ANALYSIS OF HYBRID SANDWICH PLATE STRUCTURES

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Abstract – Honeycomb sandwich structures are those structures which are mainly in the shape of a honeycomb . These structures are of high strength in addition to its weight therefore the applications of honeycomb structure plate are very important. Due to its high strength to weight ratio and high stiffness it can be used in automobile, aerospace and space structures. The honeycomb structures mainly consist of three parts they are of two face plates and a core. By using different shapes of core and combining them gives a hybrid core with special characteristics. This paper mainly focuses on the hybrid sandwich plate structures and their properties and also to compare the in-plane and out-of-plane compression of honeycomb structures and to conduct the behaviour prediction of honeycomb structure and hybrid structure. In this study buckling analysis, bending analysis and dynamic analysis are done in the hybrid sandwich plate structures and the analysis are done in the finite element analysis software ANSYS.

***Key Words*: Honeycomb structures , Hybrid structures, Corrugated sandwich structures, Cross supports.**

1. INTRODUCTION

A honeycomb sandwich plate structure is formed by mainly of three members they are of two face plates and a core. The face plates are made up of material like thin composite laminates of glass, aramid, carbon, aluminium and steel plates etc. and the core is made up of either metal or thin plate like materials. The most commonly used core material is aluminum [5][11]. The core is placed in between the two face plates in order to achieve high stiffness-to-weight and strength-to-weight ratios [1]. For improving the properities of honeycomb sandwich structures the hybrid structures are to be used. The hybrid structures give comprehensive thermal and mechanical advantages and also have high strength and specific energy absorption [13]. The unique character of honeycomb sandwich structure are of high stiffness to weight ratio, elimination of welding, superior insulation quality and design versatility[11]. The main aim and objective of this paper is to compare the in-plane and out-of-plane compression of the structure and to conduct the behaviour prediction of honeycomb structure and hybrid structure. The fig-1 shows a honeycomb sandwich structure.

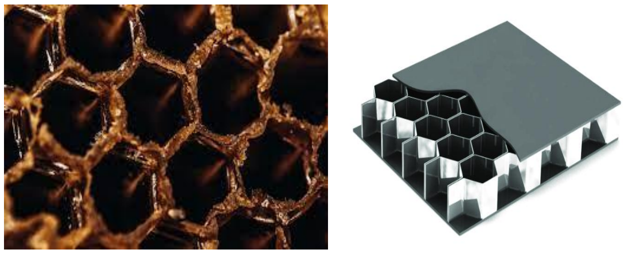


Fig -1: Honeycomb structure

1.1 Honey comb Sandwich structures

The honeycomb structures are mainly of natural or manmade structures which are in the shape of honeycomb which use minimal material to reduce the weight and cost of the material[1]. The arrangement of honeycomb sandwich structure is in such a way like a sandwich . The honeycomb structure have of two face plates and a core. The core is mainly situated in between the two face plates like a sandwich. The commonly used face plates are of carbon fibre, glass fibre etc. and the most commonly used core material is aluminum [1][5][12][14]. The core gives high compressive strength. The compressive strength of sandwich panel is depends upon the foil thickness of honeycomb core, cell size, thickness of core and face sheet thickness. The core is made up of different cells and it is of different shapes like hexagonal cells, square and flex core. For adhesively bonded honeycomb hexagonal cell shape is commonly used and square cells are used mostly for resistance welded and brazed cores [11]. Typically a sandwich panel is comprised of a low stiffness, low density inner core enclosed by two stiff outer skins, as shown in Figure 2 where the whole assembly is held together by some sort of structural adhesive (Figure 3). The outer skins are typically made from stiff carbon fibre or aerospace grade aluminium. The inner core is typically a Nomex or metal honeycomb, or an open or closed cell foam. Nomex is an aramid polymer similar to Nylon that is flame-resistant and can be manufactured in paper sheet form. Nomex is a great choice for the interior of aircraft cabins such as the floor panels due to its high safety in the event of fire. Multiple sheets of Nomex paper can be placed on top of each other and glued together at the node locations by lines of adhesive, which are offset spatially between different layers. This large stack of Nomex can then be cut into smaller strips and expanded to form a sheet of Nomex honeycomb. Alternatively closed cell foams such as Rohacell® are commonly used for the core, which are denser then there open cell counterparts but prevent moisture ingress in service and have better mechanical properties[4].

