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# Cell Geometry Effect On The Vibration Behaviour Of Sandwich Composite Structure

B. Vibin[1], Dr. S. Periyasamy[2]
*Department of Mechanical Engineering[1, 2]*
*PG Scholar[1], Assistant Professor[2]*
*Email: vibinmky@gmail.com[1], Email: speriyasamy@gct.ac.in[2]*

**Abstract-** With 3D printing technology, unlimited unit cell geometries and cell arrangements can be made. However, most works done on hexagonal honeycomb unit cells versions only. Further most of it done for in-plane response. This paper investigates the effect of unit cell geometry on the vibration behaviour of different unit cell geometry. Four different unit cell geometry having the same unit cell size were created. The four different unit cells were modelled using Solidworks software. Then the first five natural frequency and mode shapes of the models were obtained using ANSYS software. Results were compared and newly developed structure that gives significant improvement in vibration behaviour.

**Keywords -** Honeycomb, Sandwich, Vibration.

## 1. INTRODUCTION

Honeycomb is a two-dimensional prismatic cellular material with a regular and periodic microstructure. The main objective of this project is to design and analyse novel structure for sandwich core that is able to withstand high frequency vibration. With advances in 3D printing technology now in honeycomb structures, unlimited unit cell geometries and cell arrangements can be made which giving a wide range of possible mechanical properties and vibration behaviour. The compression behaviour, mechanical properties and out of plane response of honeycombs are not just a function of the base material properties and the relative density, but also a function of the cell geometry [1].

Eshagh F. Joubaneh et al., studied the vibration behaviour of sandwich beam under various boundary conditions by both analytical and experiment [3]. Zhi-jia Zhang et al., discussed the vibration response of hybrid honeycomb core structure. They study their behaviour under free vibration condition [4]. Helong Wu et al., studied the vibration behaviour of sandwich beam which have CNT coated face sheets. It shows significant improvement in the vibration behaviour of sandwich beam [5].

Despite these work on honeycombs, there seems to be little research on the effect of cell shape on vibration response of honeycombs. This investigation fills this gap and provides a numerical study on the effect of cell geometry for four different type honeycombs on their vibration behaviour. The vibration response of four different honeycombs unit cell geometries are studied using Ansys software. The results were presented and compared, and the conclusions are made.

## 2. MATERIALS AND CONFIGURATION

The mechanical behaviour of sandwich structures depends on cell geometry, base metal and size of the section considered. In this study in order to investigate cell geometry effect, the other two were

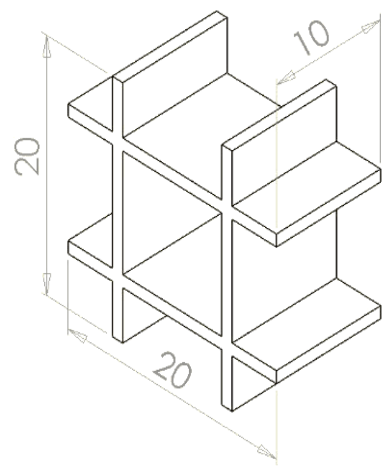



Fig 1 Unit cell dimension

kept as constant. Thus, four different unit cell geometry were modelled each have same thickness of 1 mm. Size of the unit cell kept constant 20mmx20mmx10mm as shown in figure1.

The four different unit geometry were listed in table 1.Square, Circle and Hexagon unit cells have same cross section through $X_3$ direction.

Hexagon with curved edge unit cells cross section varies from 1mm thickness to 0.5mm to the middle of the section then its again varies to its initial thickness.

For vibration behaviour prediction of sandwich structure, the specimens were modelled to a dimension of 400mmx50mm had a core thickness value of 10mm and face sheet thickness value of 0.3125mm. In addition, the vibration response was obtained for both Fixed-Free and Fixed-Fixed boundary conditions.

