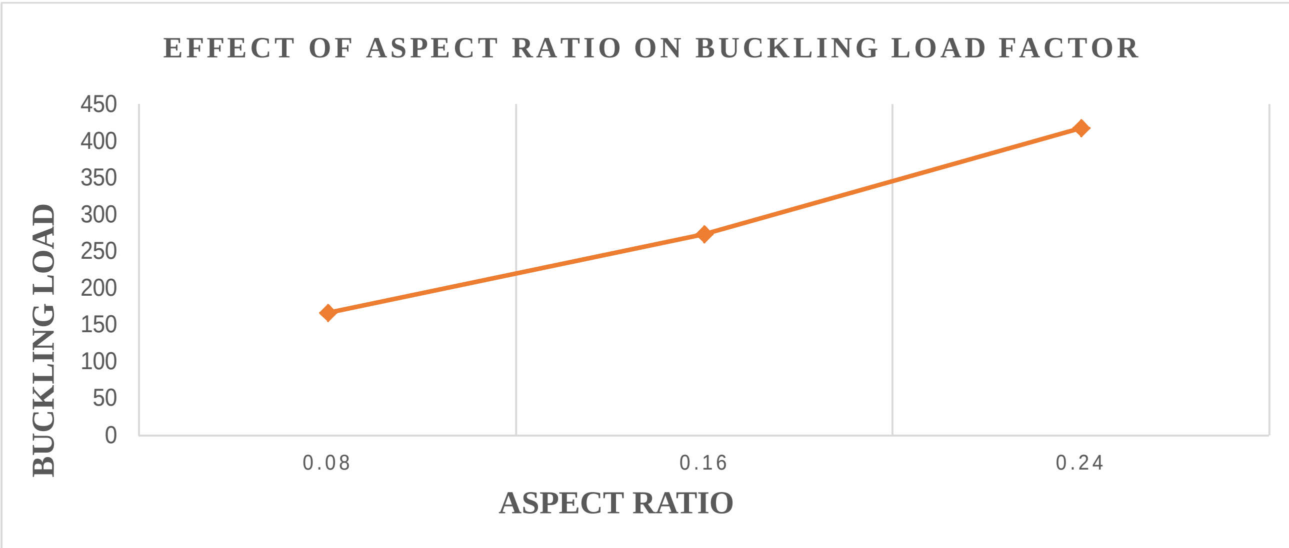


Figure 23: Effect of aspect ratio on buckling load

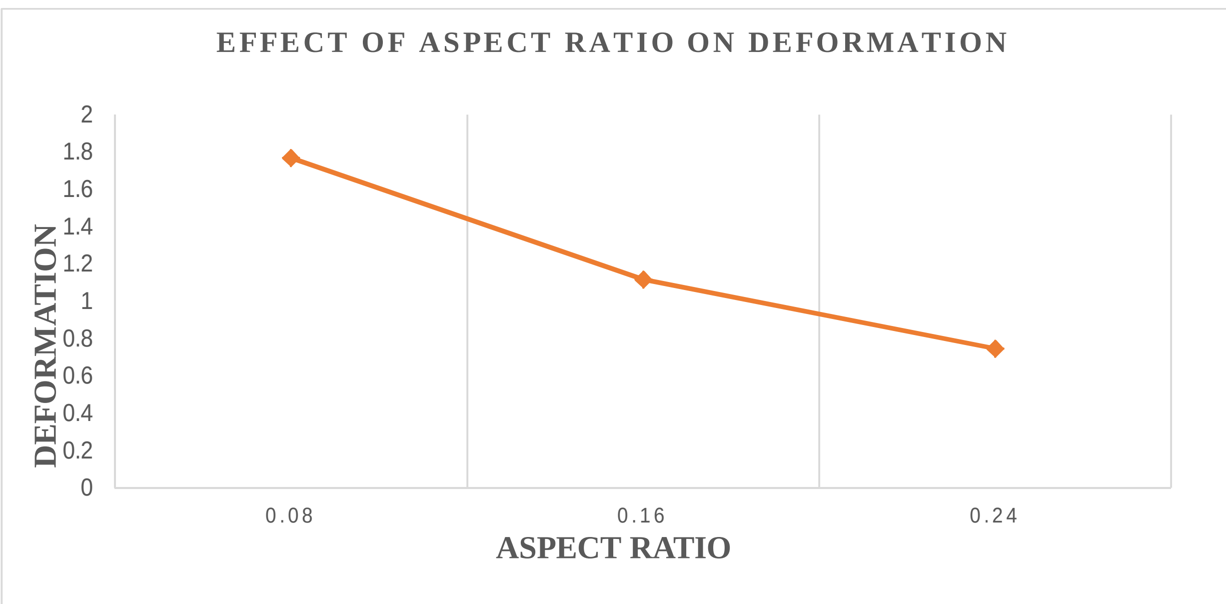


Figure 24: Effect of aspect ratio on deformation

VI. CONCLUSION

Finite Element Analysis (FEA) is a popular choice for analyzing composite plates because it provides precise and specific data on how composite structures act when subjected to varying loads. It is challenging to study complicated geometries and material characteristics using conventional analytical techniques, but FEA makes it possible to do so. When the h/b ratio was raised, the findings indicated that the plate deformation also increased. Similar to the bending moment, the buckling load rose as the h/b ratio became bigger, with the greatest buckling load being found at a h/b ratio of.24. Where buckling behavior is critical, such as in the aerospace and automotive sectors, this study's results may be valuable in the design and production of composite plates for these and other applications. Even though this study examined the buckling Behavior of a single composite material, it is crucial to highlight that future research might investigate the buckling behavior of many composite materials and plate geometries.