Fig -2: A honeycomb carbon fibre sandwich panel

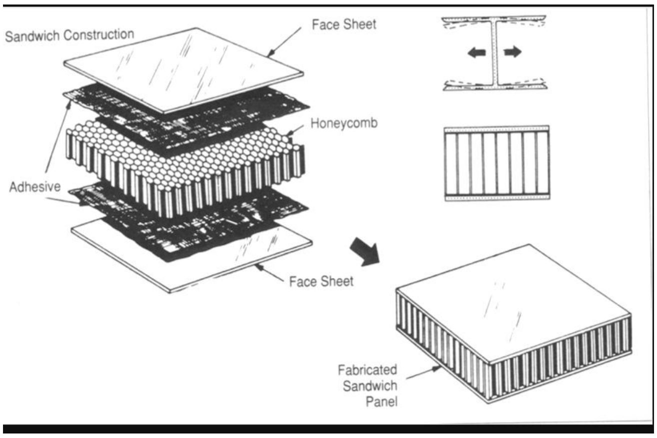


Fig -3: Sandwich panel components and construction

The materials used in this study are of carbon fibre UD and glass fibre UD as face sheets and the core material used is of Aluminium 5052 is shown in fig 4

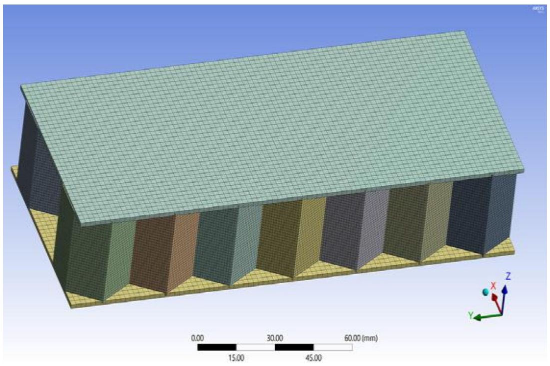


Fig -4: Honeycomb sandwich structure

1.2 Hybrid Stuctures

Hybrid structures are those structures which are used to improve the properties of honeycomb sandwich structures. The hybrid structures are commonly the combination of two structures. In the honeycomb sandwich composite structures the core is used for making hybrid structures. The cores used are of different shapes and by combining the different shaped core it gives a hybrid structure. By using the hybrid it give comprehensive thermal and mechanical advantages and also it have high strength and specific energy absorption[2][13]. There were different combination of hybrid structures one is of using the I type strut and the corrugated core by combining these two we get a hybrid core . The corrugated core is in the shape of 'V' then by combining this with' I' we get a M type or N type core [2].The hybrid structures used in this study are of corrugated sandwich structure, I strut + hexagonal honeycomb, cross support + hexagonal honeycomb. Thr fig-5 shows an example of a hybrid structure.

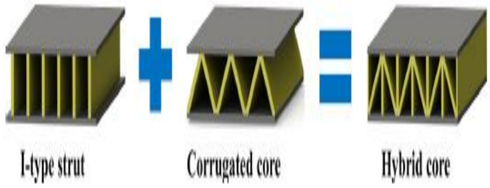


Fig -5: Hybrid structure

2. Material properties

The honeycomb sandwich structure model is made up of mostly of three materials. They are mainly of two face sheets made of carbon fibre UD and glass fibre UD and the core is made up of Aluminium 5052. The face sheets are of unidirectional fibres and they have better compressive strength, modulus of elasticity and shear strength. The core material Aluminium 5052 have good weldability. good cold formability and medium to high fatigue strength [1][4][8] .

