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

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Abstract:*The demands for automotive interior and exterior panels in present and future request is an optimal combination of materials and cost-efficient production processes. Mechanical andacoustical requirementsof high strength and a weight target result, todayoften in the selection of a sandwich design with a cost efficient and recyclable core material. Honey comb sandwich structures are used in Airplane wings, Ships, Cars, Civil Constructions, etc. Now a days 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 honey comb structures are to be analysed and compared for the best result in structure. The structures are to be developed by using SolidWorks[1] 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, Aluminum, and Stainless steelto 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 low 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.

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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 that change of present technology. The octagonal honeycomb core is designed with different materials of Aluminum, 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.

SrinivasAthreya, 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 experimentations as compared to that of full factorial analysis and yields similar results.
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 otherin 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:

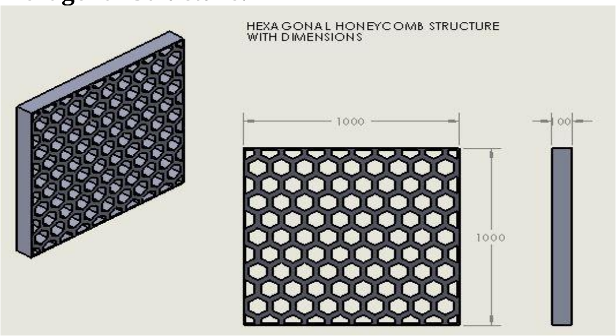

Fig 1.1: Hexagonal honeycomb structure design

b)Octagonal Structure:

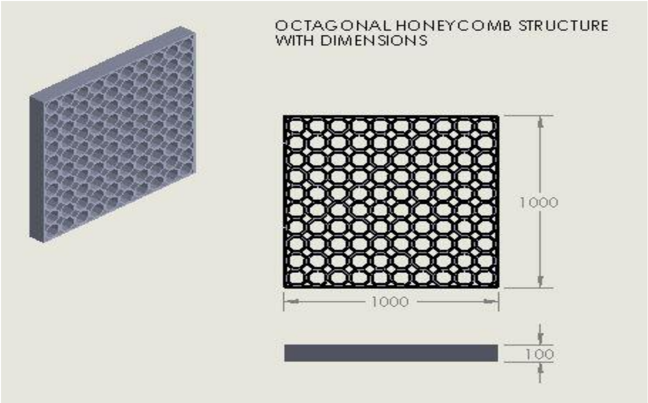

Fig 1.2: Octagonal honeycomb structure design

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-Ti6AI-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 1.1: Properties of the Materials

	Aluminum Alloy	Stainless Steel Alloy	Titanium Alloy
Material Name	7075-T6, Plate (SS)	AISI 321 Annealed Stainless Steel (SS)	Ti-6Al-4VSolution treated and aged (SS)
Model type:	LEC (Linear Elastic Isotropic))	LEI	LEI
Default failure criterion:	Max von Mises Stress	Max von Mises Stress	Max von Mises Stress
Yield strength:	5.06e+008 N/m^2	2.34421e+008 N/m^2	8.27372e+008 N/m^2
Tensile strength:	5.7e+008 N/m^2	6.2e+008 N/m^2	1.05e+009 N/m^2
Elastic modulus:	7.2e+010 N/m^2	1.93e+011 N/m^2	1.048e+011 N/m^2
Poisson's ratio:	0.33	0.27	0.31
Mass density:	2810 kg/m^3	8000 kg/m^3	4428.78 kg/m^3
Shear modulus:	2.69e+010 N/m^2	-	4.10238e+010 N/m^2
Thermal expansioncoefficient	2.4e-005 /Kelvin	1.7e-005 /Kelvin	9e-006 /Kelvin

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).

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Bending moment:

a)Stress

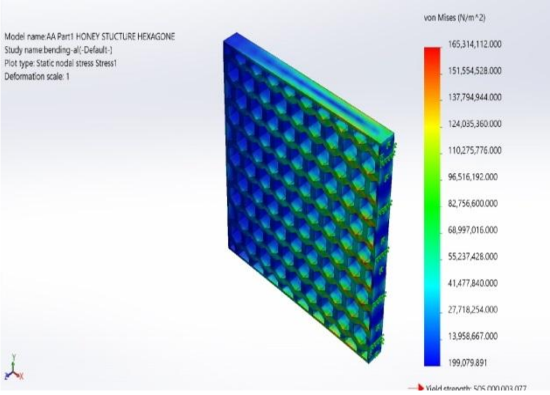


fig1.3: honey stucture hexagone-bending-al-stress

b)Strain:

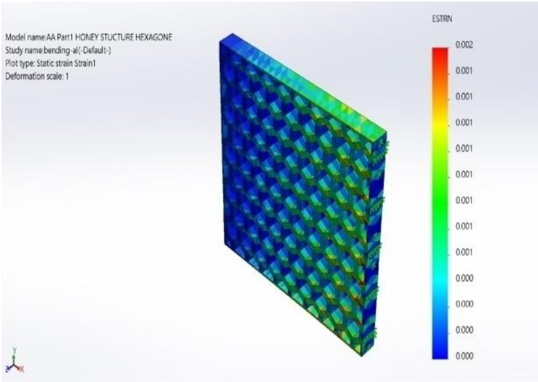


fig1.4: honey stucture hexagone-bending-al-strain

c)Displacement:

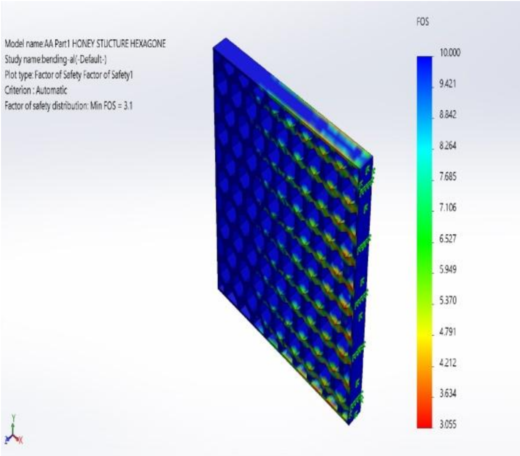


fig1.5: honey stucture hexagone-bending displacement

d)Factor of safety:

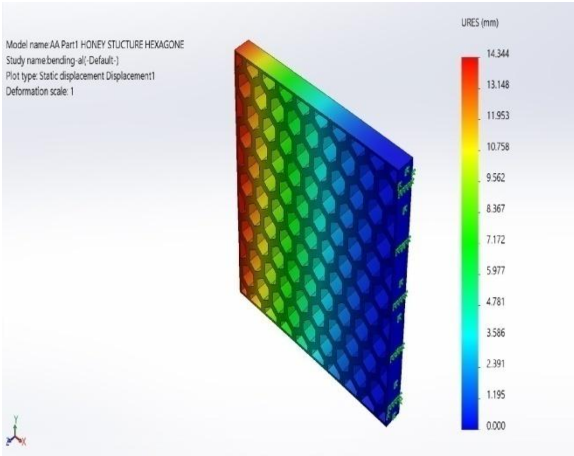


fig1.6: honey stucture hexagone-bending-al-factor of safety

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

a)Stress:

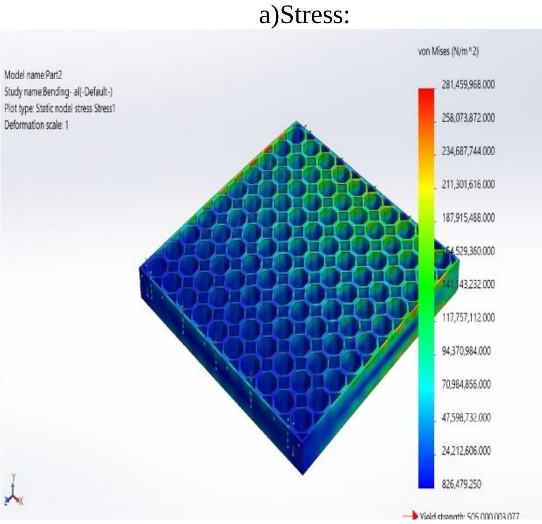


Fig1.7: honey stucture octagone-bending-Al-Stress

b)Strain:

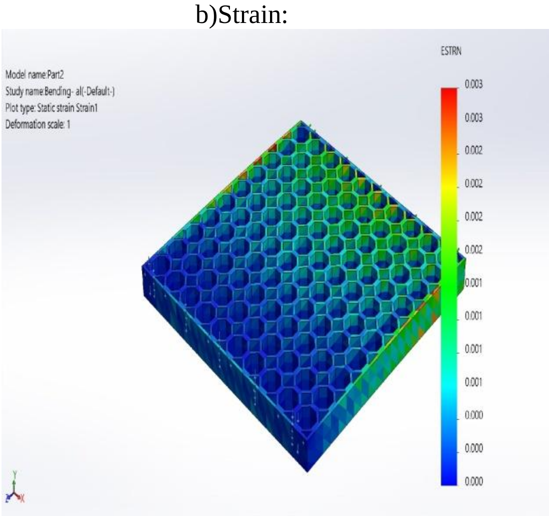
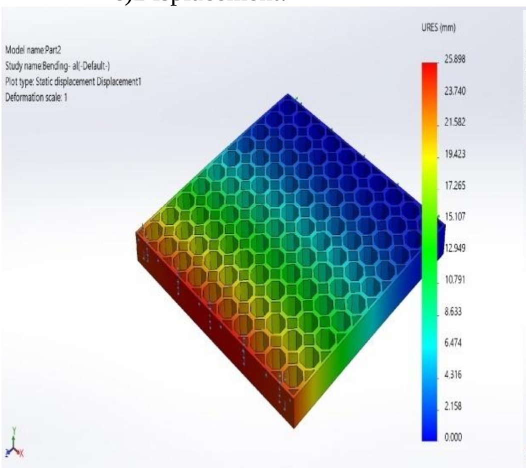


