# Bodyworks of a Vehicle, Design and Manufacturing

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**Abstract** - *The Monocoque (Automobile Outer body) is made up of different materials based upon the requirements. While the solid materials have more weight, they also are safer than the hollow materials. The hollow materials are lighter in weight but there would be a lot of compromises when it comes to safety. This paper deals with the design of a structure which can be used for the body works of the car which does not have much weight and also does not compromise on safety. It also shows how the studied design retains the characters of both hollow and solidified material*.

***Key Words***: Deformation, Equivalent Stress, Meshing, Static Structural, Solid structure, Hollow structure, Hybrid Structure.

## 1. INTRODUCTION

The Monocoque of an Automobile is generally made up of different materials like steel and aluminium composites. Some sports cars are replacing these materials with Carbon Fibres to reduce weight and to increase the strength of the body to absorb impacts during collision. To acquire much more safety features with less weight, designs like Honeycomb Structures, Hollow Structures and Hybrid Structures are made. These structures mainly provide high safety parameters while having less total weight in an Automobile.

### 1.1 SOFTWARES USED

For 3D Modelling, we used SOLIDWORKS 2016

For Design Simulations, we used ANSYS 18.1

### 1.2 PROCEDURE

- The 3D Modelling of the solid, hollow and hybrid structures are made using Solidworks Software.
- These models are later converted into .igs format to proceed the simulations in ANSYS 18.1 Software.
- The Simulations on these models are carried by varying the boundary conditions like Fixed Constraints, and Loads.
- Different results like Total Deformation, Stress Distribution are observed at the end of these simulations.
- The observed results are used to compare the properties of different structures made up of different materials.

## 2. DESIGN OF 3D MODELS

The 3D Models of the structures discussed in this paper are made using Solidworks Software. This paper studies about the properties of three types of structures:

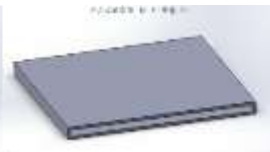
- Solid Structure
- Hollow Structure
- Hybrid Structure

And every structure is made with two different thickness values.

- 6mm
- 4mm

**Solid Structure:** The Solid Structure is a small part of car body (Monocoque) which is having dimensions of 100mm*100mm*6 mm (100mm Length, 100mm breadth, 6mm thickness) and 100mm*100mm*4 mm (100mm Length, 100mm breadth, 4mm thickness)


**Hollow Structure:** The Hollow Structure is having dimensions of 100*100*6 mm and 100*100*4 mm with a rectangular hole of dimensions 94mm*3mm (96mm Length, 3mm breadth) and 94mm* 2mm on the thickness surface respectively.

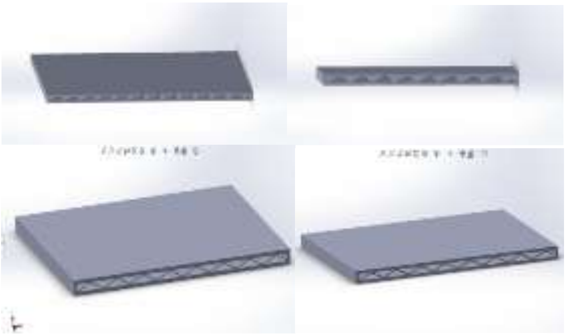



**Hybrid Structure:** These are the key structures to be studied and compared with the above two structures and are made with the dimensions of 100*100*6 mm and 100*100*4 mm with a rectangular hole of dimensions

94*3 mm and 94* 2 mm on the thickness surface respectively. These structures include a Zigzag Structural Support within the rectangular hole with different angles. The angles we used here are

- $120^0$
- $135^0$

These legs are having a thickness of 0.5mm and start from the first corner and continue till the end with the inclination angles mentioned above.



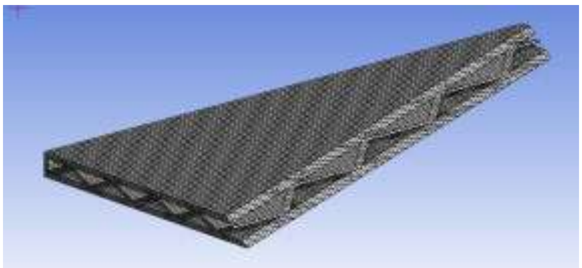
**2. Design Analysis:**

The Design Analysis for all these structures is done by applying the basic properties of two materials for better comparison of results. The two material properties used for these structures are:

- Structural Steel
- Aluminium

The properties of these materials are given to all these structures to perform the Simulations on each one of them. To run the simulations on above structures with different boundary conditions ANSYS 18.1 software is used. Static Structural Analysis Workbench is used in ANSYS 18.1 software.

**Mesh**: For this analysis the Quad type Meshing Element is used with a size of 1mm.



The entire specimen are simulated in three different ways:

1. Both Side faces fixed and applying 4 g-forces on top face.
2. One side face fixed and applying 3 g-forces on top face.
3. Both side faces fixed and applying 0.5 N (Common load) on top face.

**2.1 STRUCTURAL STEEL SIMULATIONS:**

**1) Solid Structure**

**a) 6mm Thickness**

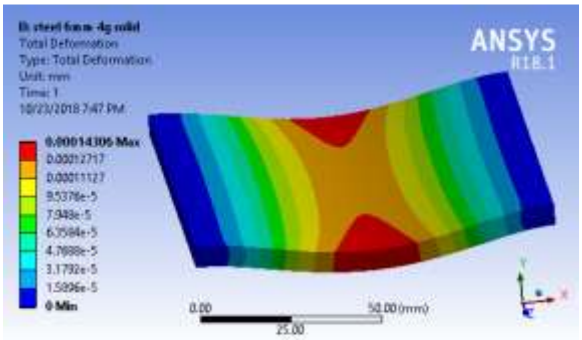
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **18.49 N**

Weight of Specimen: **0.471 kg**

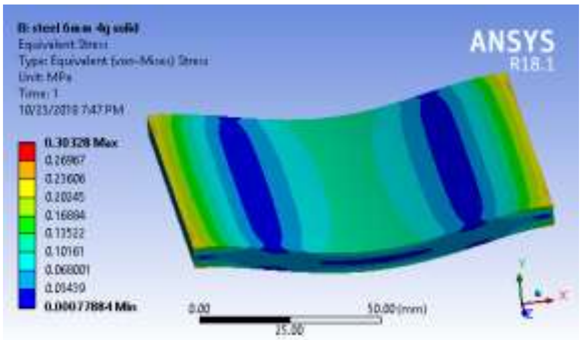
Nodes: **274013**

Elements: **60000**




Maximum Deformation: 1.43e-4 mm

Average Deformation: 8.73e-5 mm




Maximum Equivalent Stress: 0.303 MPa

Average Equivalent Stress: 0.182 MPa

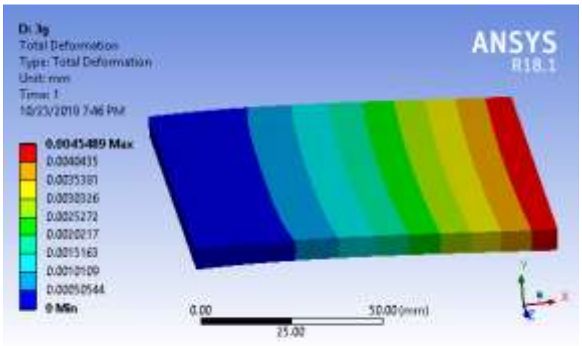
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **13.86 N**

Weight of Specimen: **0.471 kg**

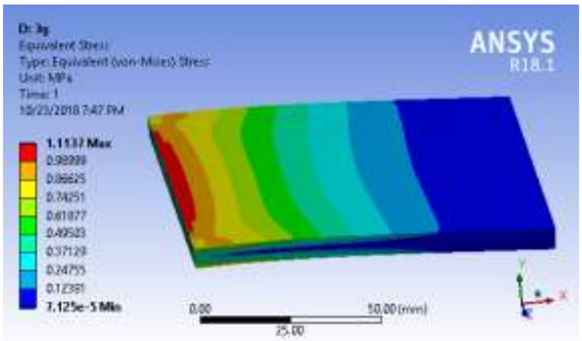
Nodes: **274013**

Elements: **60000**




Maximum Deformation: 4.54e-3 mm

Average Deformation: 2.775e-3 mm




Maximum Equivalent Stress: 1.1137 MPa

Average Equivalent Stress: 0.679 MPa

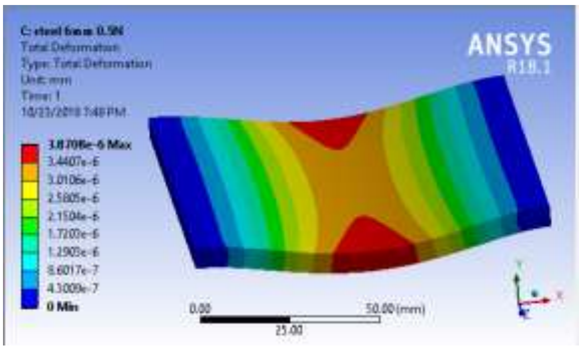
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.471 kg**

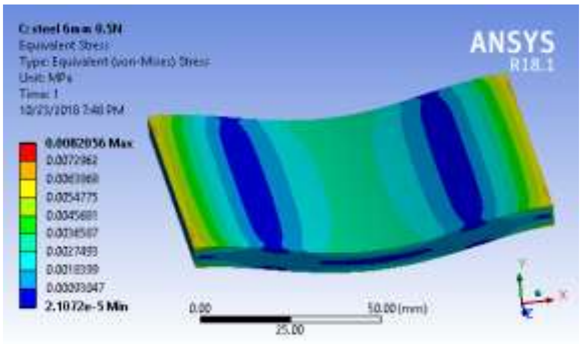
Nodes: **274013**

Elements: **60000**




Maximum Deformation: 3.87e-6 mm

Average Deformation: 2.115e-6 mm




Maximum Equivalent Stress: 8.205e-3 MPa

Average Equivalent Stress: 5.0175e-3 MPa

**b) 4mm Thickness**

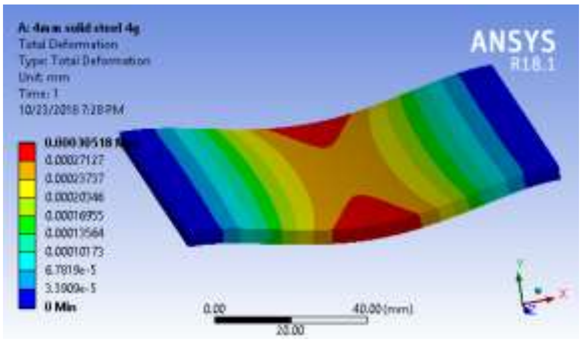
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **12 N**