The table- 1 below shows the material properties

Table -1: Material Properties

Material	Aluminium 5052	Carbon Fibre UD	Glass Fibre UD
Density (kg/m3)	83	1490	2000
Ex (MPa)	1.48	1.21e + 05	45,000
Ey (MPa)	0.49	8600	10,000
Ez	2129	8600	10,000
υxy	0.58	0.27	0.30
υyz	7.5e _ 05	0.4	0.4
υzx	2.4e _ 04	0.27	0.27
Gx (MPa)	0.72	4700	5000
Gy (MPa)	253	3100	3846.2
Gz (MPa)	524	4700	5000

3. Numerical investigation

3.1. Cell geometry of the model

The analysis is done in finite element method using ANSYS Firstly the model is created using solidworks and the thickness of the sheet and meshing is done in Ansys[1] [3] [8] [10] [13]. The core and the sheets were designed using SOLIDWORKS.. The cell geometry of the honeycomb core is given in the figure below.

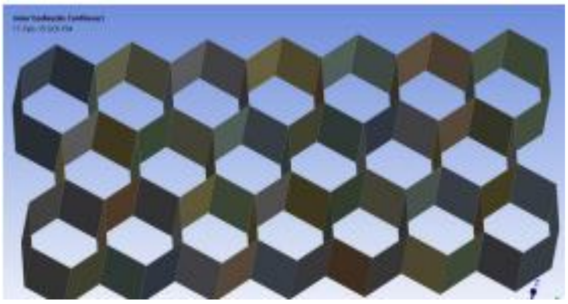


Fig -6: Cell geometry of hexagonal honeycomb core

3.2. Boundary conditions

The modal analysis, buckling analysis, bending analysis & static structural analysis is done for the specimen under fixed end conditions. Here the von mises stresses and total deformation should be calculated. By applying various forces we can study the behaviour of the model and also the faces of the plates are in fixed condition. For commonly the varying forces are from 100 Pa to 700 Pa [1] [15].

3.3. Dimensions of the honeycomb sandwich structure

The main part of the honeycomb sandwich structure is face sheet or face plate the face sheet thickness used here is of 1.5mm ,the edge length is 15mm, the height of the core is 32mm and the core thickness is 0,5mm and the element size used is of 2mm

4. Finite element analysis of honey comb sandwich structure

The finite element analysis is used for finding the analytical value of the honeycomb sandwich structure. The software used here is of Ansys for the analysis[16]. To make other individual cells here first a unit cell is modelled and it is replicated in X-direction and Y- direction. For assembling the honeycomb core of sandwich panel the individual cells are merged together.To the honeycomb core to develop the full part of honey comb sandwich panel the face sheets are modeled and assembled on it[21].Then the meshig is done. .After meshing the model the boundary condition and load should be assigned. The result from the analyses are of deformation and stresses[1]. The analysis in ANSYS confirms the natural frequency.The analyzing process of each mode in ANSYS is shown in below figure.

