Structural Health Monitoring of Aluminium Stiffened Sandwich Plate using Ultrasonic Guided Wave Signals

Manthale S N[1], Pol C B[2]

[1]PG Student, Dept. of Civil Engineering, Walchand College of Engineering, Sangli, Maharashtra, India, 416415
[2]Professor, Walchand College of Engineering, Sangli, Maharashtra, India, 416415

---***---

Abstract -*Stiffened sandwich plates are mechanically resistant structural components and used in a lot of engineering applications ranging from bridges and buildings to planes and ships. In the shipping sector, a large number of these structures are required to withstand very high stresses caused by their own structure's weight or by sea conditions faced during navigation. These constructions must be exceptionally resistant to shear stresses and bending moments due to the high loadings. Adding more material to a structure can improve its strength, but it also increases its weight, which should be avoided when building projects for the offshore and naval industries. The use of mechanical stiffeners becomes necessary in this situation. These stiffeners are long structural profiles that are fixed horizontally to the plates. The present report describes the results and insights developed for load analysis of an aluminium stiffened plate with varying stiffener configurations as required for the loading criterion based on ANSYS 18.2. High-strength aluminium alloys have become more widely used in the design and building of high-speed boats over the last decade, as their size has increased and their operations have shifted into more harsher ocean-going conditions. As a result, in terms of strength or reliability analysis and fabrication quality control, the design and building procedure to assure the structural safety of aluminium high-speed vessels has become more complicated.*

Key Words: Stiffener, Finite Element, Configuration, Stiffened sandwich plate etc.

1. INTRODUCTION

Structural health monitoring is an emerging technology that has several uses. The broad subject of smart structures gave rise to SHM, which also includes fields like structural dynamics, materials and structures, nondestructive testing, sensors and actuators, and data science. signal processing, acquisition, and perhaps much more. Traditional NDT methods, include Thermography, radiography, and ultrasonic C-scan have all been used successfully to inspect structural soundness. The use of these conventional methods, though, has been restricted to testing very simple shapes or looking at the area where the transducer changes. Most some of these techniques might not be appropriate for monitoring very big and complex systems online or in situ structures.

Monitoring changes to the material and geometric qualities of engineering structures, such as bridges and buildings, is known as structural health monitoring. Damage can be easily found by evaluating measures that are periodically sampled. Monitoring the health of structures is crucial since they are all susceptible to internal and external causes that could result in malfunctions or wear-related damage. Use of a damage identification system is crucial to detecting these flaws. A system like this would enable superfluous check-ups or maintenance to be avoided and substituted by work that has been determined to be essential. Damage could be identified early on, before any significant damage has occurred.

The stiffened sandwich plated structures are of common occurrence in present day engineering. The components of ship, a traffic road bridge and a launching pedestal of a rocket are only a few examples of stiffened plated structures. With such a wide range of application, it is obvious that stiffened plates are subjected to dynamic loads of varying magnitude and complexity. An aircraft structure necessitates analysis for flutter, jet noise, etc. The wing or the fuselage of an aircraft consists of a skin with an array of stiffening ribs. A road bridge is designed to withstand moving vehicle load as well as those due to possible earthquake. Stiffened plated structures encounter ocean waves and earthquakes which are random in nature. The narrow-banded spectra of sea waves for such cases requires the spectral analysis to design an offshore platform or a ship hull. Both deterministic and stochastic methods have been applied to solve these problems. Steel plates are structural elements that can bear mechanical stresses and are utilized in a variety of engineering areas, including bridge and building construction, as well as aviation and ship construction.

Many scholars have done a diverse set of studies for the resilient design of ships and offshore buildings, analyzing and forecasting the structural condition of undamaged and damaged structures. The finite element method (FEM), for example, is a well-known numerical method that may be used to solve problems in a variety of sectors, including engineering and medicine. Furthermore, as computer technology advances, numerical simulations based on computational fluid dynamic (CFDs) and fluid-structure interaction (FSIs) are becoming increasingly prevalent in structural design.