Fig1.8: honey stucture octagone-bending-al-strain-

c)Displacement:



d)Factor of safety:

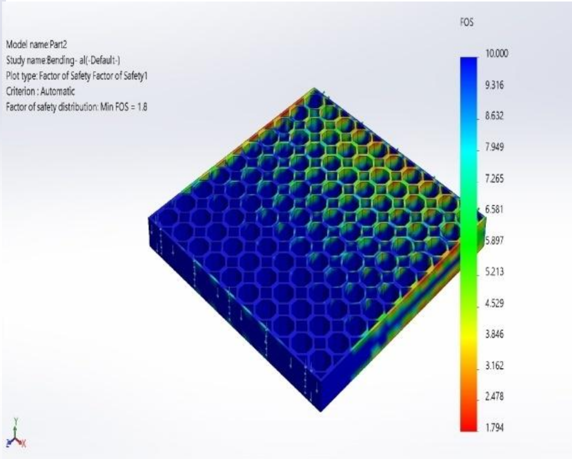
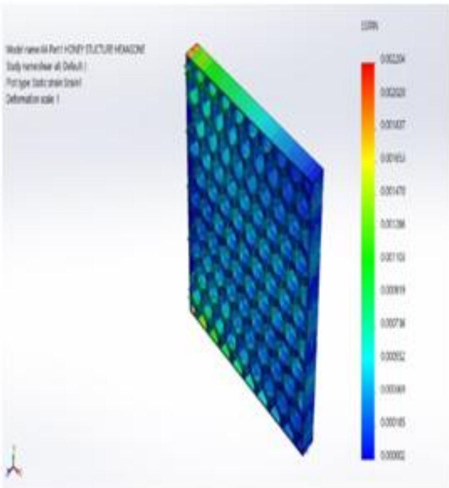


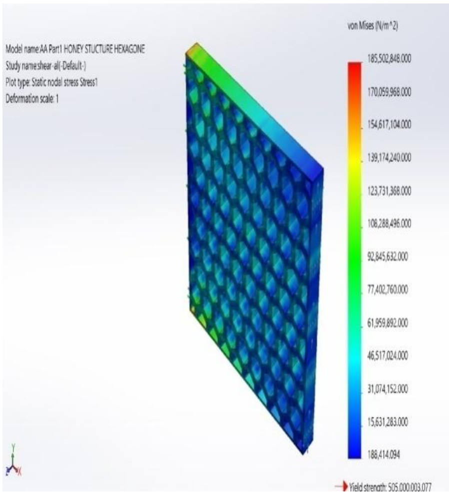
fig1.8: honey stucture Octagone-bending-al-displacement **fig1.9: honey stucture Octagone- bendingfactor of safety**

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

a)Stress:



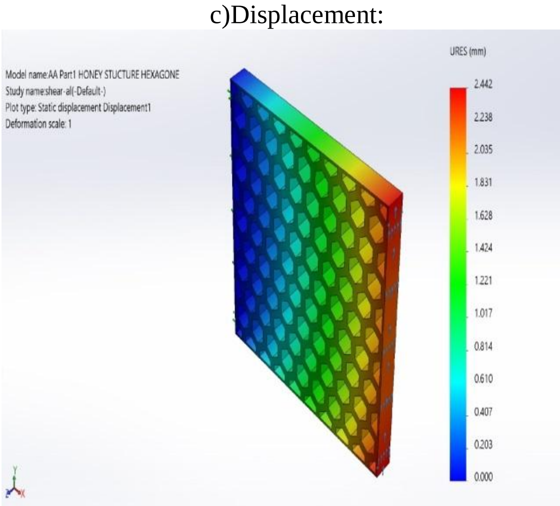
b)Strain



:

fig1.10: honey stucture hexagone- shear -al-stress **fig1.11: honey stucture hexagone- shear -al-strain**

c)Displacement:



d)Factor of safety:

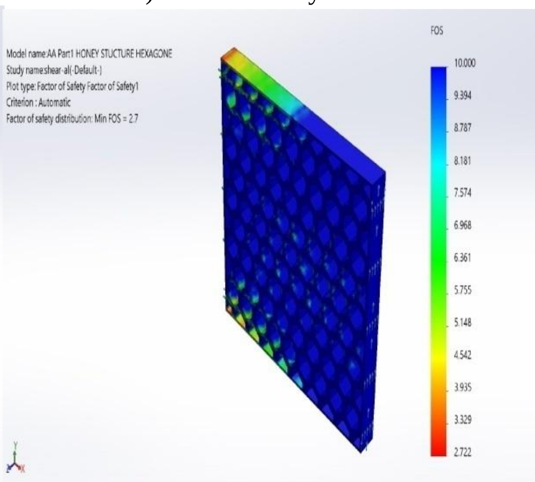


fig1.12: fig1.8: honey stucture hexagone-shearal-displacement **fig1.9: honey stucture hexagoneshear-Al-factor of safety -**