4.1. Modeling of hexagonal honeycomb sandwich structure and meshing

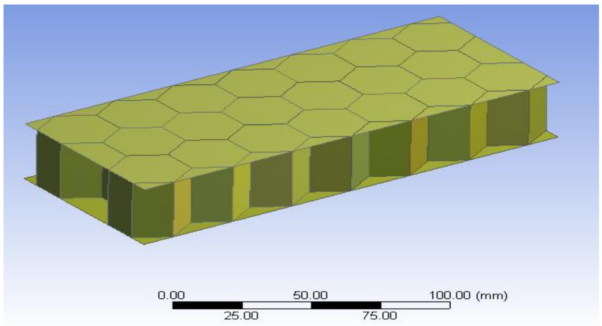


Fig -7: Model of 1,5mm thickness

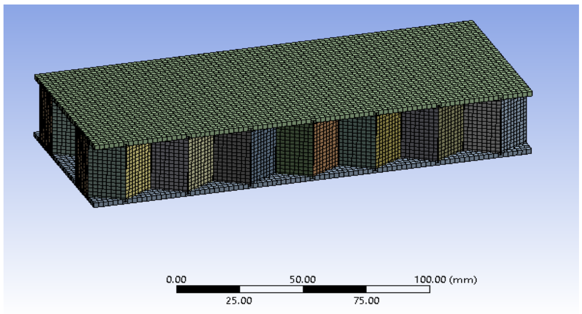
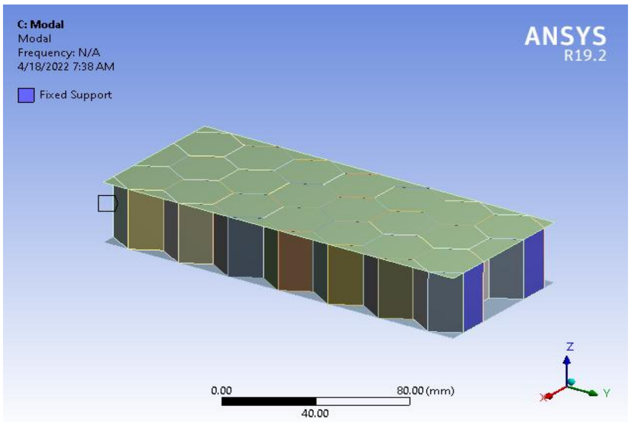


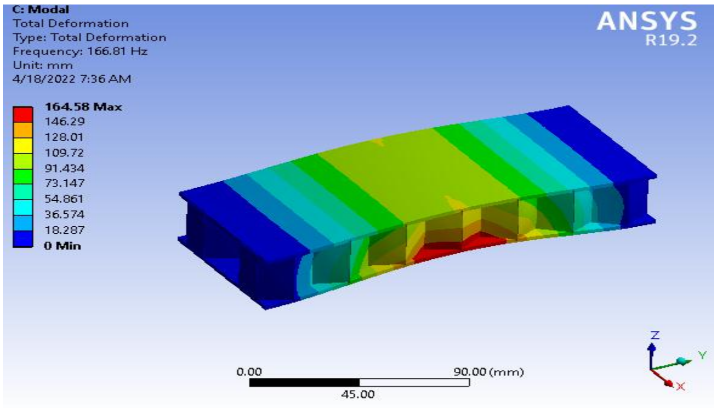
Fig -8: Meshed model of honeycomb sandwich structure