2. OBJECTIVES

1. Formulation of problem statement and development of methodology using high quality research article.

2. Simulation of aluminium stiffened sandwich plate subjected to transient load by using FEM based software.

3. Modelling of various stiffener placement types for aluminium stiffened sandwich plate.

4. Analysis for different configurations of aluminium stiffened sandwich plate subjected to Transient load.

3. PROBLEM STATEMENT

For the present study, an aluminium stiffened sandwich plate is considered. The dimensions of the plate are 1200×1200×3 mm. The support and boundary conditions for the plate are assumed as fixed. The configuration of the plate is given below. The aluminium stiffened sandwich plate is subjected to transient load and the corresponding deformation in each of the plate is calculated and by comparing the results, best configuration of stiffeners is determined.

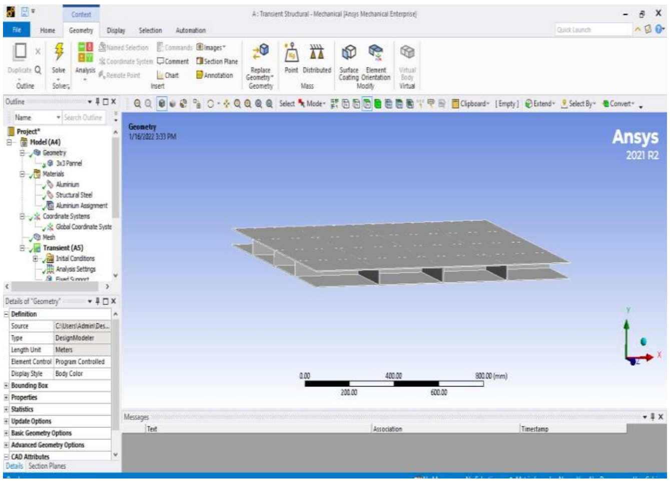

Figure 1- Dimensions of reference plate

- Plate type : stiffened sandwich plate
- Dimensions of reference plate Plate: 1200×1200×3 mm
- Plate material : Aluminium
- Height of stiffener: 50 mm
- Thickness of stiffener: 5 mm

4. Types of models considered for present study

For the present study, different configurations of stiffeners are considered which are rectangular, hexagonal and triangular. The analysis is carried out for each configuration of stiffeners and optimum configuration of stiffeners is determined.

4.1 Stiffened sandwich plate having rectangular stiffeners

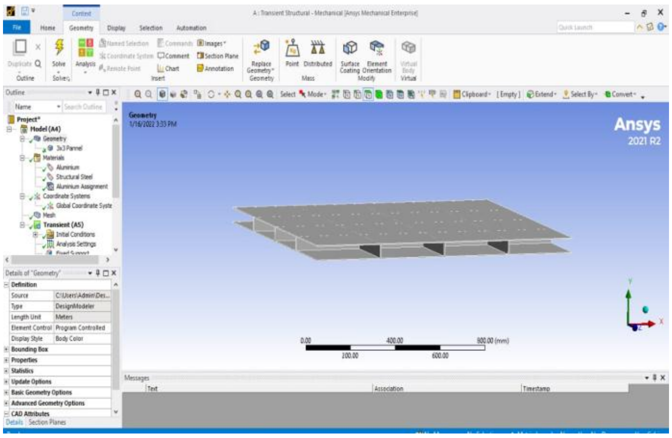

Figure-2 Stiffened sandwich plate having rectangular stiffeners

Above figure shows aluminium stiffened sandwich plate having rectangular configuration of stiffeners. The spacing of stiffeners is constant which is 300 mm in both the directions. Three stiffeners are provided between two aluminium plates in both the directions.

4.2 Stiffened sandwich plate having hexagonal stiffeners

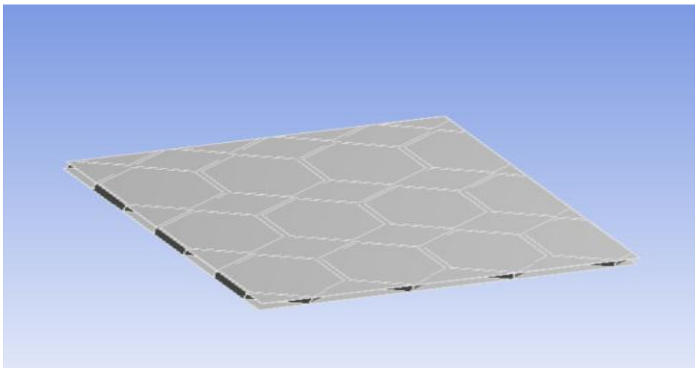

Figure-3 Stiffened Sandwich plate having hexagonal stiffeners

Above figure shows aluminium stiffened sandwich plate having hexagonal configuration of stiffeners. The area of each hexagonal stiffener is same as the rectangular stiffener.