Table 1 CAD model of different unit cell

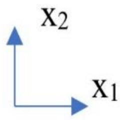
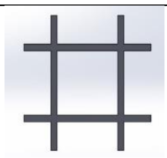
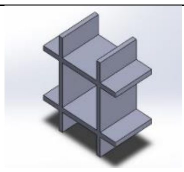
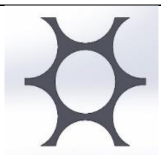
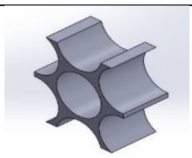
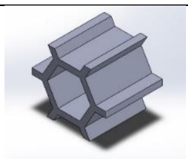
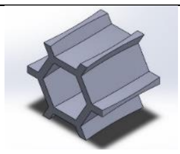
| Unit cell Type | Front view <br>   | Isometric view |
|---|---|---|
| Square |  |  |
| Circle |  |  |
| Hexagon |  |  |
| Hexagon with Curved Edge |  |  |

Table 2 Material properties of Aluminium 6061

| Material | Aluminum alloy |
|---|---|
| Elastic modulus | 71000 MPa |
| Poison's ratio | 0.33 |
| Density | 2770 kg/$m^3$ |
| Yield stress | 55.2 MPa |

Table 3 Material properties of Epoxy E-glass unidirectional

| Material | Epoxy E-glass UD |
|---|---|
| E1 | 45000 MPa |
| E2 | 10000 MPa |
| E3 | 10000 MPa |
| Poison's ratio 1 | 0.3 |
| Poison's ratio 2 | 0.4 |
| Density | 2000 kg/m3 |

For vibration analysis, Aluminium 6061 material was used in cell geometry was used for core section and for face sheets Epoxy E-glass unidirectional were used.

## 3. VIBRATION ANALYSIS OF THE HONEYCOMB STRUCTURES

In these section modal analysis features of ANSYS simulation software was used to find the first five fundamental frequency and mode shapes. The core section of the sandwich beam was assigned with aluminium material and the top face sheets were assigned with epoxy E-glass unidirectional material. To obtain significant accurate result an element size of 2mm were used for meshing. For fixed-free boundary condition, one side of the sandwich beam is given as fixed support as shown in figure 2 and for fixed-fixed boundary condition; both sides were given as fixed support.

## 4. RESULTS AND DISCUSSION

Initially the mass of the four different of unit cell geometry were compared

Table 4 Mass of different unit cell geometry

| S. No | Unit Cell Type | Mass (grams) |
|---|---|---|
| 1 | Square | 1.51 |
| 2 | Circle | 1.81 |
| 3 | Hexagon | 0.73 |
| 4 | Hexagon with Curved Edge | 0.5 |

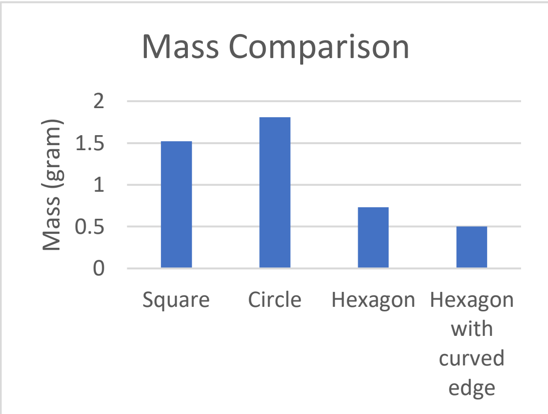



Figure 2 Mass comparison of different unit cell geometry

From the above figure, we can see that the mass of the circle has the high mass and the hexagon with curved edge has the less mass.

### *4.1. VIBRATION ANALYSIS*

To understand the vibration behaviour the modal analysis was done. Modal analysis is the study of the dynamic properties of structures under vibrational excitation. It is critical that a designer understands the natural vibration frequencies of a system in order to ensure that they are not the same as excitation frequencies, thus ensuring safety standards. Modal analysis provides an overview of the limits of the response of a system. The mode analysis results of the square, circular, hexagon, hexagon with curved unit cell sandwich beams were listed in table 5, table 6, table 8, and table 9 respectively.