Weight of Specimen: **0.314 kg**

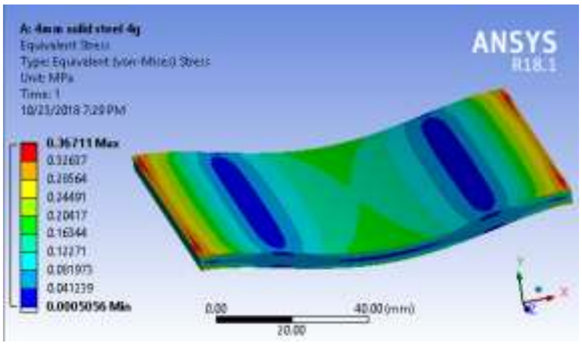
Nodes: **192809**

Elements: **40000**




Maximum Deformation: 3.051e-4 mm

Average Deformation: 2.03e-4 mm



Maximum Equivalent Stress: 0.367 MPa

Average Equivalent Stress: 0.2041 MPa

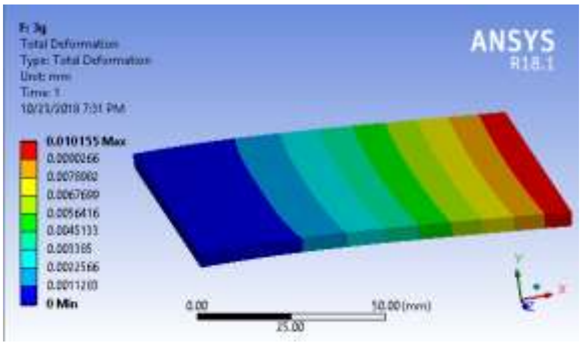
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **9.2 N**

Weight of Specimen: **0.314 kg**

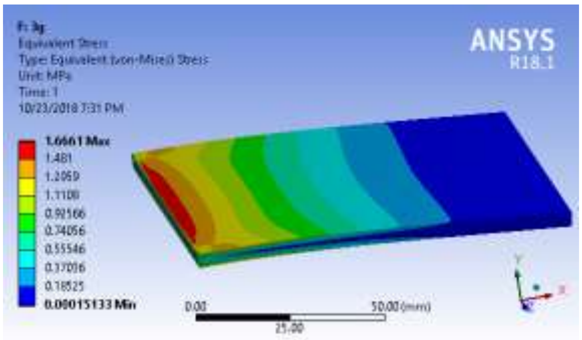
Nodes: **192809**

Elements: **40000**




Maximum Deformation: 1.015e-2 mm

Average Deformation: 6.21e-3 mm




Maximum Equivalent Stress: 1.661 MPa

Average Equivalent Stress: 0.924 MPa

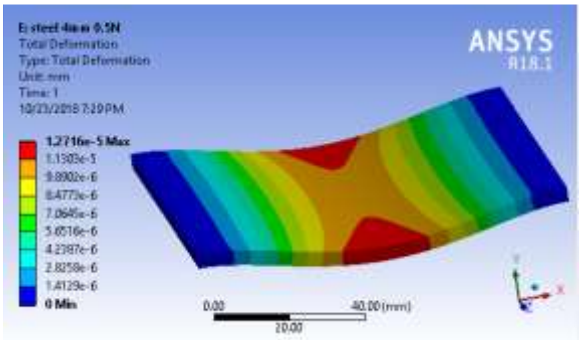
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.314 kg**

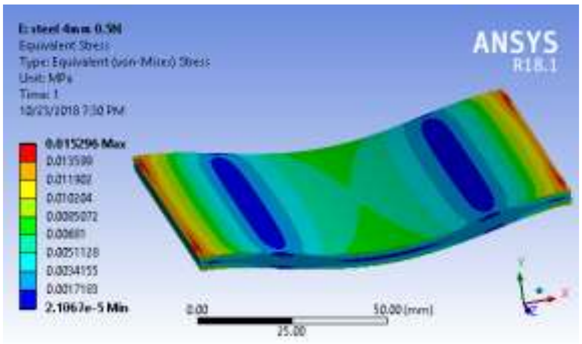
Nodes: **192809**

Elements: **40000**




Maximum Deformation: 1.27e-5 mm

Average Deformation: 7.76e-6 mm




Maximum Equivalent Stress: 1.52e-2 MPa

Average Equivalent Stress: 9.32e-3 MPa

**2) Hollow Structure**

**a) 6mm Thickness**

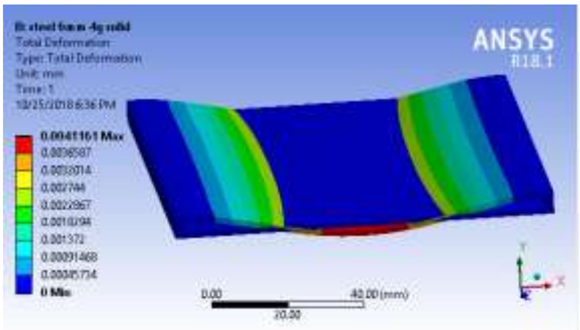
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **9.61 N**

Weight of Specimen: **0.24492kg**

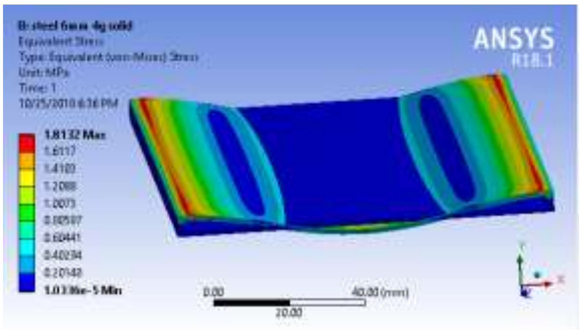
Nodes: **226838**

Elements: **41000**




Maximum Deformation: 4.116e-2 mm

Average Deformation: 2.508e-2 mm




Maximum Equivalent Stress:1.812 MPa

Average Equivalent Stress: 1.021 MPa

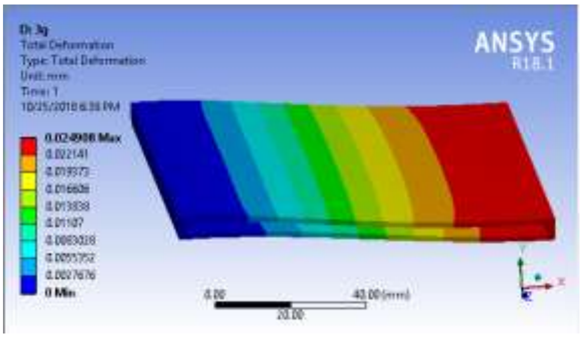
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **7.207 N**

Weight of Specimen: **0.24492 kg**

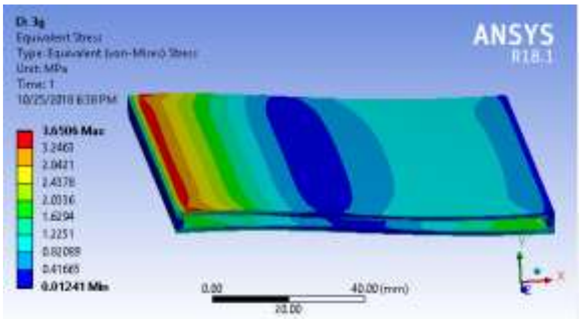
Nodes: **226838**

Elements: **41000**




Maximum Deformation: 2.49e-2 mm

Average Deformation: 1.38e-2 mm




Maximum Equivalent Stress: 3.65 MPa

Average Equivalent Stress: 2.225 MPa

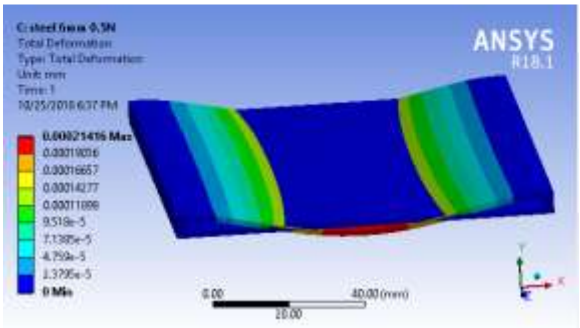
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.24492 kg**

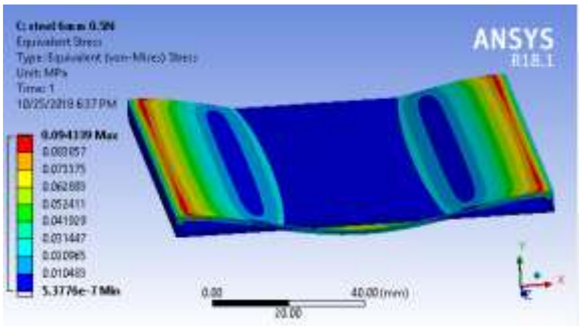
Nodes: **226838**

Elements: **41000**




Maximum Deformation: 2.14e-4 mm

Average Deformation: 1.3-7e-4 mm




Maximum Equivalent Stress: 9.43e-2 MPa

Average Equivalent Stress: 4.819e-2 MPa

**b) 4mm Thickness**

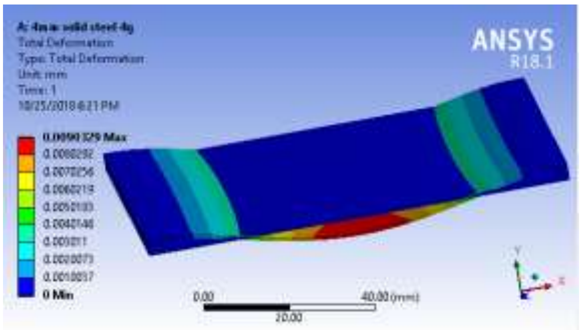
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **6.407 N**

Weight of Specimen: **0.16328 kg**

Nodes: **144828**

Elements: **20800**



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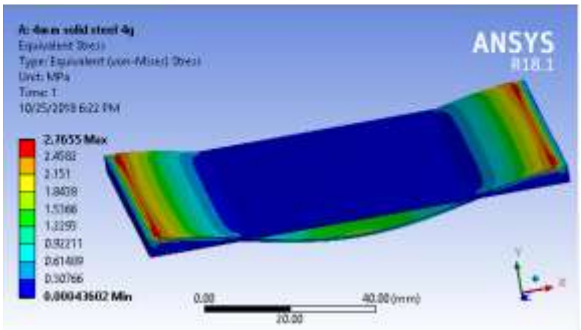
Maximum Deformation: 9.03e-3 mm

Average Deformation: 5.51e-3 mm




Maximum Equivalent Stress: 2.76 MPa

Average Equivalent Stress: 1.689 MPa

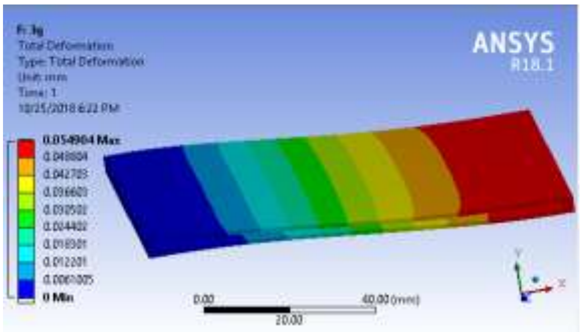
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **4.805 N**

Weight of Specimen: **0.16328 kg**

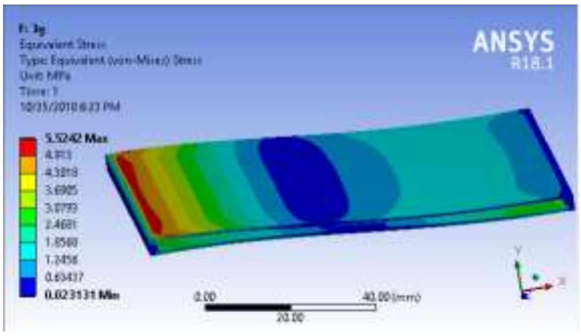
Nodes: **144828**

Elements: **20800**




Maximum Deformation: 5.42e-2 mm

Average Deformation: 3.31e-2 mm




Maximum Equivalent Stress: 5.52 MPa

Average Equivalent Stress: 3.075 MPAa

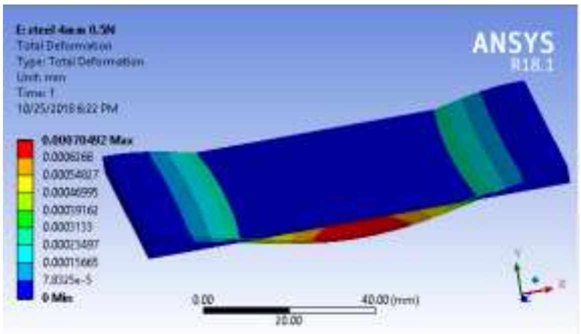
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.16328 kg**