4.3 Stiffened Sandwich plate having triangular stiffeners

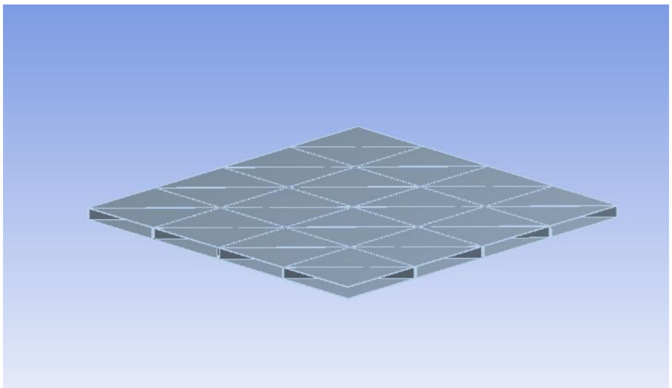

Fig- 4: Stiffened sandwich plate having triangular stiffeners

Above figure shows Aluminium stiffened sandwich plate having triangular configuration of stiffeners.

5. Results and Discussion

In this chapter, the results of deformation of aluminium stiffened sandwich plate having different configuration of stiffeners are determined and based on the comparison of maximum deformation for each configuration of stiffener, optimum configuration of stiffener is determined.

5.1 Analysis of aluminium stiffened sandwich plate having rectangular stiffeners

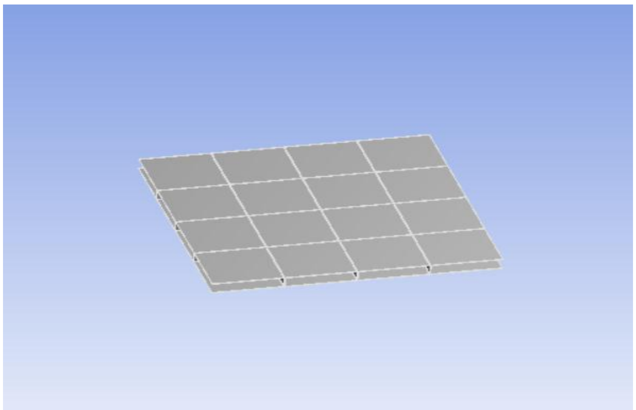

Fig- 5: Geometry of aluminium stiffened sandwich plate having rectangular stiffeners

Above figure shows aluminium stiffened sandwich plate having rectangular configuration of stiffeners. The spacing of stiffeners is constant which is 300 mm in both the directions. Three stiffeners are provided between two aluminium plates in both the directions.

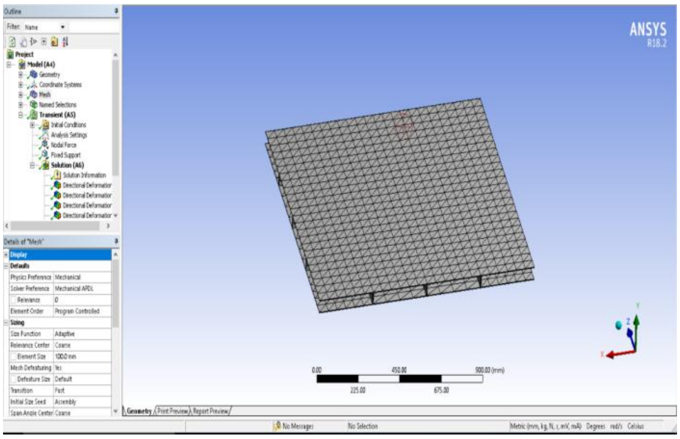

Fig- 6: Mesh of aluminium stiffened sandwich plate

Figure shows meshing of aluminium stiffened sandwich plate. For this model, quadrilateral meshing is used.