4.2. Modal Analysis

Boundary Conditions

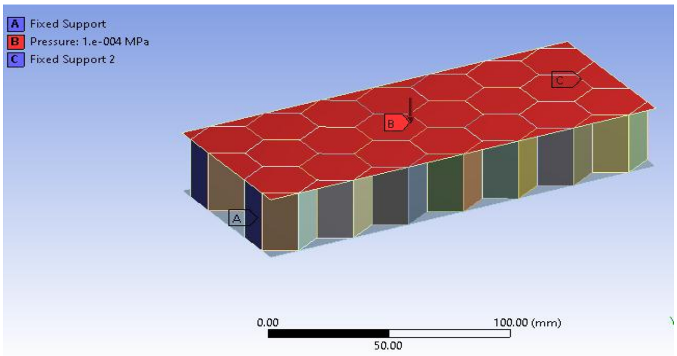


(a) First mode shape

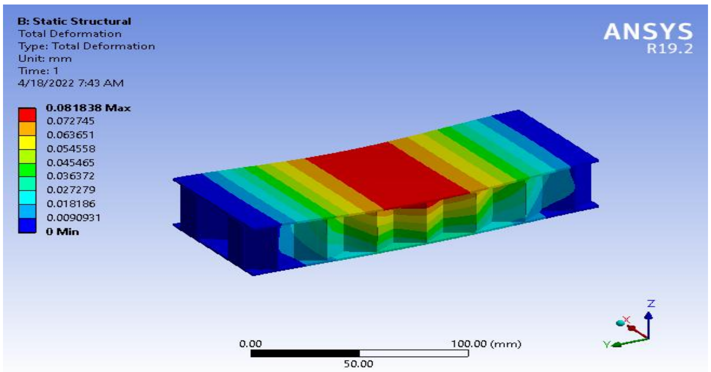


4.3. Static Analysis

(a) Boundary Conditions



4.4. Total Deformation and Von misses Stress at 100pa



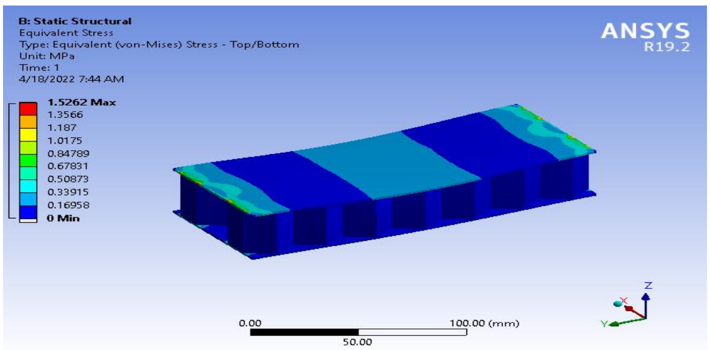


Fig -9: Modal analysis, Static analysis, Total deformation and equivalent von mises stresses

5. Parametric study

The parametric study means changing the parameters like changing the loads, thickness, shapes, heights, length etc. and finding out the effect of each parameter. In the present study involves changing the loads, changing the face sheet thickness and changing the core shapes and atlast finding the effect of each parameter. The table- 2 shows the effect due to load change. It mainly shows the total deformation and equivalent stress due to different loads. From the table it can be understand that the total deformation and equivalent stress is increasing when the load is more.

Table -2: Results obtained for different loads

Loads	Total deformation	Equivalent stress
200	0.035796	1.8803
300	0.053694	2.8204
400	0.071592	3.7606
500	0.089489	4.7007
600	0.10739	5.6409
700	0.12529	6.581

The effect due to face sheet thickness is shown in the table-3. The effect of different face sheet thickness affects the natural frequency. When the thickness of face sheet increases the natural frequency also increases.

Table -3: Results obtained for different face sheet thickness

Face sheet thickness	ω_{n1} (Hz)	ω_{n2} (Hz)	ω_{n3} (Hz)	ω_{n4} (Hz)	ω_{n5} (Hz)	ω_{n6} (Hz)
0.5	73.164	124.63	168.63	173.99	179.64	183.24
1.0	123.40	167.04	179.64	183.24	184.96	185.55
1.5	166.81	180.48	183.23	184.96	188.67	188.91
2.0	179.64	183.24	184.96	188.67	188.91	194.52
2.5	179.64	183.24	184.96	188.67	188.91	194.52

The different core shapes that are used are of hexagonal, corrugated etc . The fig below shows the different core shapes of a honeycomb sandwich plate structure.