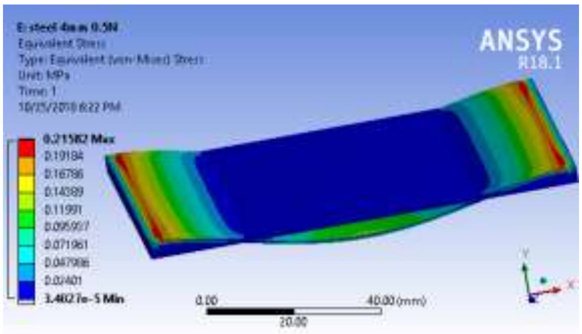
Nodes: **144828**

Elements: **20800**




Maximum Deformation: 7.04e-4 mm

Average Deformation: 4.32e-4 mm




Maximum Equivalent Stress: 0.218 MPa

Average Equivalent Stress: 0.1326 MPa

### 3) Hybrid Structure(120$^0$)

#### a) 6mm Thickness

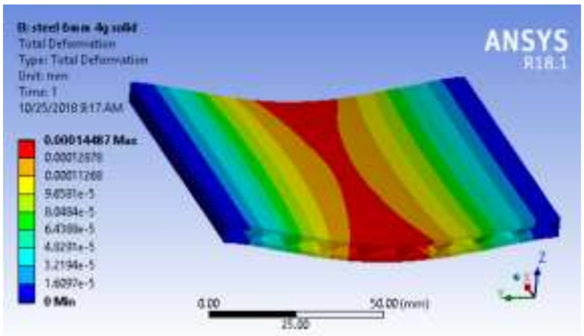
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **10.3 N**

Weight of Specimen: **0.26258 kg**

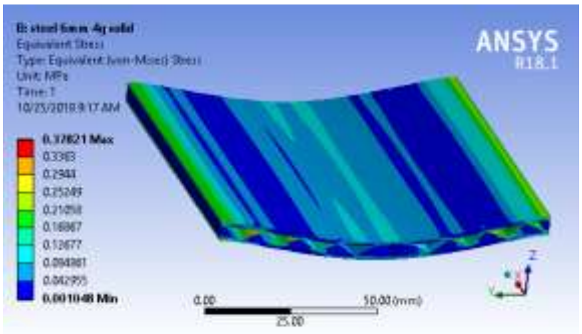
Nodes: **394042**

Elements: **68500**




Maximum Deformation: 1.4e-4 mm

Average Deformation: 9.6e-5 mm




Maximum Equivalent Stress: 0.318 MPa

Average Equivalent Stress: 0.201 MPa

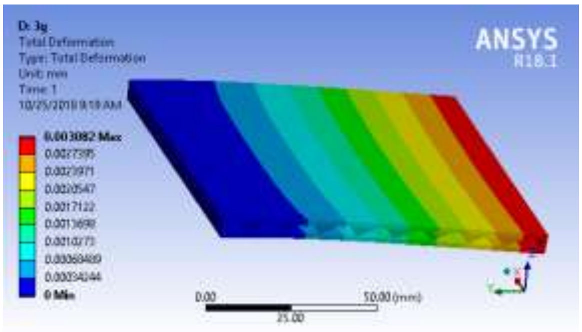
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **7.72 N**

Weight of Specimen: **0.26258 kg**

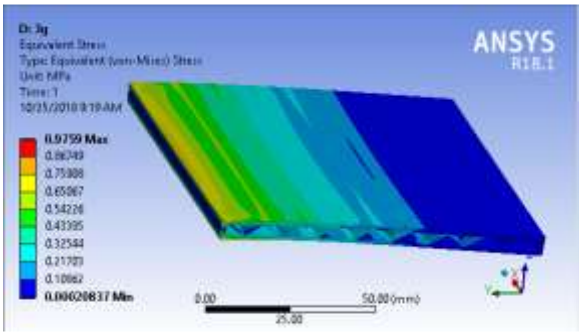
Nodes: **394042**

Elements: **68500**




Maximum Deformation: 3.08e-3 mm

Average Deformation: 2.012e-3 mm




Maximum Equivalent Stress: 0.975 MPa

Average Equivalent Stress: 0.596 MPa

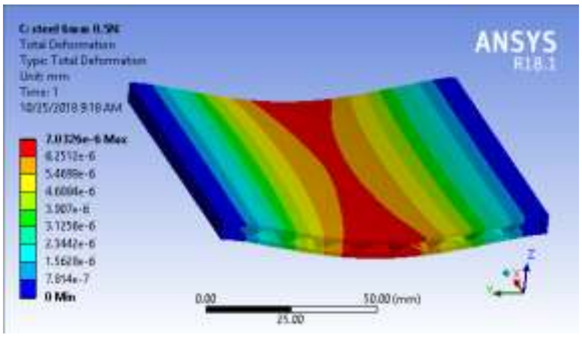
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.26258 kg**

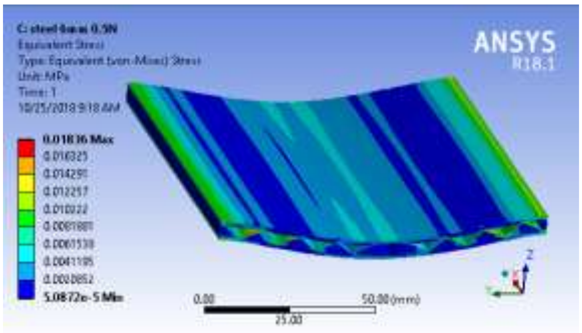
Nodes: **394042**

Elements: **68500**




Maximum Deformation: 7.03e-6 mm

Average Deformation: 4.3e-6 mm




Maximum Equivalent Stress: 1.8e-2 MPa

Average Equivalent Stress: 1.1e-2 MPa

**b) 4mm Thickness**

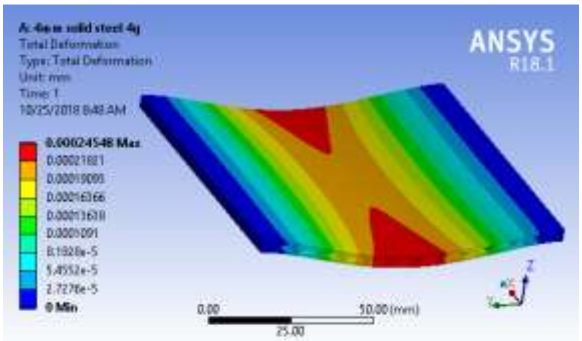
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **7.04 N**

Weight of Specimen: **0.17957 kg**

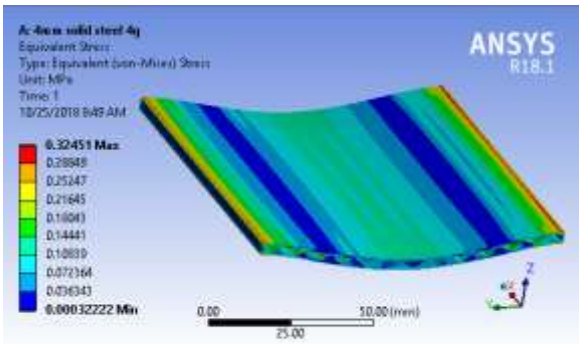
Nodes: **394345**

Elements: **68000**




Maximum Deformation: 2.4e-4 mm

Average Deformation: 1.47e-4 mm




Maximum Equivalent Stress: 0.32 MPa

Average Equivalent Stress: 0.196 MPa

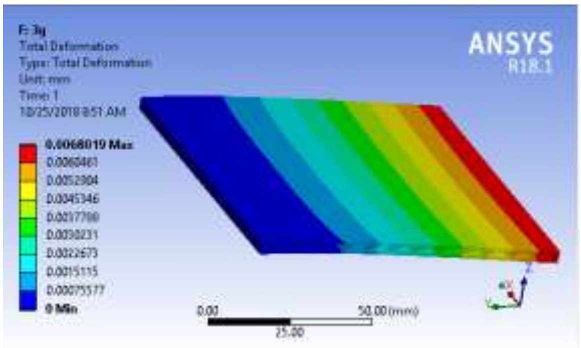
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **5.28 N**

Weight of Specimen: **0.17957**

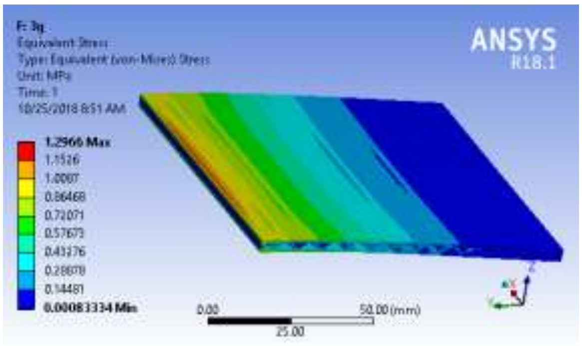
Nodes: **394345**

Elements: **68000**




Maximum Deformation:6.8e-3 mm

Average Deformation: 4.53e-3 mm




Maximum Equivalent Stress: 1.296 MPa

Average Equivalent Stress: 0.72 MPa

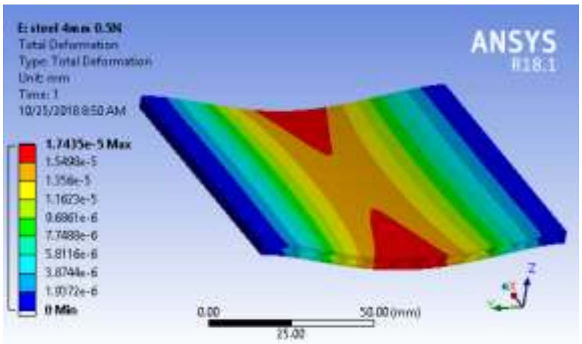
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.17957 kg**

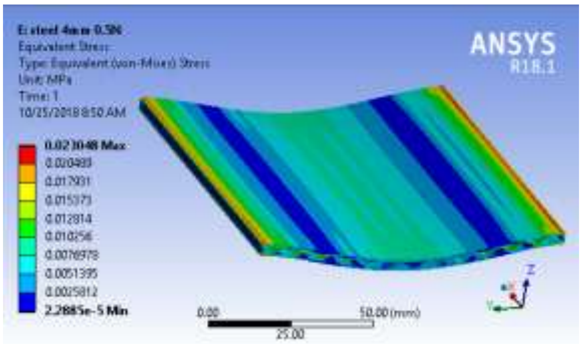
Nodes: **394345**

Elements: **68000**




Maximum Deformation: 1.74e-5 mm

Average Deformation: 1.06e-5 mm




Maximum Equivalent Stress: 2.3e-2 MPa

Average Equivalent Stress: 1.405e-2 MPa

**4) Hybrid Structure(135$^0$)**

**a) 6mm Thickness**

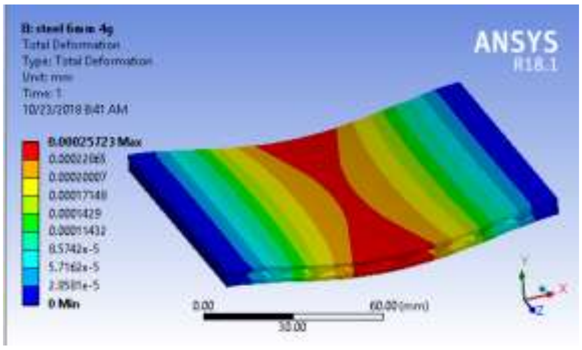
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **13 N**