REFERENCES

[1] A. Garg and H. D. Chalak, "Buckling Analysis of Laminated Composite Plates under Thermal Conditions," ASPS Conf. Proc., 2022, doi: 10.38208/acp.v1.463.

[2] P. Lengvarský, J. Bocko, and M. Hagara, "The Buckling Analysis of the Composite Plates with Different Orientations of Layers," Am. J. Mech. Eng., 2016.

[3] A. Teter and J. Gawryluk, "Experimental modal analysis of a rotor with active composite blades," Compos. Struct., 2016, doi 10.1016/j.compstruct.2016.06.013.

[4] H. Eslami, N. Khalili, and U. S. Gandi, "Vibration of Long Rectangular Composite Plates and Buckling of such Plates under Shear and Axial loads," 2017. doi 10.2514/6.2017-1987.

[5] M. D. P.V. and M. S. G.D., "Modal Analysis of Composite Sandwich Panel," Int. J. Curr. Eng. Technol., vol. 2, no. 10, p. `1-7, 2011, doi: 10.14741/ijcet/22774106/spl.4.2016.53.

[6] T. Wang et al., "Microstructure evolution of Al/Mg/Al laminates in the deep drawing process," J. Mater. Res. Technol., vol. 9, no. 3, p. 8, 2020, doi: 10.1016/j.jmrt.2020.03.111.