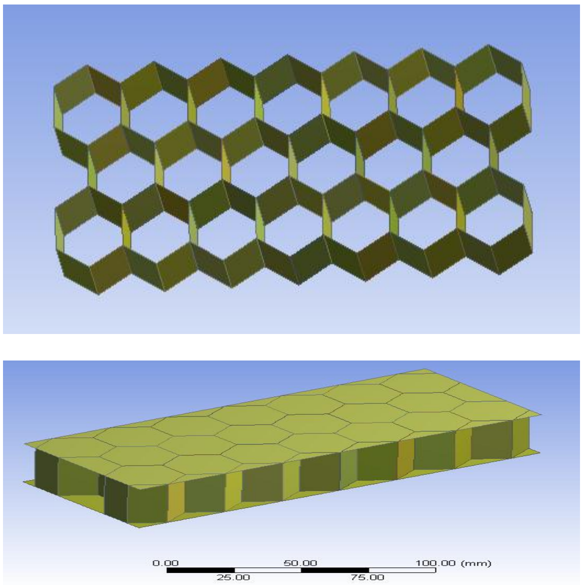


Fig -10: Hexagonal honeycomb sandwich plate structure

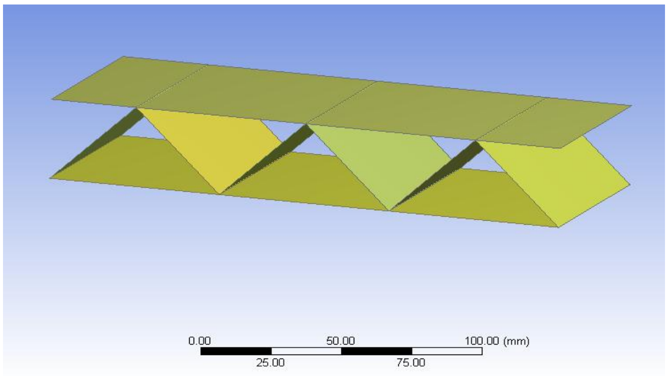


Fig -11: Corrugated honeycomb sandwich plate structure

6. Modelling of hybrid sandwich plate sucture

The hybrid structures are a combination of two core shape which has many properties like comprehensive thermal and mechanical advantages and also it have high strength and specific energy absorption. The hybrid structure used in this study are of I strut + hexagonal honeycomb and the analysis is done in finite element method software ANSYS. The fig-12 shows the geometry of the model in this the face sheets are carbon and glass fibre and the core is of aluminium. The fig -13 shows the meshed model and the meshing is done at an element size of 2mm. The fig-14 shows the fixed boundary condition and the load given is of 100 Pa .The total deformation and equivalent von mises stress are to be get from the analysis and it is given in the fig -15.