Weight of Specimen: **0.33147 kg**

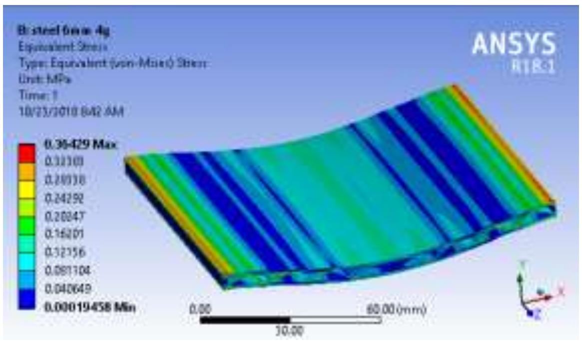
Nodes: **489831**

Elements: **85100**




Maximum Deformation: 2.573e-4 mm

Average Deformation: 1.30e-4 mm




Maximum Equivalent Stress: 0.3642 MPa

Average Equivalent Stress: 0.2024 MPa

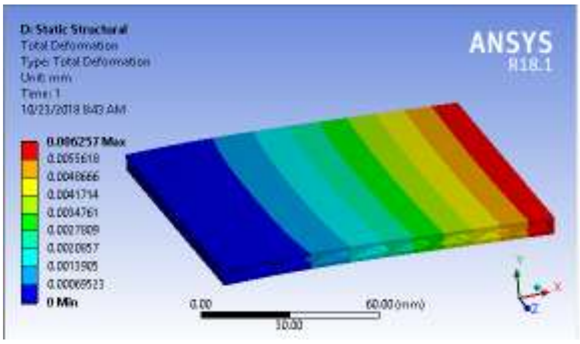
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **9.75 N**

Weight of Specimen: **0.33147 kg**

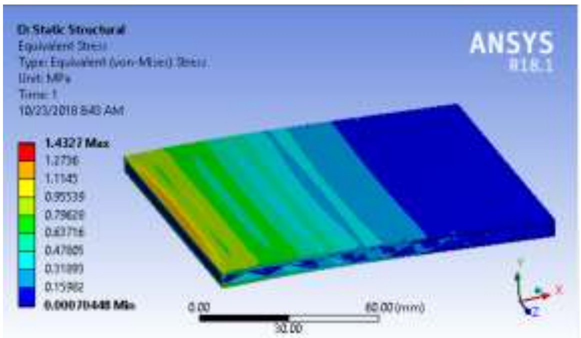
Nodes: **489831**

Elements: **85100**




Maximum Deformation: 6.257e-3 mm

Average Deformation: 3.823e-3 mm




Maximum Equivalent Stress: 1.4327 MPa

Average Equivalent Stress: 0.7322 MPa

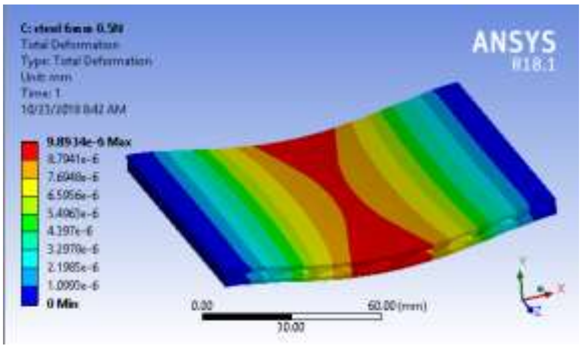
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.33147 kg**

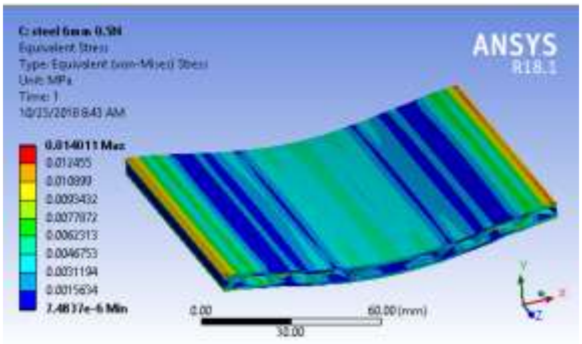
Nodes: **489831**

Elements: **85100**




Maximum Deformation: 9.893e-6 mm

Average Deformation: 6.044e-6 mm




Maximum Equivalent Stress: 1.401e-2 MPa

Average Equivalent Stress: 8.566e-3 MPa

**b) 4mm Thickness**

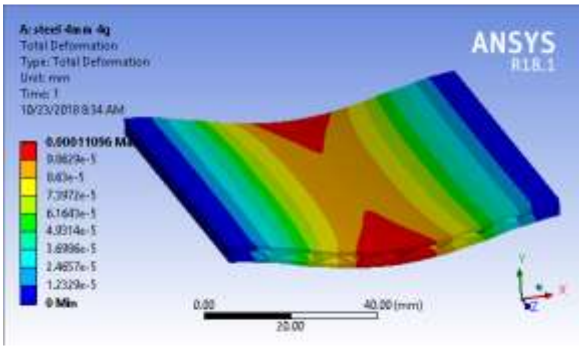
**i)** Both Sides faces fixed and applying 4 g-forces on top face.

Load Applied: **6.15 N**

Weight of Specimen: **0.1569 kg**

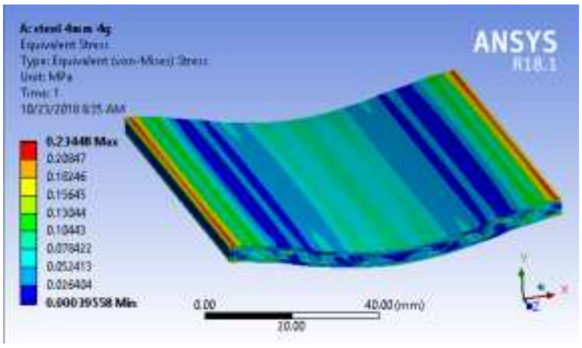
Nodes: **303888**

Elements: **51400**




Maximum Deformation: 1.1096e-4 mm

Average Deformation: 6.7808e-5 mm




Maximum Equivalent Stress: 0.234 MPa

Average Equivalent Stress: 0.123 MPa

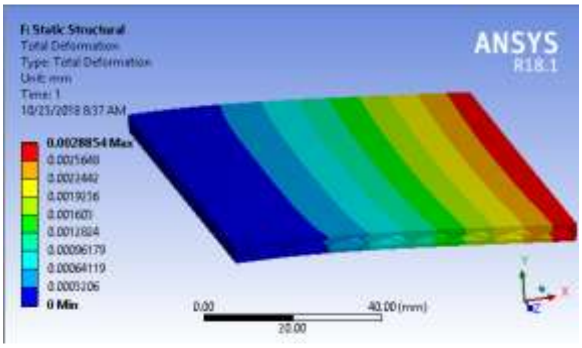
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **4.61 N**

Weight of Specimen: **0.1569 kg**

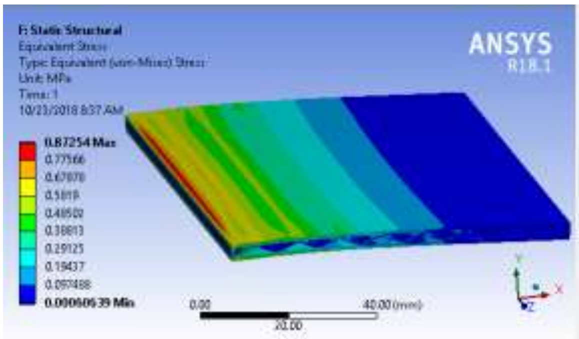
Nodes: **303888**

Elements: **51400**




Maximum Deformation: 2.885e-3 mm

Average Deformation: 1.653e-3 mm




Maximum Equivalent Stress: 0.8725 MPa

Average Equivalent Stress: 0.5334 MPa

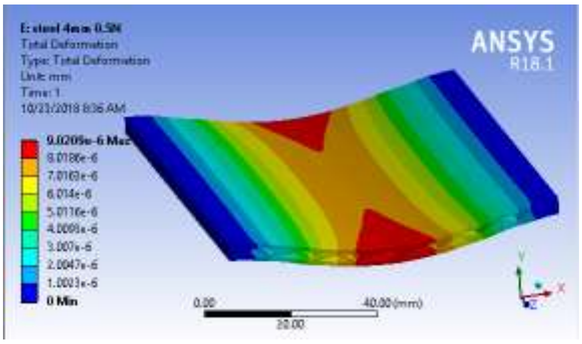
**iii)** Both Sides faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.1569 kg**

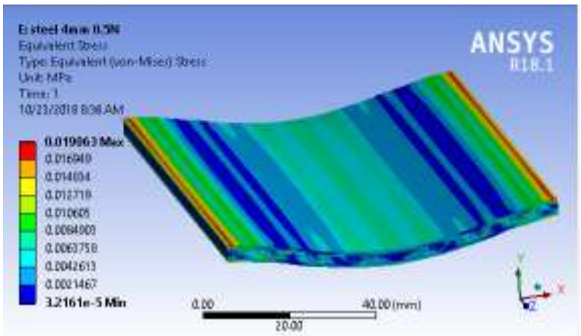
Nodes: **303888**

Elements: **51400**




Maximum Deformation: 9.0209e-6 mm

Average Deformation: 5.253e-6 mm




Maximum Equivalent Stress: 1.906e-2 MPa

Average Equivalent Stress: 1.0662e-2 MPa

**2.2 ALUMINIUM SIMULATIONS:**

**5) Solid Structure**

**a) 6mm Thickness**

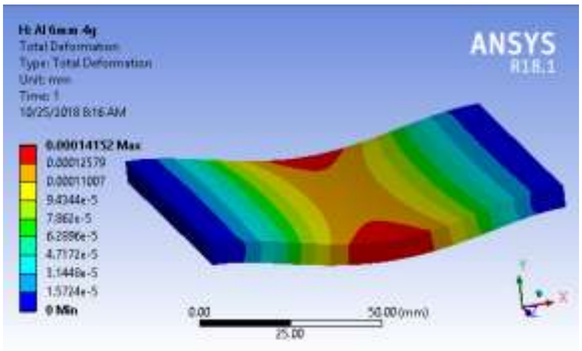
**i)** Both Sides faces fixed and applying 4 g-forces on top face.