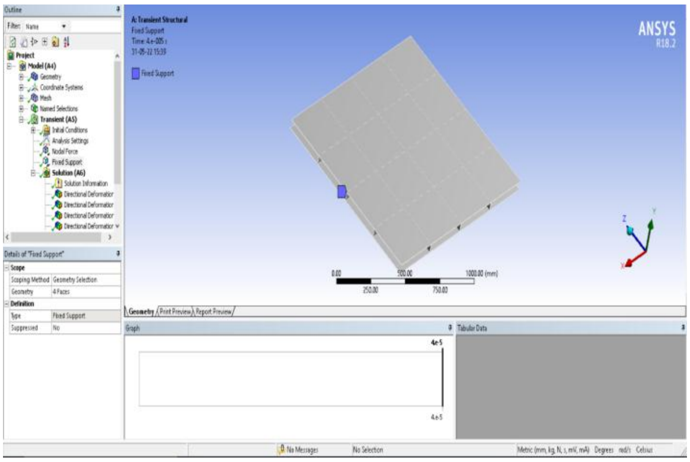

Fig- 7: Fixed Support Conditions

Above figure shows supports conditions of the plate. Fixed supports are applied on all the four sides of plate and analysis is carried out.

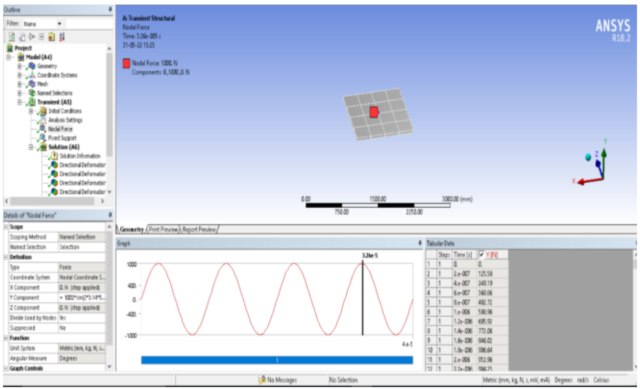

Fig- 8: Nodal Force of 1000N amplitude and 100 KHz frequency

Figure shows the force applied on the aluminium stiffened sandwich plate having rectangular configuration of stiffeners. Four cycles of sinusoidal load having 1000 N amplitude and 10 microseconds cycle time is considered for this analysis.

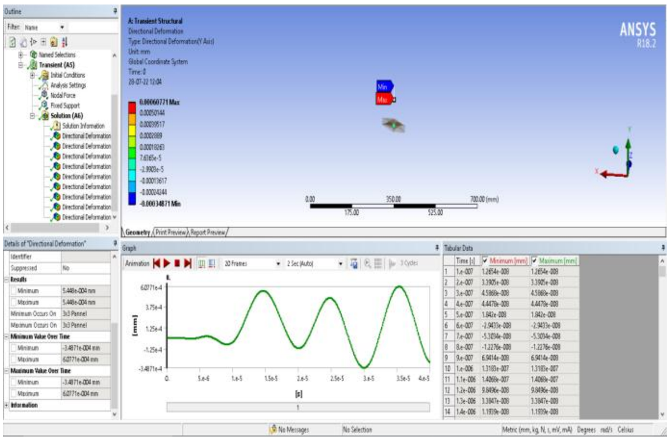

Figure- 9: Deformation results of aluminium stiffened sandwich plate having rectangular stiffeners

Figure shows directional deformation of plate at central node for aluminium stiffened sandwich plate having rectangular stiffeners for 100 KHz frequency.

Table-1 Deflection results for rectangular stiffened sandwich plate

SR. No	Node No	Deflection (mm)	
		Maximum	Minimum
1	Node 1	6.0771e-004	-3.4871e-004
2	Node 2	6.2289e-005	-7.209e-005
3	Node 3	4.531e-005	-5.0762e-005
4	Node 4	3.0499e-005	-3.5718e-005
5	Node 5	7.5955e-005	-5.9597e-005
6	Node 6	3.9882e-005	-4.926e-005
7	Node 7	4.6149e-005	-3.9814e-005
8	Node 8	3.9882e-005	-4.926e-005
9	Node 9	4.6149e-005	-3.9814e-005

Above table shows results of directional deformation at different nodes. The maximum deformation occurs at node 1 which is central node.