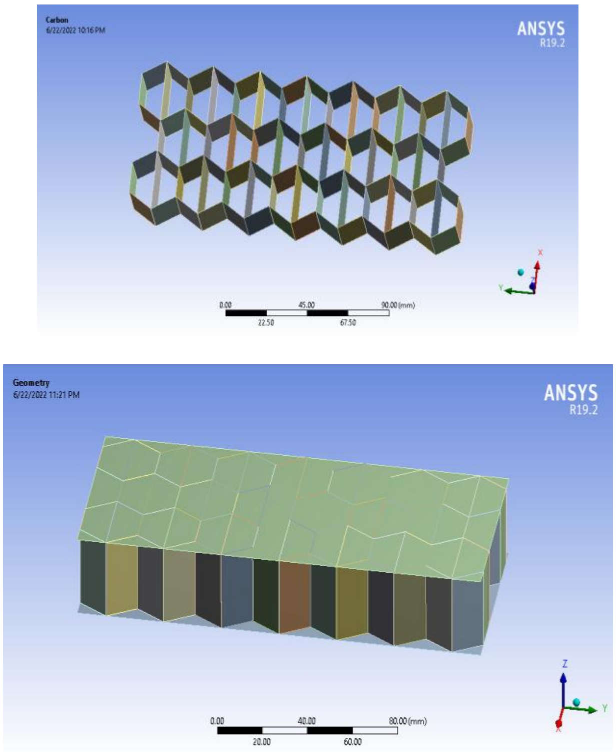


Fig -12: Geometrical model of the hybrid structure

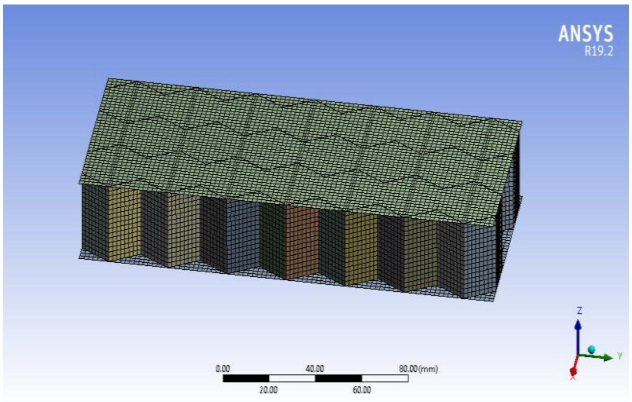


Fig -13: Meshed model of the hybrid structure

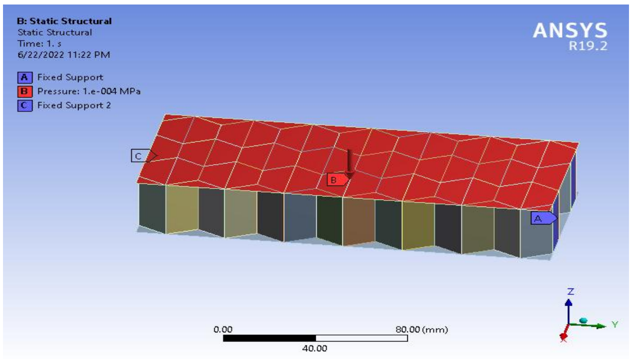
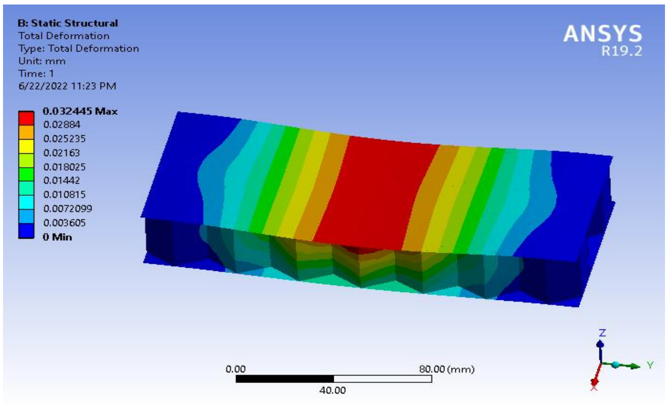


Fig -14: Boundary condition and load application of the hybrid structure



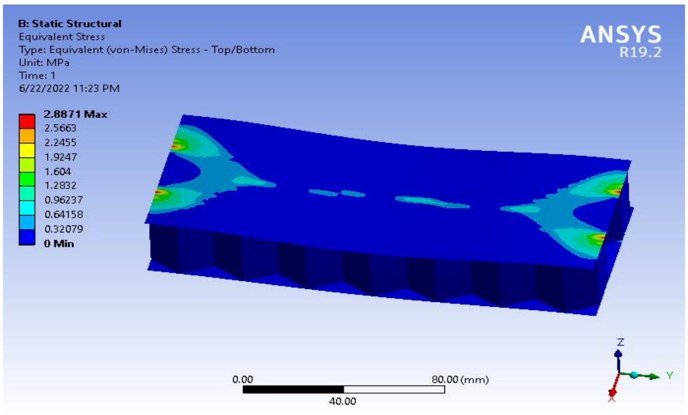


Fig -15: Total deformation and von mises stresses of the hybrid structure

7. CONCLUSIONS

This study mainly focuses on the behavior prediction of honeycomb sandwich structure and the hybrid structure. For finding out the natural frequency due to different loading in the honeycomb structure the finite element modeling software ANSYS is used. In the honeycomb sandwich structure homogeneous shaped material is used as the core and in the hybrid structure the combination of different type cores are to be seen. In this paper different type of parametric study should be done and the effect of different parameter on the structure can be identified. From the FEM analysis the total deformation and the equivalent von mises stresses of the honeycomb structure and the hybrid structure can be obtained. By comparing the two structures the hybrid structure will undergo less defomation than the honeycomb structure because the hybrid structure have comprehensive thermal and mechanical advantages and also it have high strength and specific energy absorption. So the hybrid structure is most efficient than the honeycomb structure.

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