Load Applied: **6.51 N**

Weight of Specimen: **0.1662 kg**

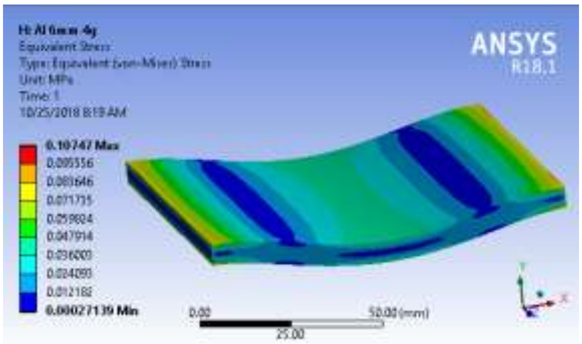
Nodes: **274013**

Elements: **60000**




Maximum Deformation: 1.41e-4 mm

Average Deformation: 8.62e-5 mm




Maximum Equivalent Stress: 0.107 MPa

Average Equivalent Stress: 6.55e-2 MPa

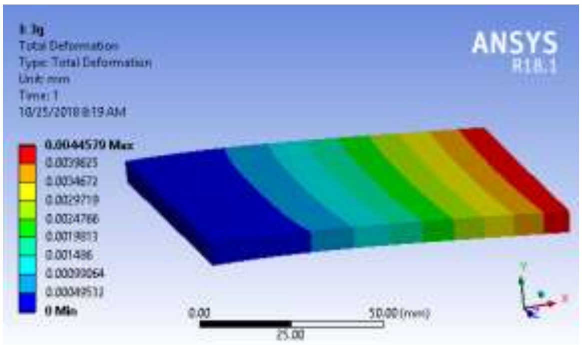
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **4.89 N**

Weight of Specimen: **0.1662 kg**

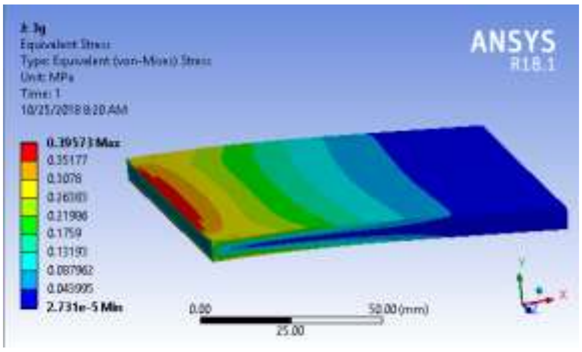
Nodes: **274013**

Elements: **60000**




Maximum Deformation: 4.45e-3 mm

Average Deformation: 2.92e-3mm




Maximum Equivalent Stress: 0.395 MPa

Average Equivalent Stress: 0.241 MPa

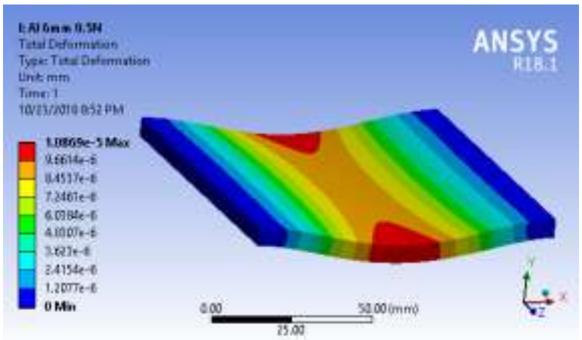
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.1662 kg**

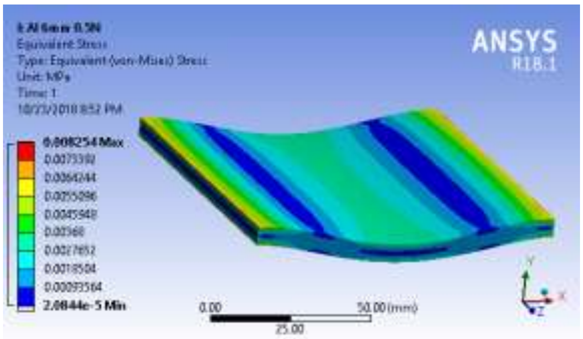
Nodes: **274013**

Elements: **60000**




Maximum Deformation: 1.086e-5 mm

Average Deformation: 6.03e-6 mm




Maximum Equivalent Stress: 8.25e-3 MPa

Average Equivalent Stress: 5.05e-3 MPa

**b) 4mm Thickness**

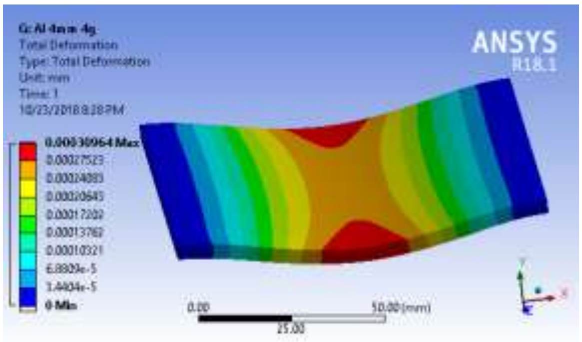
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **4.34 N**

Weight of Specimen: **0.1108 kg**

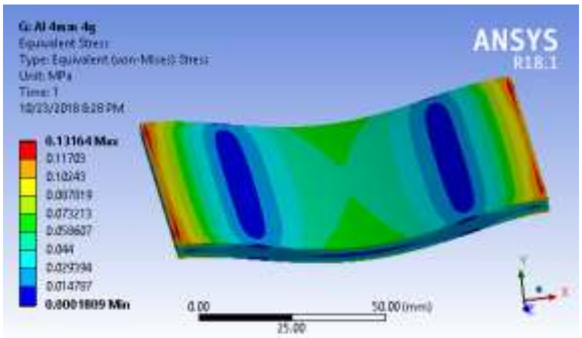
Nodes: **192809**

Elements: **40000**




Maximum Deformation: 3.096e-4 mm

Average Deformation: 1.885e-4 mm




Maximum Equivalent Stress: 0.131MPa

Average Equivalent Stress: 8.7e-2 MPa

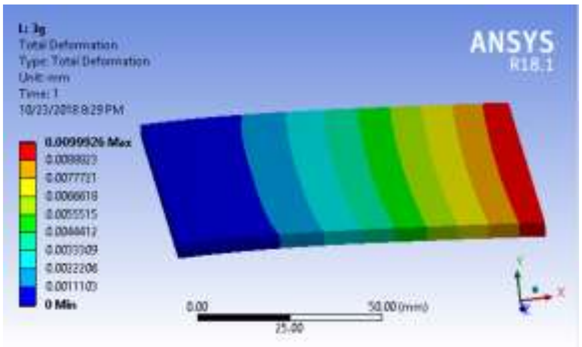
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **3.26 N**

Weight of Specimen: **0.1108 kg**

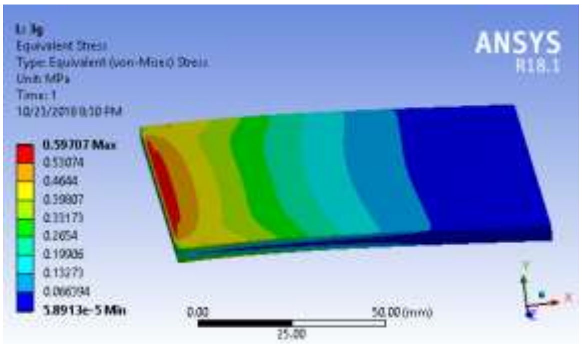
Nodes: **192809**

Elements: **40000**




Maximum Deformation: 9.99e-3 mm

Average Deformation: 6.1e-3 mm




Maximum Equivalent Stress: 0.597 MPa

Average Equivalent Stress: 0.3635 MPa

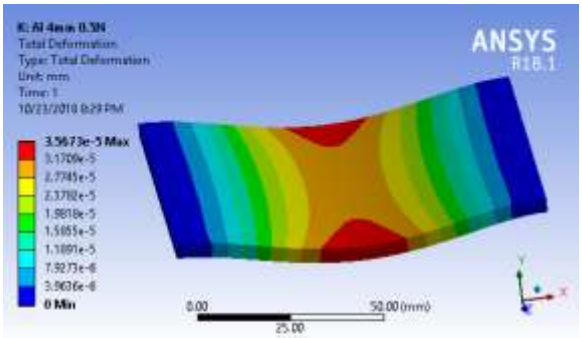
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.1108 kg**

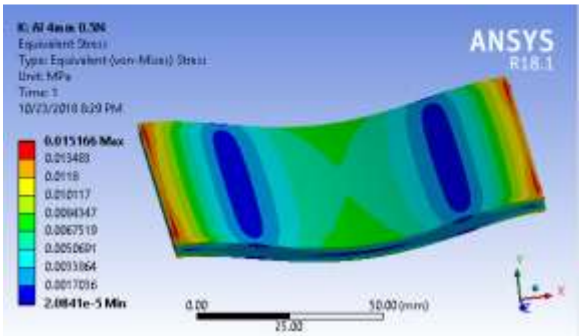
Nodes: **192809**

Elements: **40000**




Maximum Deformation: 3.56e-5 mm

Average Deformation: 1.9e-5 mm




Maximum Equivalent Stress: 1.51e-2 MPa

Average Equivalent Stress: 9e-3 MPa

**6) Hollow Structure**

**a) 6mm Thickness**

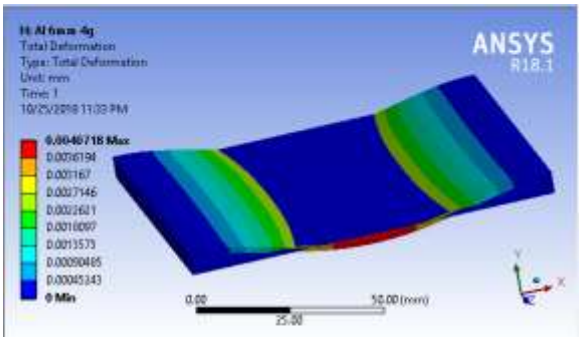
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **3.39 N**

Weight of Specimen: **0.08642 kg**

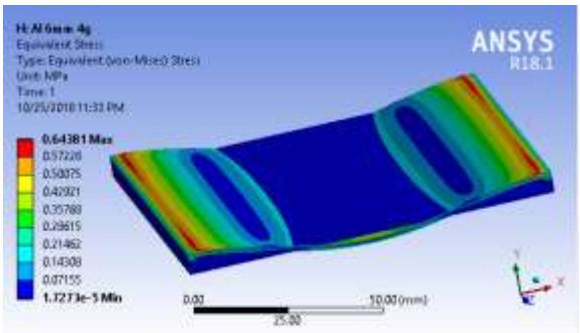
Nodes: **226838**

Elements: **41000**




Maximum Deformation: 4.07e-2 mm

Average Deformation: 2.71e-2 mm




Maximum Equivalent Stress: 0.643 MPa

Average Equivalent Stress: 0.393 MPa

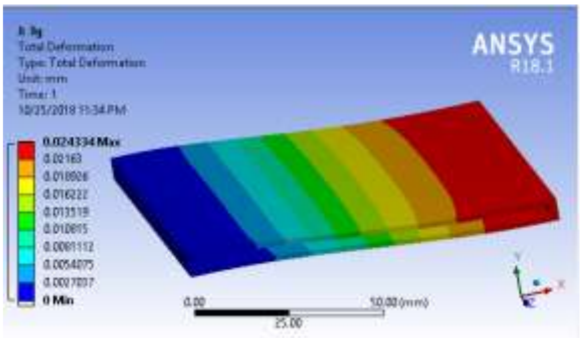
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **2.54 N**

