Design and Analysis of Hexagonal and Octagonal Honey Comb Structures with Various Materials and FEM Analysis.

Penumaka Dhananandh, Venkata Ramesh Mamilla, K. Sri Rama Murthy

Abstract: The demands for automotive interior and exterior panels in present and future market is an optimal combination of materials and cost-efficient production processes. Mechanical and acoustical requirements of high strength and a weight target result, today often in the selection of a sandwich design with a cost efficient and recyclable core material. Honeycomb sandwich structures are used in Airplane wings, Ships, Cars, Civil Constructions, etc. Now a day this technology is being used all over the automotive fields. These designs are the best way for low material usage and high strength.

In this project the designs of hexagonal and octagonal honeycomb structures are to be analysed and compared for the best result in structure. The structures are to be developed by using SolidWorks software. Solidworks flow simulation is to be used to test the effectiveness and limitations of the structures. Thermal and static analysis are to be analysed by using solidworks simulation software with different types of materials like Titanium, Aluminium, and Stainless steel to identify the best material at low cost and high efficient by applying various loads of finite element method analysis.

Keywords: Cost-efficient, high strength, low material, SolidWorks, Thermal and static analysis, finite element method.

I. INTRODUCTION

The geometry of a honeycomb structure minimizes the amount of material used to minimal weight and minimal cost. The geometry of honeycomb structure may vary. In mechanical structures stiffness, strength and weight efficiency are the most important factors. These honeycomb structures are used in satellites, Trains, space craft, Aircraft, boats, trucks etc. Core material is selected on the basis of performance density. Honeycomb sandwich structures exhibit high stiffness and strength to weight ratios. In the aerospace and transportation industry different types of sandwich core structures are used. Such as foam/solid core type are used in ships and aircrafts, honeycomb types of core are used in aircrafts and satellites, truss core type are used in buildings and bridges and web types of core is manufactured by using a variety of base materials.

With the development of aerospace technology, the demand of high-strength-low-density materials is becoming more and more requirement.

Severe mechanical environment and aerodynamic coupling are inevitable because of high launch acceleration and high frequency vibration, so the requirements for strength and stiffness of aeronautical structures are extremely high. Moreover, launch costs have strong restrictions on the overall mass of spacecraft, so the mass of aeronautical structures must be minimized as far as possible. Severe contradiction between strength and mass spurs extensive utilization of advanced alloy material and composite material in aerospace applications, such as aluminum alloy, titanium alloy, stainless steel (SS). So that the honeycomb structure are designed in different shapes like triangular, square and hexagonal Structures. So beyond that according to the structures and requirements, we need more efficient and less weighted structure. So in that process of discovering we are hoping that Octagonal structure can be change of present technology. The octagonal honeycomb core is designed with different materials of Aluminium, Stainless steel and Titanium composites. The results obtained from the experiment compared with the Hexagonal structure results with same composition of materials and dimensions.

Honeycomb composites: Honeycomb composites are manufactured in different shapes which are used for minimizing the weight and minimize the cost of the production. These structures are made of different mixing of materials for gaining good strength. These composites are the most demanded structures in these days.

II. LITERATURE REVIEW

Tom Bitzer’s Honeycomb Technology book [2] deals with honeycomb and honeycomb sandwich construction. After reading this book you will have a good understanding of what honeycomb is, how it is manufactured, and how to use it. You also will have the necessary knowledge to design honeycomb sandwich panels and honeycomb energy absorption systems. The honeycomb manufacturing methods, materials, cell configuration, terminology, and uses are all explained. The basic honeycomb sandwich concepts are discussed, failure modes shown and the standard design formulas are given. The standard honeycomb and sandwich test methods are also reviewed.

Srinivas Athreya, Dr. Y.D. Venkatesh [3] Studied application of the taguchi method for optimization of process parameters in improving the surface roughness of lathe facing operation. Taguchi method is a statistical method developed by Taguchi and Konishi. Taguchi’s method of parameter design can be performed with a lesser number of experimentation as compared to that of full factorial analysis and yields similar results.
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It is found that the parameter design of the Taguchi method provides a simple, systematic, and efficient methodology for optimizing the process parameters.

III. EXPERIMENTAL PROCESS

Design Considerations:
The structures of Hexagonal honeycomb and Octagonal honeycomb structures are designed in Solidworks Software with the same particular dimensions. The structures are analysed and compared to each other in three different types of materials. These analysis are done using Solidworks simulation 2018 Software.

Structure dimensions:
For better analysis and considerations both hexagonal and octagonal structures are designed in 1000mm*1000mm*100mm (Length*Height*width). These designs are designed using Solidworks 2018.