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

a)Stress:

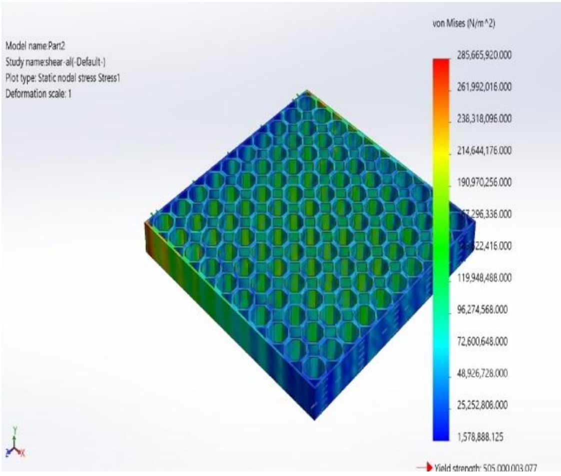


Fig1.14: honey stucture octagone-shear-al-stress

b)Strain:

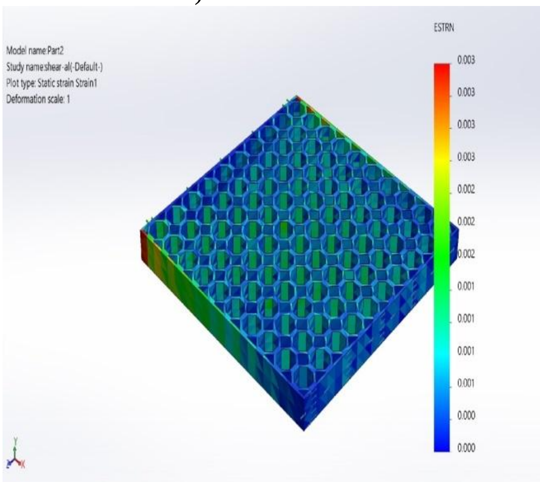


fig1.15: honey stucture octagone-shear-al-strain

c)Displacement:

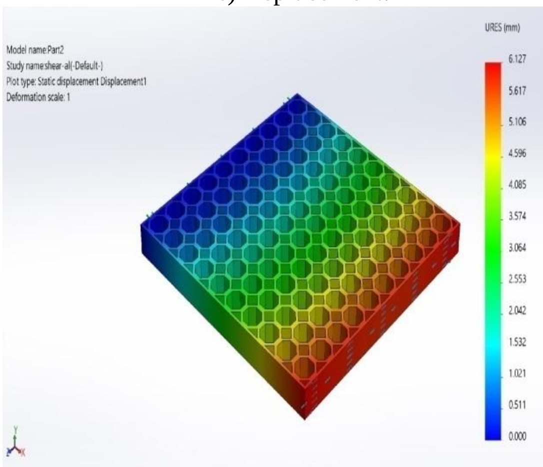


fig1.16: honey stucture Octagone-shear -al-dispalcement

d)Factor of safety:

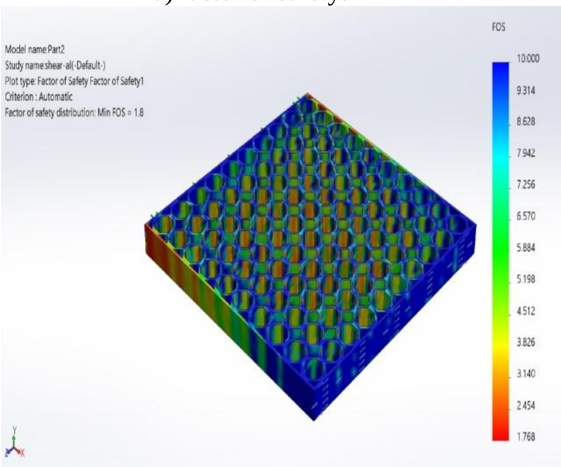


fig1.17: honey stucture Octagone-shear-al-Factor of safety

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

a)Stress:

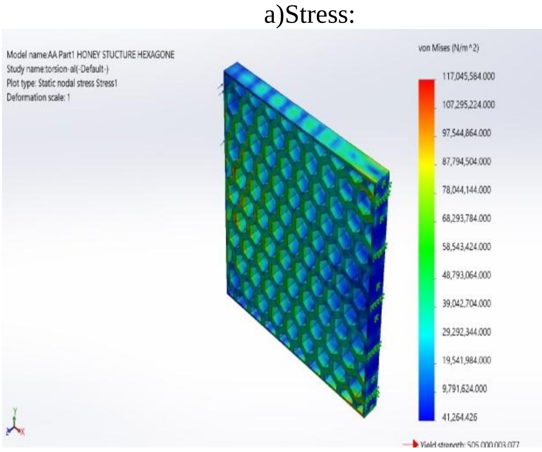


fig1.18: honey stucture hexagone-torsion-al-stress

b)Strain:

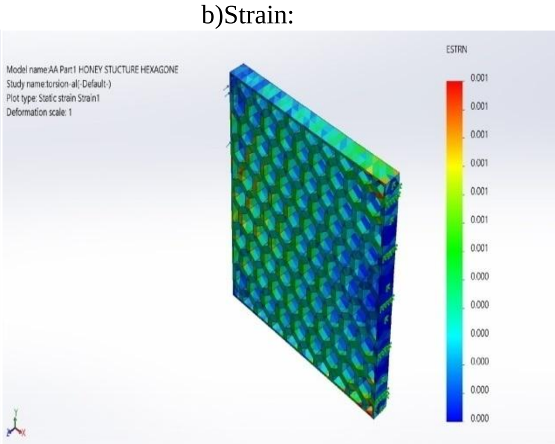
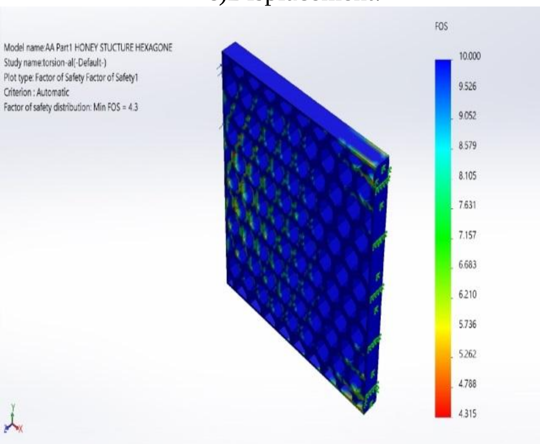


fig1.19: honey stucture hexagone-torsion-al-Strain

c)Displacement: d)Factorof safety



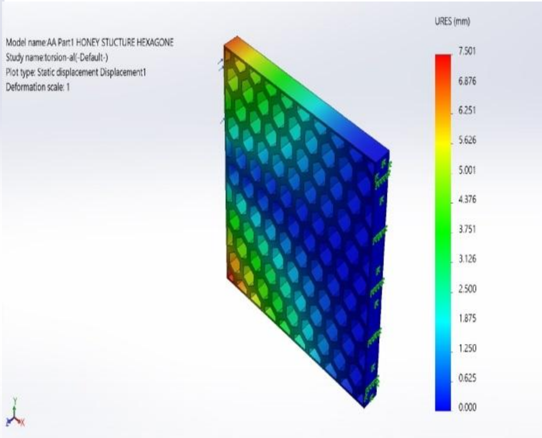


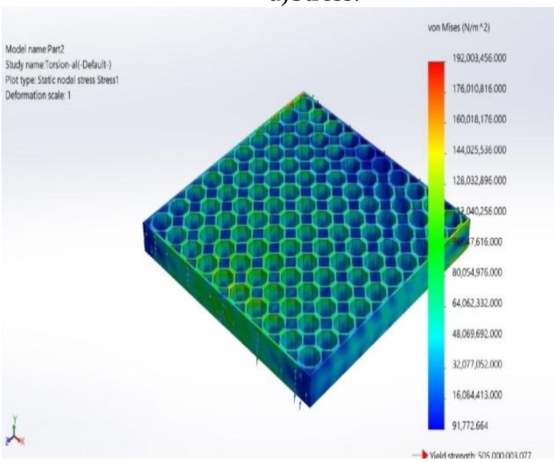
fig1.20: honey stucture hexagone- torsion -al-displacement fig1.21: honey stucture hexagone- torsion -al-factor of safety

Application of loads on the Octagonal honeycomb Structure:

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

Torsion Load:

a)Stress: b)Strain:



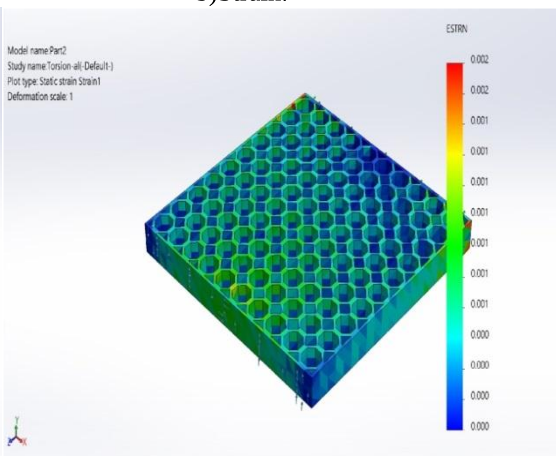
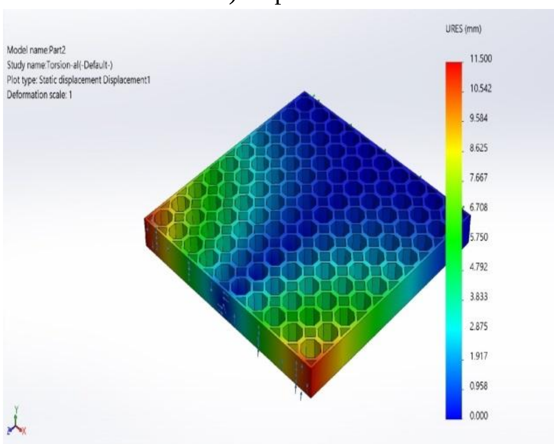