5.2 Analysis of aluminium stiffened sandwich plate having hexagonal stiffeners

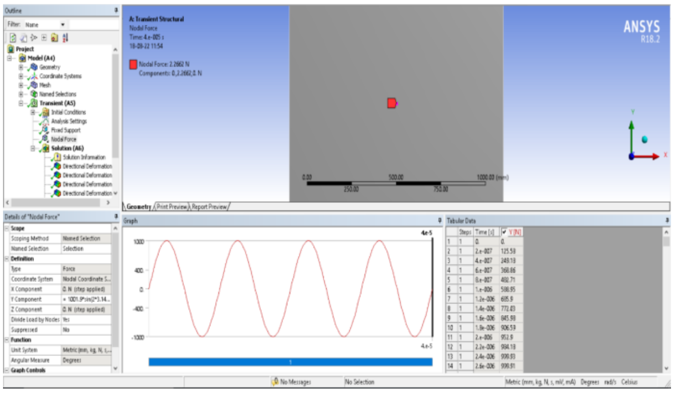

Figure-10 Nodal Force of 1000N amplitude and 100KHz frequency

Figure shows the force applied on the aluminium stiffened sandwich plate having hexagonal stiffeners. Four cycles of sinusoidal load having 1000 N amplitude and 10 microseconds cycle time is considered for this analysis.

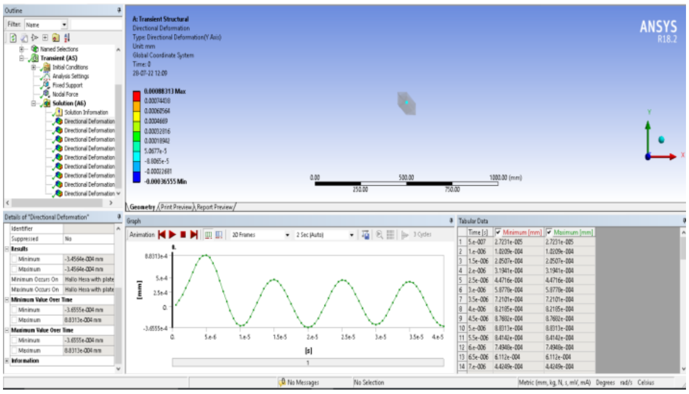

Figure-11 Deformation results of aluminium stiffened sandwich plate having hexagonal stiffeners

Figure shows directional deformation of plate at central node for aluminium stiffened sandwich plate having hexagonal stiffeners for 100 KHZ frequency.

Table-2 Deflection results for hexagonal stiffened sandwich plate

SR.No	Node No	Deflection (mm)	
		Maximum	Minimum
1	Node 1	8.8313e-004	-3.6555e-004
2	Node 2	2.8299e-005	-3.2472e-005
3	Node 3	3.6238e-005	-4.0494e-005
4	Node 4	1.9807e-005	-2.0466e-005

5	Node 5	3.6013e-005	-4.0197e-005
6	Node 6	2.4171e-005	-2.1605e-005
7	Node 7	6.7401e-006	-1.7886e-005
8	Node 8	7.6946e-006	-9.2976e-006
9	Node 9	8.7114e-006	-1.2683e-005

Above table shows results of directional deformation at different nodes. The maximum deformation occurs at node 1 which is central node.

5.3 Analysis of aluminium stiffened sandwich plate having triangular stiffeners

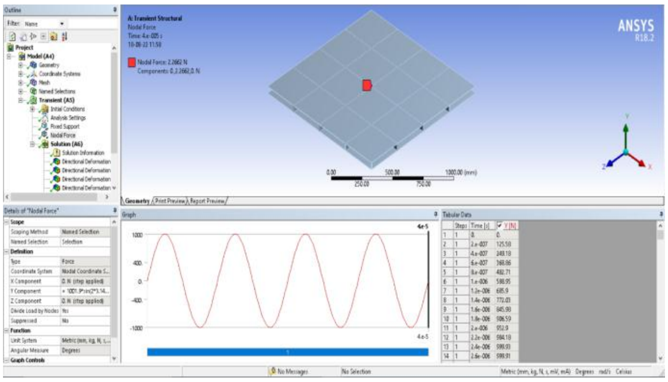

Figure-12 Nodal Force of 1000N amplitude and 100KHz frequency

Figure shows the force applied on the aluminium stiffened sandwich plate having triangular stiffeners. Four cycles of sinusoidal load having 1000 N amplitude and 10 microseconds cycle time is considered for this analysis.