Weight of Specimen: **0.08642 kg**

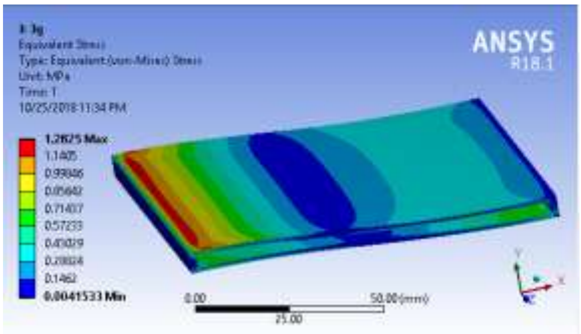
Nodes: **226838**

Elements: **41000**




Maximum Deformation: 2.4e-2 mm

Average Deformation: 1.47e-2 mm




Maximum Equivalent Stress: 1.282 MPa

Average Equivalent Stress: 0.785 MPa

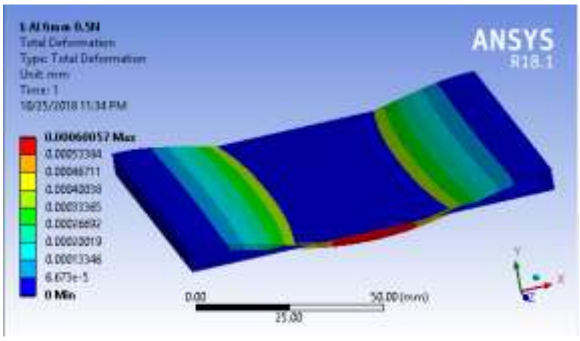
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.08642 kg**

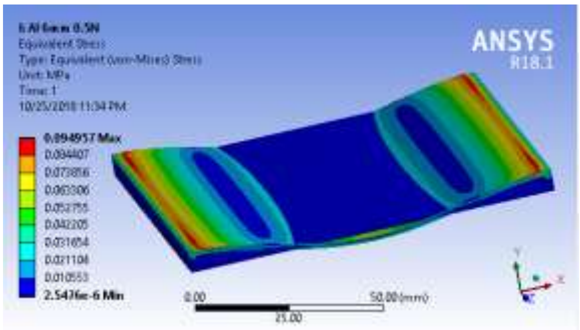
Nodes: **226838**

Elements: **41000**




Maximum Deformation: 6.005e-4 mm

Average Deformation: 4e-4 mm




Maximum Equivalent Stress: 9.49e-2 MPa

Average Equivalent Stress: 5.8e-2 MPa

**b) 4mm Thickness**

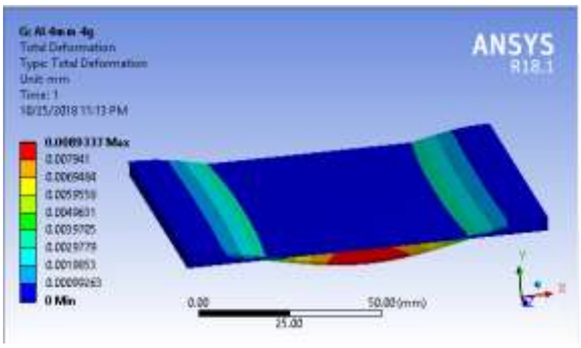
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **2.26 N**

Weight of Specimen: **0.0576 kg**

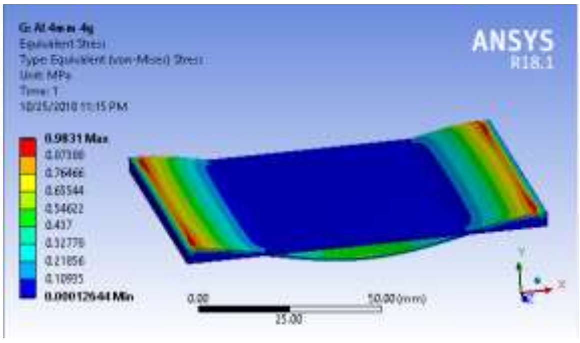
Nodes: **144828**

Elements: **20800**




Maximum Deformation: 8.93e-3 mm

Average Deformation: 5.455e-3 mm




Maximum Equivalent Stress: 0.83 MPa

Average Equivalent Stress: 0.6 MPa

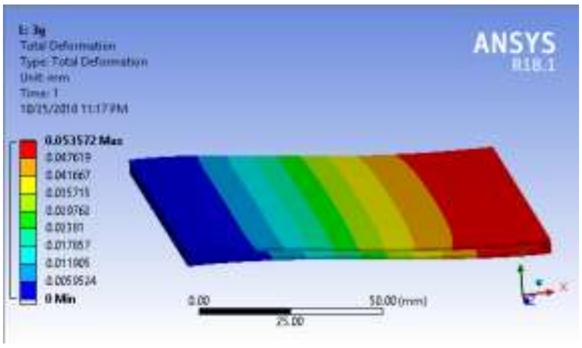
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **1.69 N**

Weight of Specimen: **0.0576 kg**

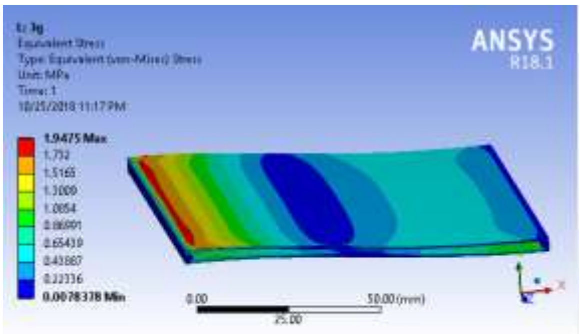
Nodes: **144828**

Elements: **20800**




Maximum Deformation: 0.053 mm

Average Deformation: 0.032 mm




Maximum Equivalent Stress: 1.9475 MPa

Average Equivalent Stress: 1.188 MPa

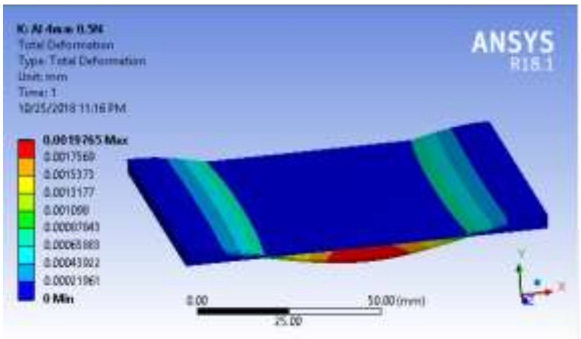
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.0576kg**

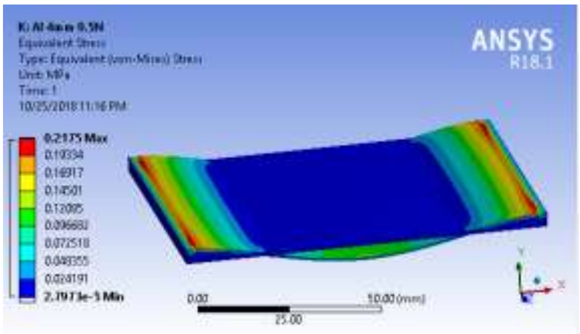
Nodes: **144828**

Elements: **20800**




Maximum Deformation: 1.97e-3 mm

Average Deformation: 1.21e-3 mm




Maximum Equivalent Stress: 0.2175 MPa

Average Equivalent Stress: 0.132 MPa

**7) Hybrid Structure(120$^0$)**

**a) 6mm Thickness**

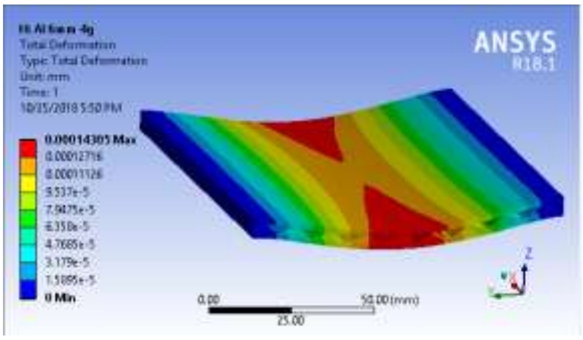
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **3.63 N**

Weight of Specimen: **0.0.0926 kg**

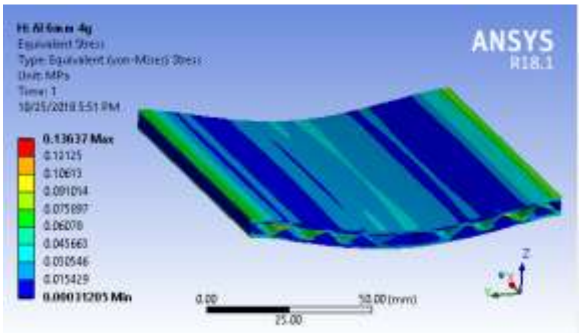
Nodes: **394042**

Elements: **68500**




Maximum Deformation: 1.43e-4 mm

Average Deformation: 8.7e-5 mm




Maximum Equivalent Stress: 0.136 MPa

Average Equivalent Stress: 0.083 MPa

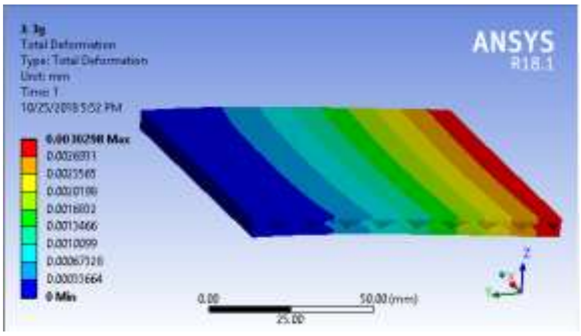
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **2.726 N**

Weight of Specimen: **0.0926 kg**

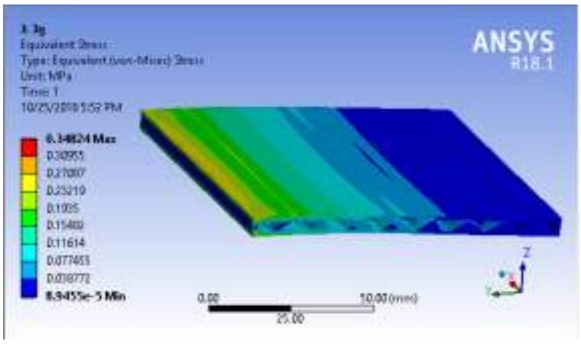
Nodes: **394042**

Elements: **68500**




Maximum Deformation: 3.02e-3 mm

Average Deformation: 1.84e-5 mm




Maximum Equivalent Stress: 0.348 MPa

Average Equivalent Stress: 0.212 MPa

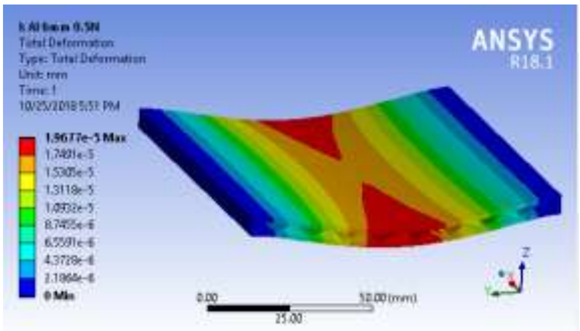
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.0926 kg**

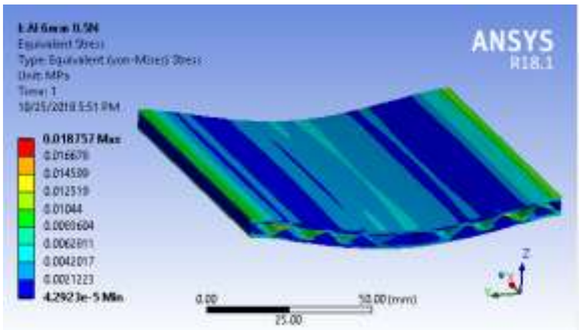
Nodes: **394042**

Elements: **68500**




Maximum Deformation: 1.96e-5 mm

Average Deformation: 1.198e-5 mm




Maximum Equivalent Stress: 0.0187 MPa

Average Equivalent Stress: 0.0114 MPa

**b) 4mm Thickness**

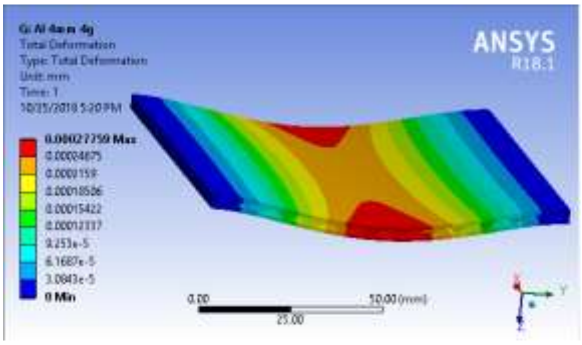
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **2.486 N**