Table 5 Natural frequency for square unit cell under two boundary condition

| fixed-free | | fixed-fixed | |
|---|---|---|---|
| Mode | Frequency (Hz) | Mode | Frequency (Hz) |
| 1 | 48.169 | 1 | 301.96 |
| 2 | 160.75 | 2 | 643.86 |
| 3 | 298.38 | 3 | 670.5 |
| 4 | 299.55 | 4 | 819.88 |
| 5 | 745.57 | 5 | 1347.8 |

Table 6 Natural frequency for circular unit cell under two boundary condition

| fixed-free | | fixed-fixed | |
|---|---|---|---|
| Mode | Frequency (Hz) | Mode | Frequency (Hz) |
| 1 | 43.688 | 1 | 277.36 |
| 2 | 141.49 | 2 | 756.58 |
| 3 | 272.24 | 3 | 759.89 |
| 4 | 397.92 | 4 | 842.21 |
| 5 | 756.54 | 5 | 1464.7 |

Table 7 Natural frequency for hexagon unit cell under two boundary condition

| fixed-free | | fixed-fixed | |
|---|---|---|---|
| Mode | Frequency (Hz) | Mode | Frequency (Hz) |
| 1 | 43.516 | 1 | 277.47 |
| 2 | 130.77 | 2 | 704.9 |
| 3 | 271.06 | 3 | 756.62 |
| 4 | 387.44 | 4 | 821.28 |
| 5 | 724.31 | 5 | 1463.7 |

Table 8 Natural frequency for hexagon with curved edge unit cell under two boundary condition

| fixed-free | | fixed-fixed | |
|---|---|---|---|
| Mode | Frequency (Hz) | Mode | Frequency (Hz) |
| 1 | 47.601 | 1 | 303.98 |
| 2 | 138.48 | 2 | 764.75 |
| 3 | 296.72 | 3 | 826.74 |
| 4 | 435.81 | 4 | 936.56 |
| 5 | 774.97 | 5 | 1593.5 |

The natural frequency of the four different core sandwich beams were compared for the first five mode for two different boundary conditions fixed-free and fixed-fixed. The results show that the hexagon with the curved edge show a significant higher frequency in all modes.

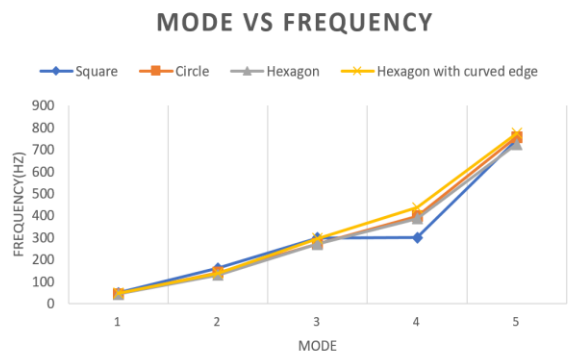



Fig 3 Mode vs Frequency at fixed- free condition

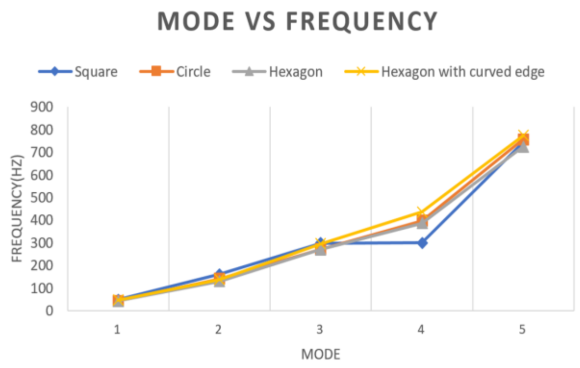



Fig 5 Mode vs Frequency at fixed- fixed condition

## 5. CONCLUSION

The CAD model of four honeycombs of different unit cell geometry, but with same material and size, was considered. The impact behaviour of four different unit cells were numerically analysed using Abaqus software. The vibration behaviour was analysed using Ansys modal analysis feature. The results showed that the cell geometry affect the energy absorption capacity and vibration behaviour of these structures significantly. Among the four types of honeycomb structures that were analysed, the hexagon with curved edge provided 9% higher energy absorption capacity and 6% high natural frequency than regular hexagon shape. The newly developed honeycomb with curved edge unit cell also provides 31.5% amount of mass reduction from the previous regular hexagon unit cell. The results of this finite element study provide more insight into the effect of different cell geometry of honeycombs.

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