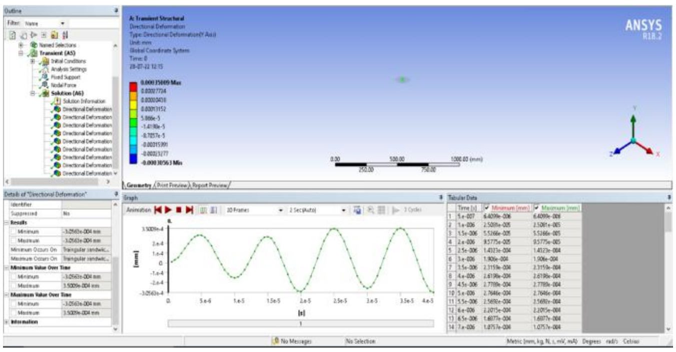

Figure-13 Deformation results of aluminium stiffened sandwich plate having hexagonal stiffeners

Figure shows directional deformation of plate at central node for aluminium stiffened sandwich plate having triangular stiffeners for 100 KHz frequency.

Table-3 Deflection results for triangular Stiffened sandwich plate for 100KHZ frequency

SR.No	Node No	Deflection (mm)	
		Maximum	Minimum
1	Node 1	3.5009e-004	-3.0563e-004
2	Node 2	4.0635e-006	-4.6643e-006
3	Node 3	7.3532e-006	-8.878e-006
4	Node 4	9.0477e-006	-9.8517e-006
5	Node 5	1.3871e-005	-1.5951e-005
6	Node 6	-1.9047e-006	-1.9047e-006
7	Node 7	6.6951e-006	-8.5207e-006
8	Node 8	2.7194e-006	6.6951e-006
9	Node 9	-3.2162e-006	-3.2162e-006

Above table shows results of directional deformation at different nodes. The maximum deformation occurs at node 1 which is central node.

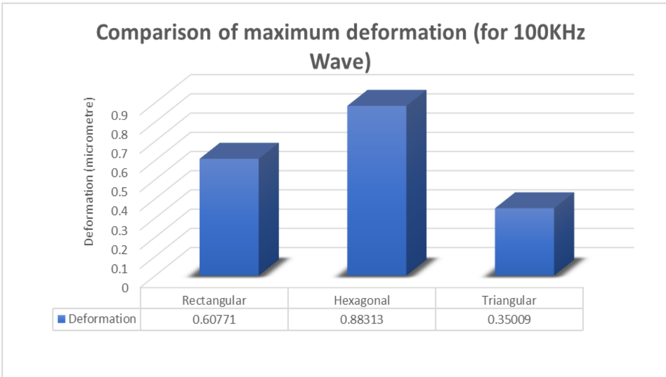

Figure-14 Comparison of maximum deformation due to four cycles sinusoidal wave of 100 KHz frequency for different configuration of stiffeners

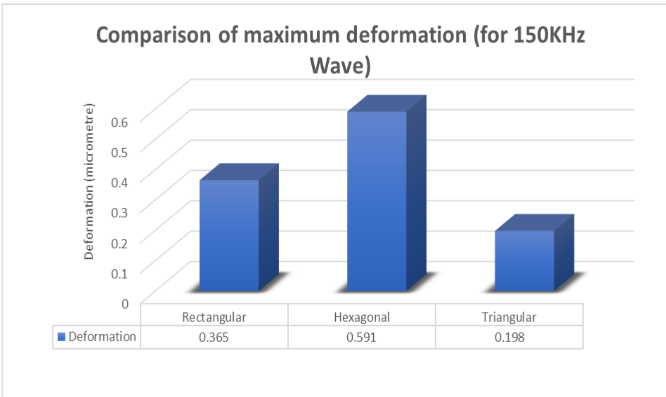

Figure-15 Comparison of maximum deformation due to four cycles sinusoidal wave of 150 KHz frequency for different configuration of stiffeners

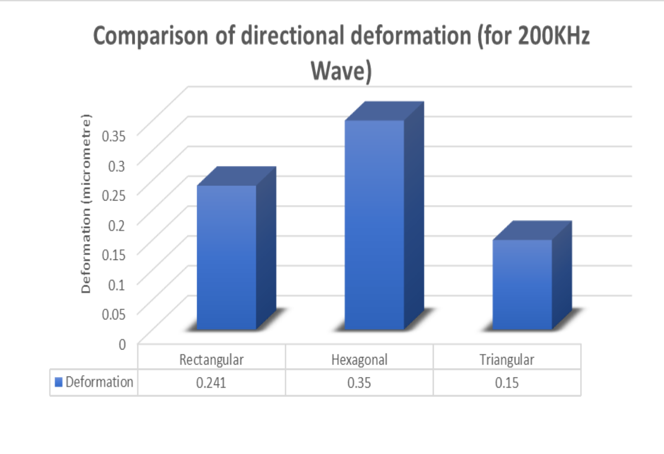

Figure-16 Comparison of maximum deformation due to four cycles sinusoidal wave of 200 KHz frequency for different configuration of stiffeners