Weight of Specimen: **0.0633 kg**

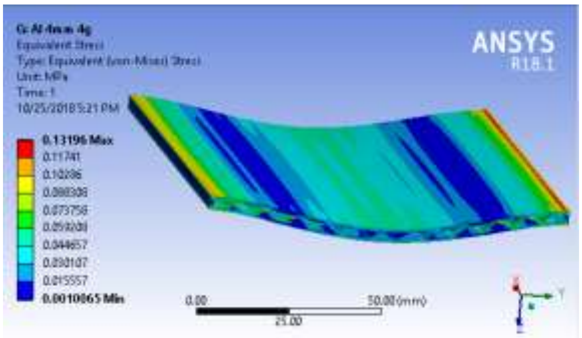
Nodes: **394345**

Elements: **68000**




Maximum Deformation: 2.77e-4 mm

Average Deformation: 1.69e-4 mm




Maximum Equivalent Stress: 0.1319 MPa

Average Equivalent Stress: 0.081 MPa

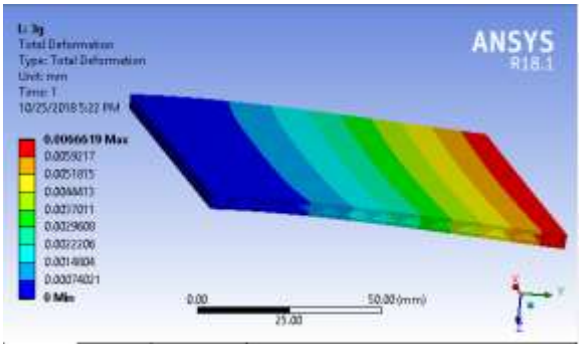
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **1.86 N**

Weight of Specimen: **0.0633 kg**

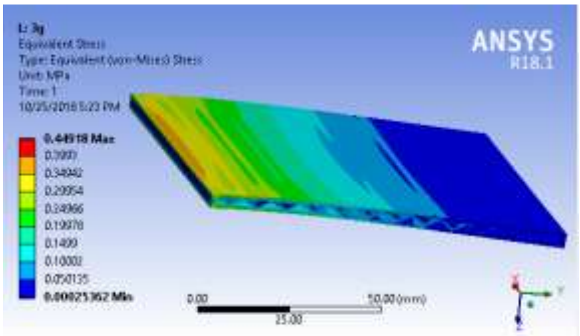
Nodes: **394345**

Elements: **68000**




Maximum Deformation: 6.661e-3 mm

Average Deformation: 4.07e-3 mm




Maximum Equivalent Stress: 0.449 MPa

Average Equivalent Stress: 0.274 MPa

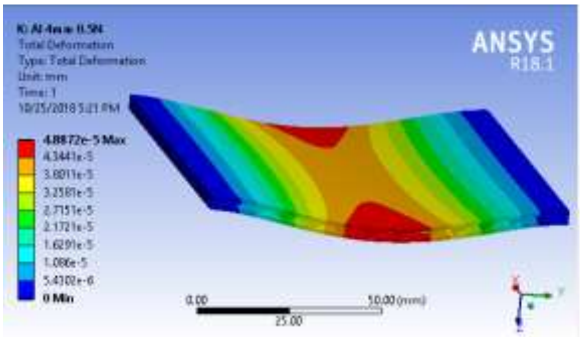
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.0633 kg**

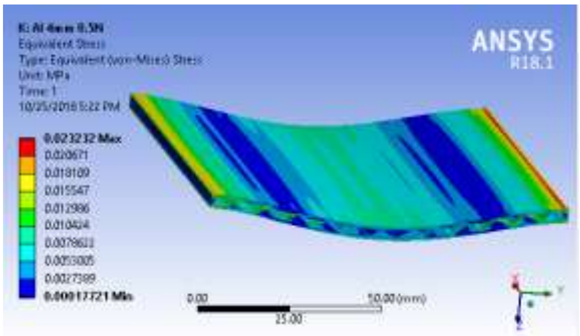
Nodes: **394345**

Elements: **68000**




Maximum Deformation: 4.88e-5mm

Average Deformation: 2.98e-5mm




Maximum Equivalent Stress: 0.02323 MPa

Average Equivalent Stress: 0,0142 MPa

**8) Hybrid Structure(135$^0$)**

**a) 6mm Thickness**

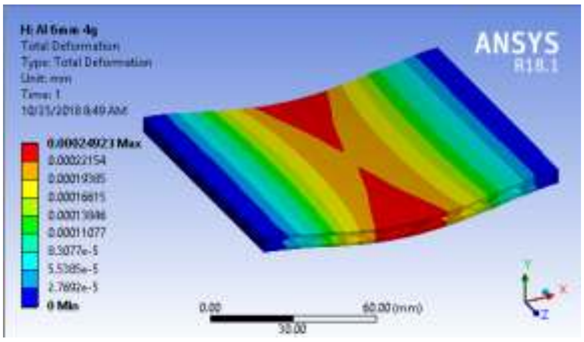
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **4.5 N**

Weight of Specimen: **0.1169 kg**

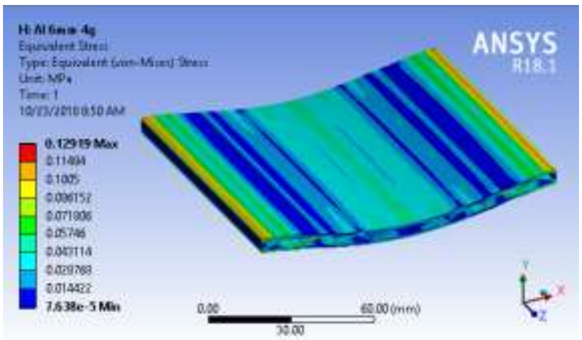
Nodes:**489831**

Elements: **85100**




Maximum Deformation: 2.4e-4 mm

Average Deformation: 1.75e-4 mm




Maximum Equivalent Stress: 0.129 MPa

Average Equivalent Stress: 0.078 MPa

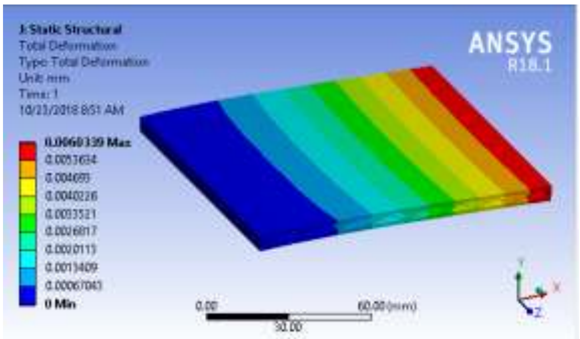
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **3.375 N**

Weight of Specimen: **0.1169 kg**

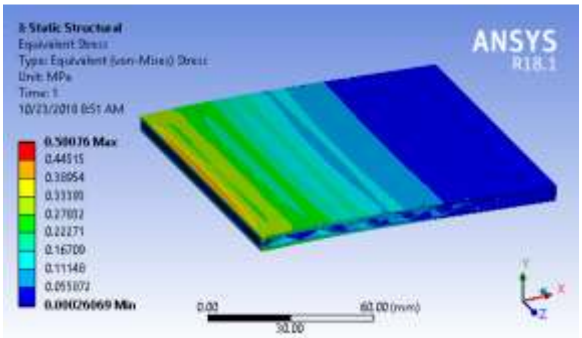
Nodes: **489831**

Elements: **85100**




Maximum Deformation: 6.09e-3 mm

Average Deformation: 3.715e-3 mm




Maximum Equivalent Stress: 0.5 MPa

Average Equivalent Stress: 0.305 MPa

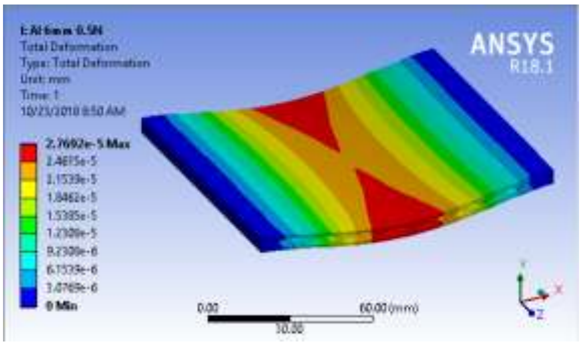
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.11697 kg**

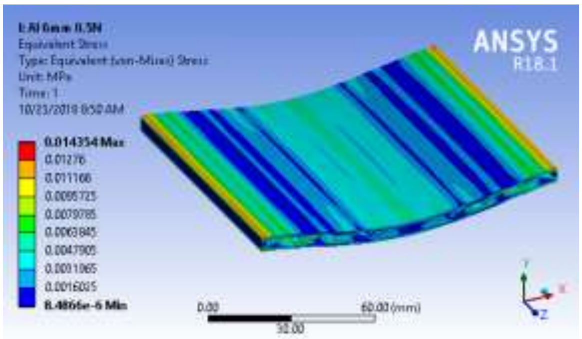
Nodes: **489831**

Elements: **85100**




Maximum Deformation: 2.76e-5 mm

Average Deformation: 1.68e-5 mm




Maximum Equivalent Stress: 1.43e-2 MPa

Average Equivalent Stress: 8.74e-3 MPa

**b) 4mm Thickness**

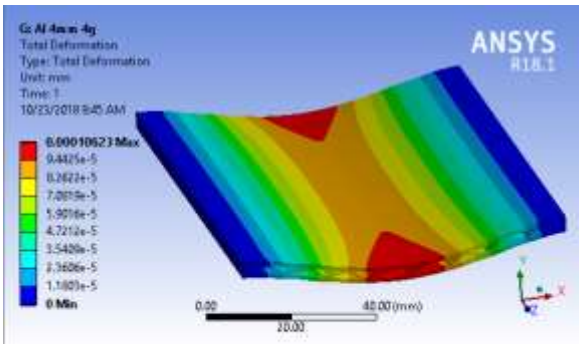
**i)** Both Side faces fixed and applying 4 g-forces on top face.

Load Applied: **2.1 N**

Weight of Specimen: **0.05539 kg**

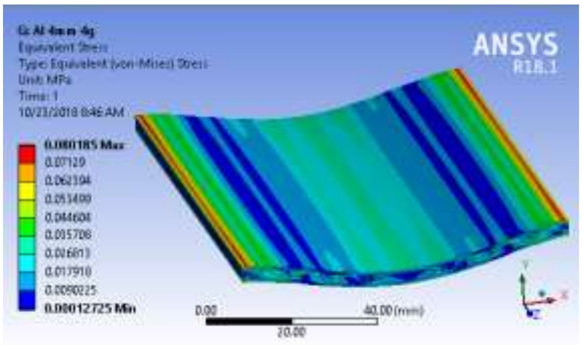
Nodes: **303888**

Elements: **51400**




Maximum Deformation: 1.06e-4 mm

Average Deformation: 6.48e-5 mm




Maximum Equivalent Stress: 8.01e-2 MPa

Average Equivalent Stress: 4.9e-2 MPa

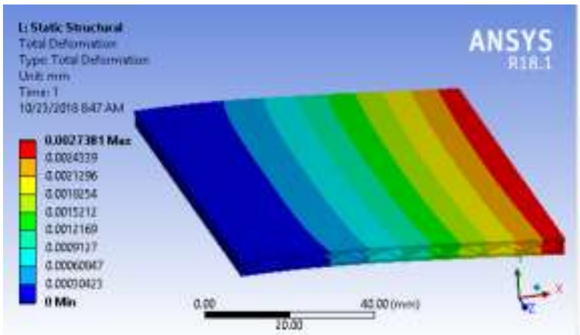
**ii)** One Side Face Fixed and Applying 3 g-forces on top face.