Note: All dimensions are in mm.
a) Hexagonal Structure:

Material Selection:
According to the research in aerospace technology the most used material for the honeycomb structures are Aluminum Alloy-7075[4], Stainless Steel Alloy-321[5], Titanium-Ti6Al-4V(Grade-5) [6]. These three materials are applied for the designs and simulation is processed. The mechanical properties of the materials according to the grades used in Airplanes and Aerospace technology.

Material properties:
The properties of the different materials used in this analysis are given in the following tabular form.

<table>
<thead>
<tr>
<th>Material Name</th>
<th>Aluminum Alloy</th>
<th>Stainless Steel Alloy</th>
<th>Titanium Alloy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model type</td>
<td>LEC (Linear Elastic Isotropic))</td>
<td>LEI</td>
<td>LEI</td>
</tr>
<tr>
<td>Default failure criterion:</td>
<td>Max von Mises Stress</td>
<td>Max von Mises Stress</td>
<td>Max von Mises Stress</td>
</tr>
<tr>
<td>Yield strength</td>
<td>5.06e+008 N/m^2</td>
<td>2.34421e+008 N/m^2</td>
<td>8.27372e+008 N/m^2</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>5.7e+008 N/m^2</td>
<td>6.2e+008 N/m^2</td>
<td>1.05e+009 N/m^2</td>
</tr>
<tr>
<td>Elastic modulus</td>
<td>7.2e+010 N/m^2</td>
<td>1.93e+011 N/m^2</td>
<td>1.048e+011 N/m^2</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>0.33</td>
<td>0.27</td>
<td>0.31</td>
</tr>
<tr>
<td>Mass density</td>
<td>2810 kg/m^3</td>
<td>8000 kg/m^3</td>
<td>4428.78 kg/m^3</td>
</tr>
<tr>
<td>Shear modulus</td>
<td>2.69e+010 N/m^2</td>
<td>-</td>
<td>4.10238e+010 N/m^2</td>
</tr>
<tr>
<td>Thermal expansion coefficient</td>
<td>2.4e-005 /Kelvin</td>
<td>1.7e-005 /Kelvin</td>
<td>9e-006 /Kelvin</td>
</tr>
</tbody>
</table>

These three materials are mostly used in the manufacturing of honeycomb structures in Aerospace technology. So with each material all the loads are applied and compared.

Application of loads on the Hexagonal honeycomb Structure:
Material: Aluminum alloy- 7075-T6, Plate(SS).

b) Octagonal Structure:
Bending moment:

a) Stress

b) Strain:

\[ \text{fig1.3: honey structure hexagon-bending-al-stress} \quad \text{fig1.4: honey structure hexagon-bending-al-strain} \]

c) Displacement:

d) Factor of safety:

\[ \text{fig1.5: honey structure hexagon-bending-displacement} \quad \text{fig1.6: honey structure hexagon-bending-al-factor of safety} \]

Application of loads on the Octagonal honeycomb Structure:

Material: Aluminum alloy- 7075-T6, Plate(SS).

Bending moment:

a) Stress:

b) Strain:
C) Displacement: 

D) Factor of safety: 

Application of loads on the Hexagonal honeycomb Structure: 
Material: Aluminum alloy- 7075-T6, Plate(SS). 
Shear Load: 

A) Stress: 

B) Strain: 

Displacement: 

Factor of safety: 

Application of loads on the Hexagonal honeycomb Structure: 
Material: Aluminum alloy- 7075-T6, Plate(SS). 
Shear Load: 

A) Stress: 

B) Strain: 

Displacement: 

Factor of safety:
Application of loads on the Octagonal honeycomb Structure:
Material: Aluminum alloy- 7075-T6, Plate(SS).
Shear Load:

- **a) Stress:**

- **b) Strain:**

Application of loads on the Hexagonal honeycomb Structure:
Material: Aluminum alloy- 7075-T6, Plate(SS).

- **Torsion Load:**
  - **a) Stress:**

- **b) Strain:**
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fig1.18: honey stucture hexagone-torsion-al-stress
fig1.19: honey stucture hexagone-torsion-al-Strain

fig1.20: honey stucture hexagone-torsion-al-displacement
fig1.21: honey stucture hexagone-torsion-al-factor of safety

Application of loads on the Octagonal honeycomb Structure:
Material: Aluminum alloy- 7075-T6, Plate(SS).
Torsion Load:

fig1.22: honey stucture octagone-torsion-al-stress
fig1.23: honey stucture octagone-torsion-al-strain

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Fig 1.24: honey structure octagone - torsion -al-displacement

Fig 1.25: honey structure octagone - torsion -al-Factor of safety

Application of loads on the Hexagonal honeycomb Structure:
Material: Aluminum alloy - 7075-T6, Plate(SS).