fig1.22: honey stucture octagone- torsion -al-stress fig1.23: honey stucture octagone - torsion -al-strain

c)Displacement: d)Factor of safety:



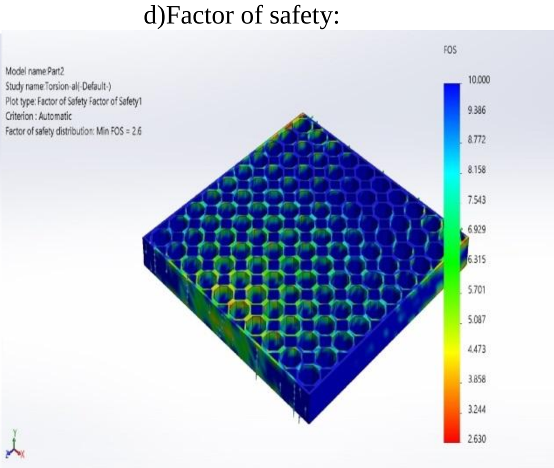


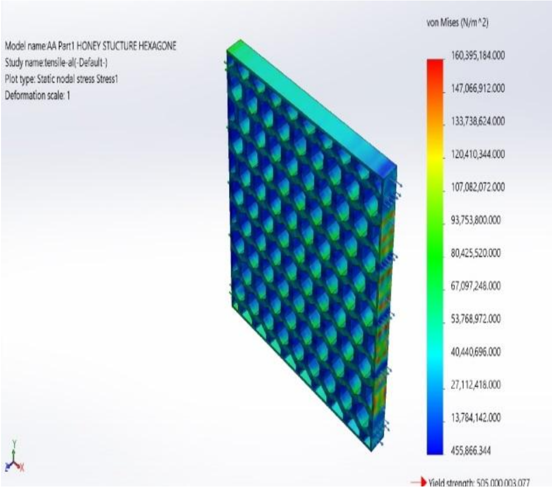
Fig1.24: honey stucture octagone - torsion -al-displacement fig1.25: honey stucture octagone - torsion -al-Factor of safety

Application of loads on the Hexagonal honeycomb Structure:

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

Tensile Load:

a)Stress:



b)Strain:

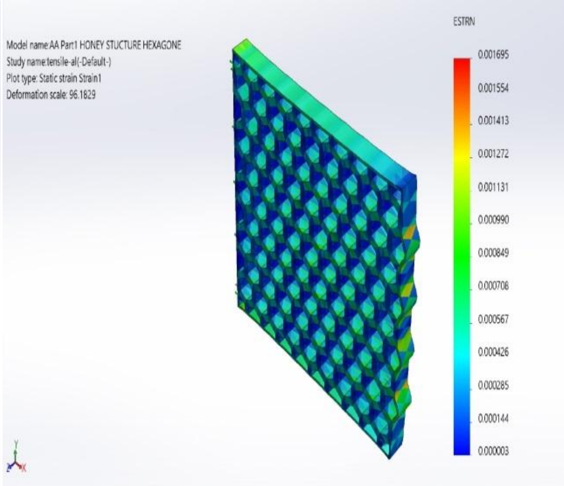
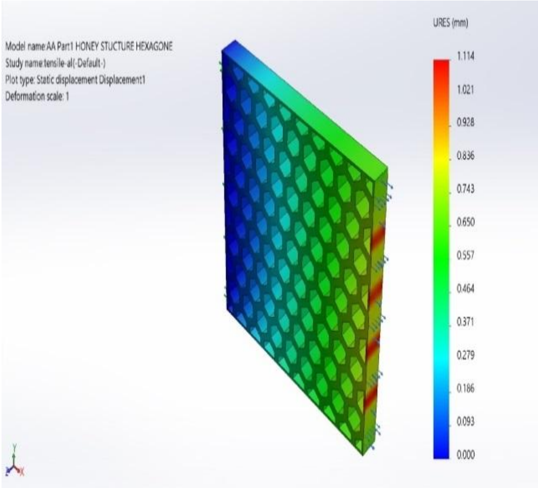


fig1.26: honey stucture hexagone-tensile-al-stress

fig1.27: honey structure hexagone- tensile -al-strain

c)Displacement:



d)Factor of safety:

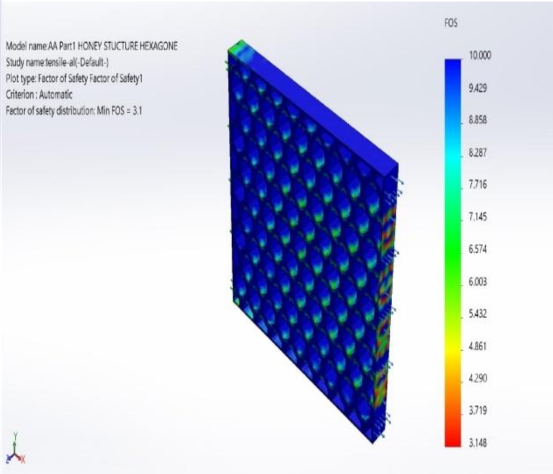


fig 1.28: honey stucture hexagone- tensile -al-displacement

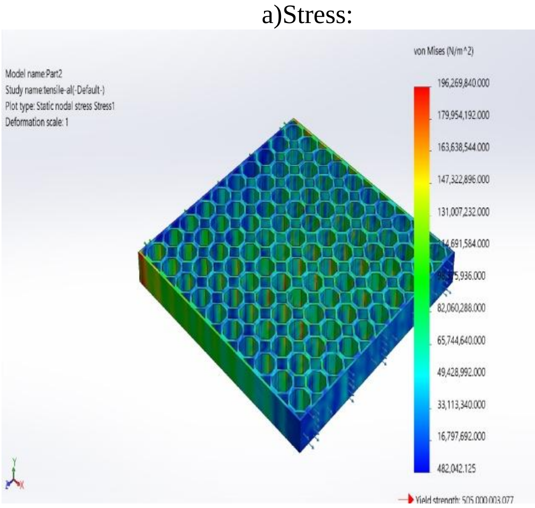
fig 1.29: honey stucture hexagone- tensile -al-factor of safety

Application of loads on the Octagonal honeycomb Structure:

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

Tensile Load:

a)Stress:



b)Strain:

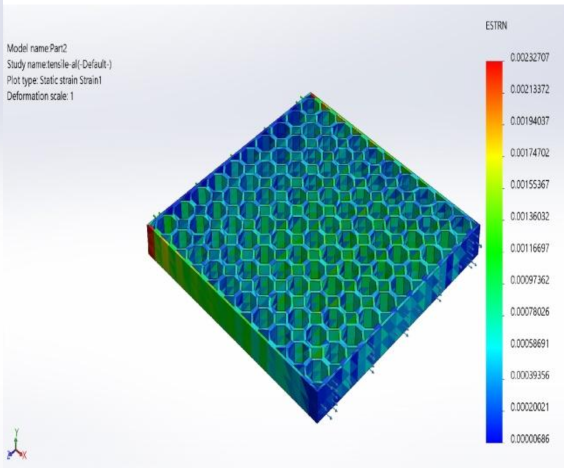


fig1.30: honey stucture octagonal - tensile -al-stress

fig1.31: honey stucture octagonal - tensile -al-strain

c)Displacement:

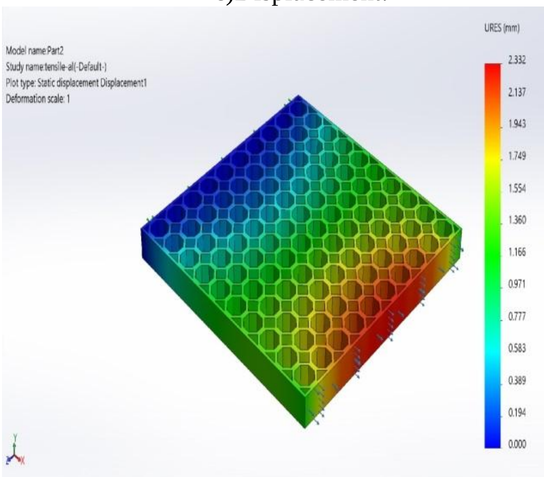


fig1.32: honey stucture octagonal - tensile -al-displacement

d)Factor of safety:

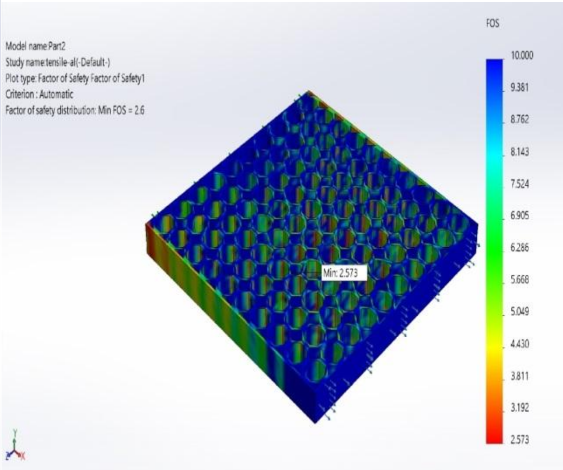


fig1.33: honey stucture octagonal - tensile -al-Factor of safety

IV. ANALYSIS RESULTS

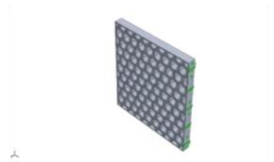
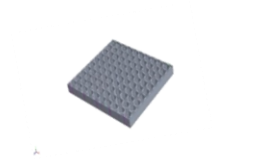
Test Type	Load (KN)	Material	Yield Strength (N/m^2)	Structure Type		Max Displacement (mm)	Min FOS
Bending	50	AISI 321 Annealed Stainless Steel (SS)	234421747.968	Hexagonal	168858320	5.396	1.413
Bending	50	AISI 321 Annealed Stainless Steel (SS)	234421747.968	Octagonal	281809056	9.722	0.832
Bending	50	Aluminum 7075 -T6, Plate(SS)	505000003.077	Hexagonal	165314112	14.344	3.055
Bending	50	Aluminum 7075 -T6, Plate(SS)	505000003.077	Octagonal	281459968	25.898	1.794
Bending	50	Ti-6Al-4V Solution Treated and Aged(SS)	827370880.000	Hexagonal	165518112	9.886	4.999
Bending	50	Ti-6Al-4V Solution Treated and Aged(SS)	827370880.000	Octagonal	281603552	17.838	2.938
Shear	400	AISI 321 Annealed Stainless Steel (SS)	234421747.968	Hexagonal	188375824	0.922	1.244
Shear	400	AISI 321 Annealed Stainless Steel (SS)	234421747.968	Octagonal	287649888	2.349	0.815
Shear	400	Aluminum 7075 -T6, Plate(SS)	505000003.077	Hexagonal	185502848	2.442	2.722
Shear	400	Aluminum 7075 -T6, Plate(SS)	505000003.077	Octagonal	285665920	6.127	1.768
Shear	400	Ti-6Al-4V Solution Treated and Aged(SS)	827370880.000	Hexagonal	186471232	1.686	4.437
Shear	400	Ti-6Al-4V Solution Treated and Aged(SS)	827370880.000	Octagonal	286293312	4.254	2.89
Tensile	1000	AISI 321 Annealed Stainless Steel (SS)	234421747.968	Hexagonal	159464752	0.423	1.47
Tensile	1000	AISI 321 Annealed Stainless Steel (SS)	234421747.968	Octagonal	195563520	0.875	1.119
Tensile	1000	Aluminum 7075 -T6, Plate(SS)	505000003.077	Hexagonal	160395184	1.114	3.148
Tensile	1000	Aluminum 7075 -T6, Plate(SS)	505000003.077	Octagonal	196269840	2.332	2.573
Tensile	1000	Ti-6Al-4V Solution Treated and Aged(SS)	827370880.000	Hexagonal	160167472	0.77	5.166
Tensile	1000	Ti-6Al-4V Solution Treated and ged(SS)	827370880.000	Octagonal	196049280	1.607	4.22

Torsion	30000N. m	AISI 321 Annealed Stainless Steel (SS)	234421747.968	Hexagonal	119671872	2.791	1.959
Torsion	30000N. m	AISI 321 Annealed Stainless Steel (SS)	234421747.968	Octagonal	193531088	4.3	1.211
Torsion	30000N. m	Aluminium 7075 - T6, Plate(SS)	505000003.077	Hexagonal	117045584	7.501	4.315
Torsion	30000N. m	Aluminium 7075 - T6, Plate(SS)	505000003.077	Octagonal	192003456	11.5	2.63
Torsion	30000N. m	Ti-6Al-4V Solution Treated and Aged(SS)	827370880.000	Hexagonal	117758552	5.152	7.026
Torsion	30000N. m	Ti-6Al-4V Solution Treated and Aged(SS)	827370880.000	Octagonal	192603168	7.914	4.296

Table 1.2: results of structures for various materials and different loading conditions

Design properties:

Table 1.3: design properties of the structures

Structure name	Structure design	Treated As	Volumetric Properties
Hexagon		Solid body	**Mass**:145.509 kg Volume:0.0517826 m^3 Density:2810 kg/m^3 Weight:1425.99 N
Octagon		Solid body	Mass:95.1561 kg Volume:0.0338634 m^3 Density:2810 kg/m^3 Weight:932.53 N

V. CONCLUSION

When the results are compared between Hexagonal honeycomb structure and octagonal honey comb structure we can observe that both the structures have equal strength in respective materials, But in some areas Octagonal structure have 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 honey comb 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.

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