Load Applied: **1.575 N**

Weight of Specimen: **0.05539 kg**

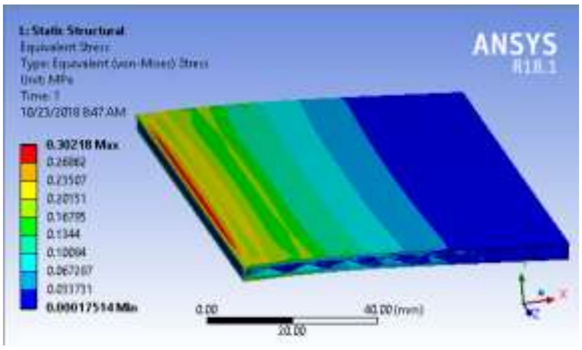
Nodes: **303888**

Elements: **51400**




Maximum Deformation: 2.73e-3 mm

Average Deformation: 1.669e-3 mm




Maximum Equivalent Stress: 0.302 MPa

Average Equivalent Stress: 0.1845 MPa

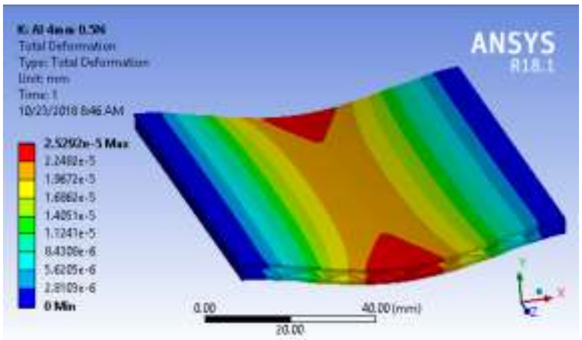
**iii)** Both Side faces fixed and applying 0.5 N on top face.

Load Applied: **0.5 N**

Weight of Specimen: **0.05539 kg**

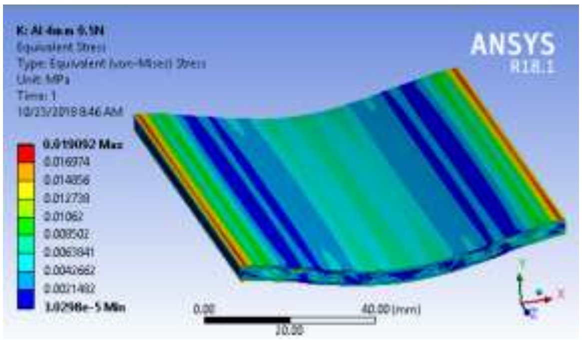
Nodes: **303888**

Elements: **51400**




Maximum Deformation: 2.52e-5 mm

Average Deformation: 1.54e-5 mm




Maximum Equivalent Stress: 1.9e-2 MPa

Average Equivalent Stress: 1.16e-2 MPa

## 3. RESULT TABLES

**TABLE 1:**

| RESULTS OBTAINED BY APPLYING 4G FORCES ON THE STRUCTURES | | | Max. Deformation | Max. Equivalent Stress |
|---|---|---|---|---|
| **Steel** | **Solid** | **6mm** | 2.4e-4 mm | 2.4e-4 mm |
| | | **4mm** | 2.4e-4 mm | 0.129 MPa |
| | **Hollow** | **6mm** | 2.4e-4 mm | 0.129 MPa |
| | | **4mm** | 1.06e-4 mm | 8.01e-2 MPa |
| | **$120^0$** | **6mm** | 2.4e-4 mm | 0.129 MPa |
| | | **4mm** | 1.06e-4 mm | 2.73e-3 mm |
| | **$135^0$** | **6mm** | 2.4e-4 mm | 0.129 MPa |
| | | **4mm** | 1.06e-4 mm | 8.01e-2 MPa |
| **Aluminium** | **Solid** | **6mm** | 2.4e-4 mm | 0.129 MPa |
| | | **4mm** | 1.06e-4 mm | 8.01e-2 MPa |
| | **Hollow** | **6mm** | 2.4e-4 mm | 0.129 MPa |
| | | **4mm** | 1.06e-4 mm | 8.01e-2 MPa |
| | **$120^0$** | **6mm** | 2.4e-4 mm | 0.129 MPa |
| | | **4mm** | 1.06e-4 mm | 8.01e-2 MPa |
| | **$135^0$** | **6mm** | 2.4e-4 mm | 0.129 MPa |
| | | **4mm** | 1.06e-4 mm | 8.01e-2 MPa |

These are the results obtained by applying 4G forces on different types of structures designed by using Solidworks on Ansys. This table compares the Maximum Deformation and Equivalent Stresses observed on the structure under different loading conditions or different types of impacts.

**TABLE 2:**

| RESULTS OBTAINED BY APPLYING 4G FORCES ON THE STRUCTURES | | | Max. Deformation | Max. Equivalent Stress |
|---|---|---|---|---|
| **Steel** | **Solid** | **6mm** | 6.09e-3 mm | 0.5 MPa |

| | | | | |
|---|---|---|---|---|
| | | 4mm | 6.09e-3 mm | 0.5 MPa |
| | Hollow | 6mm | 6.09e-3 mm | 0.5 MPa |
| | | 4mm | 2.73e-3 mm | 0.302 MPa |
| | $120^0$ | 6mm | 6.09e-3 mm | 0.5 MPa |
| | | 4mm | 2.73e-3 mm | 0.302 MPa |
| | $135^0$ | 6mm | 6.09e-3 mm | 0.5 MPa |
| | | 4mm | 2.73e-3 mm | 0.302 MPa |
| Aluminium | Solid | 6mm | 6.09e-3 mm | 0.5 MPa |
| | | 4mm | 2.73e-3 mm | 0.302 MPa |
| | Hollow | 6mm | 6.09e-3 mm | 0.5 MPa |
| | | 4mm | 2.73e-3 mm | 0.302 MPa |
| | $120^0$ | 6mm | 6.09e-3 mm | 0.5 MPa |
| | | 4mm | 2.73e-3 mm | 0.302 MPa |
| | $135^0$ | 6mm | 6.09e-3 mm | 0.5 MPa |
| | | 4mm | 2.73e-3 mm | 0.302 MPa |

These are the results obtained by applying 3G forces on different types of structures designed by using Solidworks on Ansys. This table compares the Maximum Deformation and Equivalent Stresses observed on the structure under different loading conditions or different types of impacts.

**TABLE 3:**

| RESULTS OBTAINED BY APPLYING 4G FORCES ON THE STRUCTURES | | | Max. Deformation | Max. Equivalent Stress |
|---|---|---|---|---|
| Steel | Solid | 6mm | 2.76e-5 mm | 1.43e-2 MPa |
| | | 4mm | 2.76e-5 mm | 1.43e-2 MPa |
| | Hollow | 6mm | 2.76e-5 mm | 1.43e-2 MPa |
| | | 4mm | 2.52e-5 mm | 1.9e-2 MPa |
| | $120^0$ | 6mm | 2.76e-5 mm | 1.43e-2 MPa |
| | | 4mm | 2.52e-5 mm | 1.9e-2 MPa |
| | $135^0$ | 6mm | 2.76e-5 mm | 1.43e-2 MPa |
| | | 4mm | 2.52e-5 mm | 1.9e-2 MPa |
| Aluminium | Solid | 6mm | 2.76e-5 mm | 1.43e-2 MPa |
| | | 4mm | 2.52e-5 mm | 1.9e-2 MPa |
| | Hollow | 6mm | 2.76e-5 mm | 1.43e-2 MPa |
| | | 4mm | 2.52e-5 mm | 1.9e-2 MPa |
| | $120^0$ | 6mm | 2.76e-5 mm | 1.43e-2 MPa |
| | | 4mm | 2.52e-5 mm | 1.9e-2 MPa |
| | $135^0$ | 6mm | 2.76e-5 mm | 1.43e-2 MPa |
| | | 4mm | 2.52e-5 mm | 1.9e-2 MPa |

These are the results obtained by applying 0.5N force on different types of structures designed by using Solidworks on Ansys. This table compares the Maximum Deformation and Equivalent Stresses observed on the structure under different loading conditions or different types of impacts.

## 3. MATERIAL & MANUFACTURING PROCESS:

**Material Selection:**

Materials used for the manufacturing of Monocoque are:

- Cast Iron
- Titanium Alloys
- High Strength Steel
- Magnesium Alloys
- Aluminum Alloys
- Carbon Fibres
- Polymer Composites

Considering the Weight Factor, we use Carbon Fibres and Polymer Composites with high strengths to reduce the

Overall Weight of the Body of the Vehicle, as they are the lightest materials to manufacture so far.

Reasons to select Carbon Fibre as the material in Hybrid Structures:

- It consists of 92% (Mass Fraction) of Carbon usually in the Non-Graphitic State.
- Less weight having low density.
- High Specific Strength and stiffness.
- Except in highly Oxidizing Environments, it has excellent Chemical Stability
- Bio Compatibility.
- Low Coefficient of Thermal Expansion.
- Excellent Fatigue and Creep Behavior.

The Chemical Composition of Carbon Fibre:

- 90% of Carbon Fibres produced are made from Poly Acrylo Nitrile (PAN).
- Remaining 10% are all made from Rayon or Petroleum Pitch.

All these materials are organic Polymers, characterized by long strings of Molecules bound together by Carbon Atoms.

**Manufacturing Process:**

There are many types of Manufacturing Processes by which we can initially manufacture the Hybrid Structures. Some of them are:

1. **CNC Machining**
    - This process is Complicated
    - Wastage of Material is more compared to other type of Manufacturing Processes.
    - Time taking Process.
2. **3D Printing**
    - This manufacturing process limits the Size of the Material.
    - Time taking Process.
3. **Casting**

Among all these Manufacturing Processes, the 3D Printing can be used to a certain limit to make the Hybrid Structures.

And also the Casting is used as:

- It is less costlier
- Less material wastage
- Easy to manufacture.

Properties of Carbon Fibre are

| | |
|---|---|
| Strength | 3 to 7 GPa |
| Modulus of Elasticity | 200 to 500 GPa |
| Compressive Strength | 1 to 3 GPa |
| Shear Modulus | 10 to 15 GPa |
| Density | 1.75 to 2 g/cm3 |
| Thermal Conductivity | 1000 W/mK |

## 4. CONCLUSIONS

After observing the results from how various materials of different internal arrangements are tested with varying forces, we found out that the hybrid structures designed were having higher strengths compared to their solid and hollow structures and exhibited the greatest resistance to impact forces.

From this paper, we can see how using these Hybrid Structures can reduce the weight of Automobiles without compromising safety. And this can be done with different materials considering the usage, using different Modern Manufacturing Processes.

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Preparation of zeolite sheets using a paper making technique

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