Tensile Load:

a) Stress:  

b) Strain:  

c) Displacement:  

d) Factor of safety:  

fig 1.26: honey structure hexagone- tensile-al-stress  

fig 1.27: honey structure hexagone- tensile -al-strain  

fig 1.28: honey structure hexagone- tensile -al-displacement  

fig 1.29: honey structure hexagone- tensile -al-factor of safety

Application of loads on the Octagonal honeycomb Structure:
Material: Aluminum alloy- 7075-T6, Plate(SS).
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Tensile Load:

- a) Stress:
- b) Strain:

![Fig. 1.30: Honey structure octagonal - tensile - Al-stress](image1)
![Fig. 1.31: Honey structure octagonal - tensile - Al-strain](image2)

- c) Displacement:
- d) Factor of safety:

![Fig. 1.32: Honey structure octagonal - tensile - Al-displacement](image3)
![Fig. 1.33: Honey structure octagonal - tensile - Al-Factor of safety](image4)

IV. ANALYSIS RESULTS

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Load (KN)</th>
<th>Material</th>
<th>Yield Strength (N/m²)</th>
<th>Structure Type</th>
<th>Max Displacement (mm)</th>
<th>Min FOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending</td>
<td>50</td>
<td>AISI 321 Annealed Stainless Steel (SS)</td>
<td>234421747.96</td>
<td>Hexagonal</td>
<td>168858320</td>
<td>5.396</td>
</tr>
<tr>
<td>Bending</td>
<td>50</td>
<td>AISI 321 Annealed Stainless Steel (SS)</td>
<td>234421747.96</td>
<td>Octagonal</td>
<td>281809056</td>
<td>9.722</td>
</tr>
<tr>
<td>Bending</td>
<td>50</td>
<td>Aluminum 7075 - T6, Plate(SS)</td>
<td>505000003.07</td>
<td>Hexagonal</td>
<td>165314112</td>
<td>14.344</td>
</tr>
<tr>
<td>Bending</td>
<td>50</td>
<td>Aluminum 7075 - T6, Plate(SS)</td>
<td>505000003.07</td>
<td>Octagonal</td>
<td>281459968</td>
<td>25.898</td>
</tr>
<tr>
<td>Bending</td>
<td>50</td>
<td>Ti-6Al-4V Solution Treated and Aged(SS)</td>
<td>827370880.00</td>
<td>Hexagonal</td>
<td>165518112</td>
<td>9.886</td>
</tr>
<tr>
<td>Bending</td>
<td>50</td>
<td>Ti-6Al-4V Solution Treated and Aged(SS)</td>
<td>827370880.00</td>
<td>Octagonal</td>
<td>281603552</td>
<td>17.838</td>
</tr>
<tr>
<td>Shear</td>
<td>400</td>
<td>AISI 321 Annealed Stainless Steel (SS)</td>
<td>234421747.96</td>
<td>Hexagonal</td>
<td>188375824</td>
<td>0.922</td>
</tr>
</tbody>
</table>
Table 1.2: results of structures for various materials and different loading conditions

Table 1.3: design properties of the structures

<table>
<thead>
<tr>
<th>Structure name</th>
<th>Structure design</th>
<th>Treated As</th>
<th>Volumetric Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexagon</td>
<td>Solid body</td>
<td>Mass: 145.509 kg</td>
<td>Volume: 0.0517826 m³, Density: 2810 kg/m³, Weight: 1425.99 N</td>
</tr>
<tr>
<td>Octagon</td>
<td>Solid body</td>
<td>Mass: 95.1561 kg</td>
<td>Volume: 0.0338634 m³, Density: 2810 kg/m³, Weight: 932.53 N</td>
</tr>
</tbody>
</table>

V. CONCLUSION

When the results are compared between Hexagonal honeycomb structure and octagonal honeycomb structure, we can observe that both the structures have equal strength in respective materials. But in some areas, Octagonal structure has efficient performance than Hexagonal structure. Main usage of this honeycomb structures are to reduce the weight and maintain the strength. According to weight ratio (Table 1.3) Octagonal honeycomb structure weight is less than hexagonal structure, and also the loading strength is equal as much as hexagon structure. So according to this analysis, we can prefer Octagonal honeycomb structure in manufacturing of Airplane and Aerospace technology to reduce the weight.
REFERENCES