Table-4 maximum deformation for different frequencies and configuration of stiffeners in micrometer

Shape of stiffener	Maximum deformation (micrometer)		
	100 KHz	150 KHz	200 KHz
Rectangular	0.60771	0.365	0.241
Hexagonal	0.88313	0.591	0.35
Triangular	0.35009	0.198	0.15

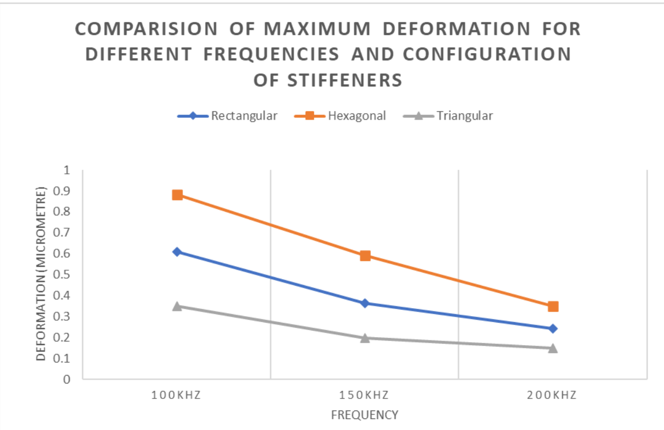

Figure-17 Comparison of maximum deformation for different frequencies and configuration of stiffeners

8. CONCLUSIONS

i. For same number of sinusoidal cycles, if the frequency of sinusoidal wave is increased, total cycle time decreases and hence maximum deformation in aluminium stiffened sandwich plate decreases.

ii. Maximum deformation at central node in aluminium stiffened sandwich plate having triangular configuration of stiffeners is less as compared to rectangular stiffeners and hexagonal stiffeners

iii. Hence the optimum configuration of stiffener that should be adopted for aluminium stiffened sandwich plate is triangular configuration of stiffeners.

iv. The deformation of aluminium stiffened sandwich plate is less as compared to conventional aluminium plate.

9. REFERENCES

1) A. Yousefi and M. Safarabadi (2020), "Damage identification of the rice husk sandwich structure for ship deck structure," International conference on marine technology. S. Popovics, Concrete Materials: Properties, Specifications, and Testing, 2nd ed. Park Ridge, NJ: Noyes, 1992.

2) Abdi Ismail (2020), "vibration based damage identification for ship sandwich plate using finite element method," Article in Open Engineering.

3) Aparna Aradhye and Dhanashri Joglekar (2021) " Adiabetic guided wave propogation through a honeycomb composite sandwich structure," International journal of solids and structures.

4) B. Janarthan (2016) "Buckling of bars, plates and shells," McGraw-Hill Company. Bambang Piscesa, Rizky Chandra Ariesta, and Tuswan (2020) "Vibrationbased damage identification for ship sandwich plate using finite element method," computational and applied mechanics.

5) C. Droza, O. Bareillea, J.-P. Lain´ea, M. N. Ichchoua (2020) "Wave-based SHM of sandwich structures using cross-sectional waves "

6) Chen, J, Su, Z and Cheng, L, (2010) "Identification of corrosion damage in submerged structures using fundamental anti-symmetric Lamb waves", Smart Materials and structures, Vol.19, 015004

7) Deepak kumar singh and S. K. duggal (2015), "Analysis of stiffened plates using FEM,"

International journal of engineering and technology.

8) Do Kyun Kim (2018), "Design with Constructal Theory," 1st International Workshop on shape and thermodynamics.

9) Joao pedro and Queiroz (2002), "Analysis of stiffened plates under lateral

10) Konstantinos N. Anyfantis (2020) "Ultimate strength of stiffened panels subjected to non uniform thrust," International journal of naval architecture and ocean engineering.

11) Mirco Muttilo and Vincezo Stornelli (2020) "Structural health monitoring: an IOT sensor system for structural damage indicator evaluation," department of industrial and information engineering and economics.