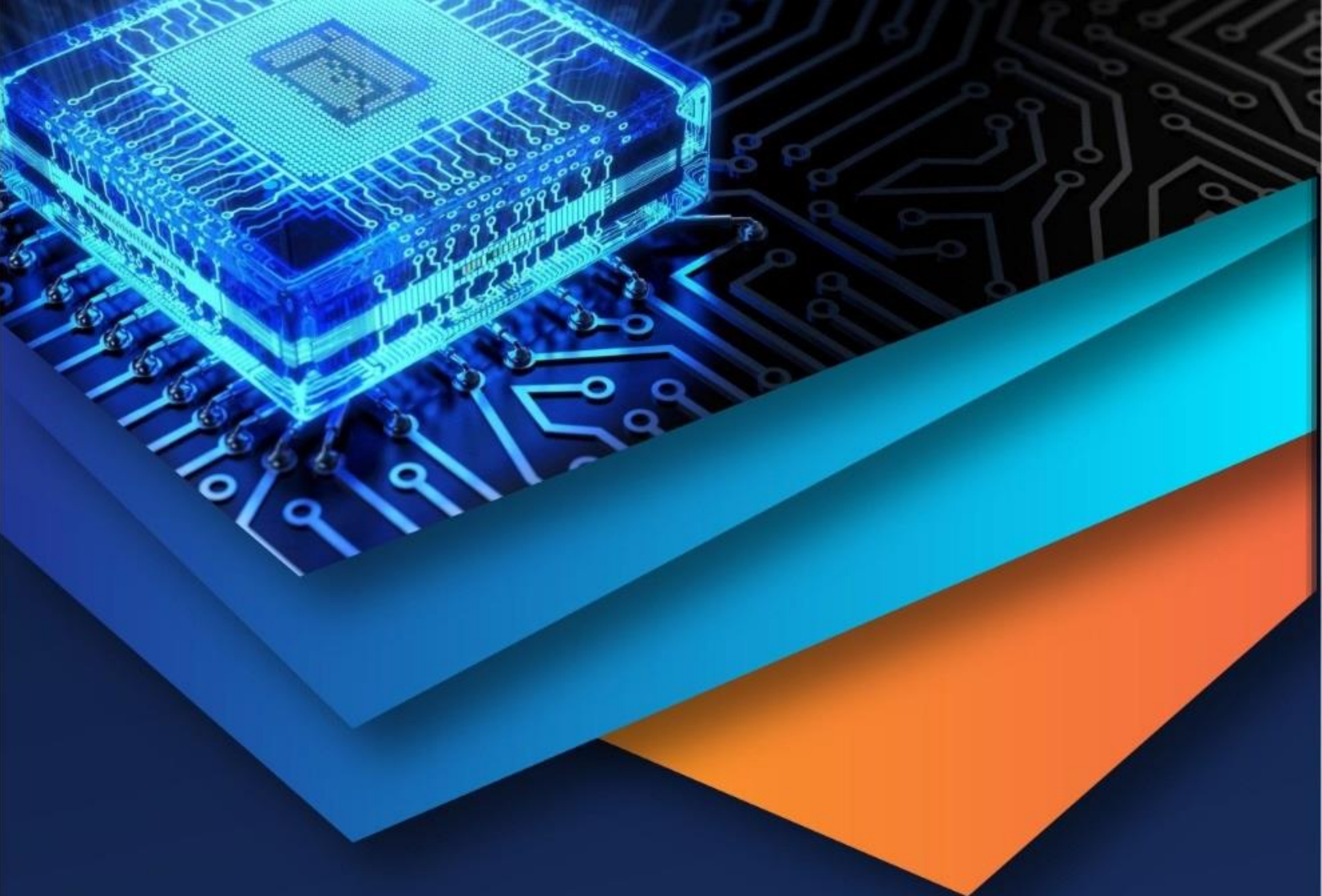
[7] H. Nie, C. Chi, H. Chen, X. Li, and W. Liang, "Microstructure evolution of Al/Mg/Al laminates in the deep drawing process," J. Mater. Res. Technol., vol. 8, no. 6, pp. 5325–5335, 2019, doi: 10.1016/j.jmrt.2019.08.053.

[8] L. W. Yu Zhaoji, Wang Tao, Liu Chao, Ma Yunzhu, "Investigation on microstructure, mechanical properties, and fracture mechanism of Mg/Al laminated composites," Mater Sci Eng, vol. 848, 2022, doi https://doi.org/10.1016/ j.msea.2022.143410.

[9] M. G. Jiang et al., "Unveiling the formation of basal texture variations based on twinning and dynamic recrystallization in AZ31 magnesium alloy during extrusion," Acta Mater., vol. 157, pp. 53–71, 2018, doi: 10.1016/j.actamat.2018.07.014.

[10] H. Y. Sun et al., "Study on the microstructure, texture and mechanical properties of hot-rolled and T6-treated Al1060/Al6061-TiCp/Al1060 laminated composites," J. Mater. Res. Technol., vol. 18, pp. 2808–2821, 2022, doi https://doi.org/10.1016/j.jmrt.2022.03.180.

[11] D. Chang, P. Wang, and Y. Zhao, "Effects of asymmetry and annealing on interfacial microstructure and mechanical properties of Cu/Al laminated composite fabricated by asymmetrical roll bonding," Journal of Alloys and Compounds. 2020. doi 10.1016/j.jallcom.2019.152453.



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