

# Analysis of Energy Absorption Capacity of Crash Box

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**Abstract** - Crash box is a device mounted between front bumper and main frame of car to absorb energy during collision. It buckles when axial compressive force exceeds limit. Energy is absorbed during buckling and damage to main frame is avoided. Recently, it has been strictly required to satisfy both reduction of body weight and improvement of crash worthiness in the design and thus, regarding crash box, it is required to ensure high energy absorption. This paper is aimed to investigate the most suitable structure of crash box with different materials at conceptual design stage. The various structures of Crash Box such as Square, triangle and hexagonal were analyzed with Aluminium, Epoxy and carbon Fiber materials

**Key Words:** Crash box, crushing load, energy absorption, FEA, ANSYS

## 1. INTRODUCTION

Naturally, there is an increase in the number of vehicles on the road with increase in the populace. The rate of motor vehicle accidents globally is alarming. The trend in the rate of road accidents is the same in many countries and it is growing. It is estimated that 1.2 million people are killed in road crashes and nearly 50 million are injured worldwide every year. In order to ensure the driver's safety in case of high-speed crashes, special impact structures are designed to absorb the race car's kinetic energy and limit the deceleration acting on the human body. These energy absorbing structures are made of laminated composite sandwich materials - like the whole monocoque chassis - and have to meet defined crash test requirements specified by the Formula SAE Rules and Regulations. This study covers the crash behavior of the front impact structure of crash box for maximum energy absorption and minimum critical deformation. When the body of occupant is moving (say at 55 kmph), it has a certain amount of kinetic energy. After the crash, when it comes to a complete stop, it will have zero kinetic energy. To minimize risk of injury, removing the kinetic energy as slowly Crash Box with which a car is equipped at the front end of its front side frame, is one of the most important automotive parts for crash energy absorption. Generated energy of the vehicle collided have been absorbed mainly by the plastic deformation of crash box. Position and structure of the crash box in the body structure as shown in Fig. 1. In order to make crash box absorb the entire energy in the low-speed collision, it requires that the impact force is evenly distributed, and the force value is not more than the value of permits to protect other structures from damage, and all the Kinetic Energy were absorbed.

## 1.1 Shape Selection

In previous research papers, the study is done for circular, square, Hexagon Sections. The impact test results are obtained. In this paper, Triangular section, Rectangular Section, Hexagonal Section are analyzed and manufacturing of Crash Box for weight optimization is proposed. Using this cross section, we are also analyzing another set of geometry for Crash Box.

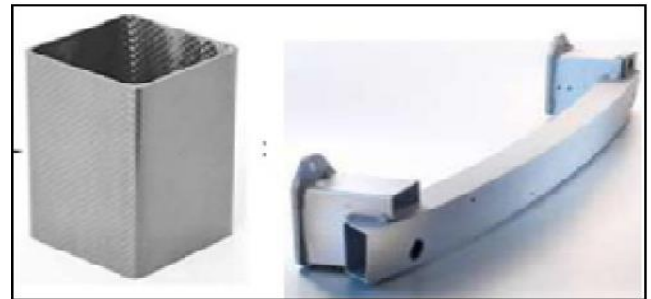


FIGURE. 1 Crash Box and Crash Box Assembly

## 1.2 Material Selection:-

Previously, most of the crash boxes are made of steel. However, in mid-80's the application of polymer composite material has been introduced to replace conventional material such as plastic, aluminum, and metal. There are many past research have been conducted using polymer composite where it can offer low weight, easier to produce complex shape, and high impact energy absorption capacity. The use of composite has been introduced to replace the use of conventional materials because it has an advantage of low density, high specific strength and stiffness.

In the past, study is done circular, square section, Hexagonal Sections with Aluminium and composite materials. The objective of this paper is to study & compare on Triangular section, Rectangular Section and Hexagonal Sections with Aluminium alloy, Glass Epoxy, Carbon Fiber for maximum energy absorption.

## 2. METHODOLOGY

- Collection of Data
- CATIA design
- FEA Testing
- Experimental testing
- Comparison & Results

## 2.1. Mechanical properties for selected materials as shown below

Table -1: Properties of material

Parameter	Al Alloy	Glass epoxy	Carbon fiber
Young's Modulus (MPa)	$7.1 \times 10^4$	$12 \times 10^3$	$70 \times 10^3$
Poisson's Ratio	0.33	0.35	0.10
Density ( kg/m <sup>3</sup> )	2770	1900	1600
Ultimate tensile strength (MPa)	310	490	600

## 2.2. Analysis Result

To check various parameters such as energy absorption capacity, various stress induced we have done some FEA simulation on the ANSYS software for the crash box designed in Catia software for Triangular, Rectangular and Hexagonal Sections models and below is total deformation results.

### FEA Boundary conditions

The Velocity generated from the action of bumping velocity are applied at the region where top of the section are touching to Bumper. Assume the velocity 33330 mm/s as a worst loading scenario. For the stimulation any model in CAE software, it is necessary to provide some boundary conditions which probable in the actual model for the accurate results. This relates to the practical uses of the model.

#### a) Aluminium

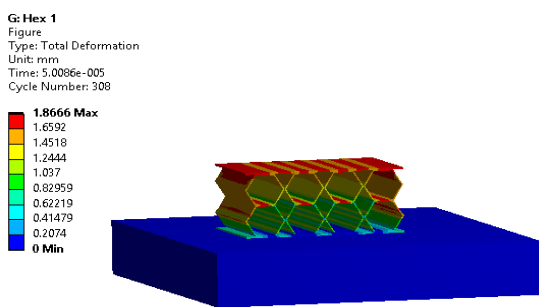


Figure -2: Deformed Hexagonal Section

#### b) Glass epoxy

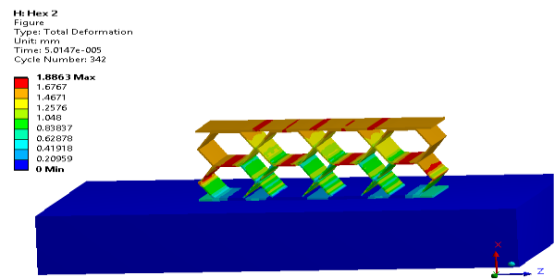


Figure -3: Deformed Hexagonal Section

#### c) Carbon Fiber

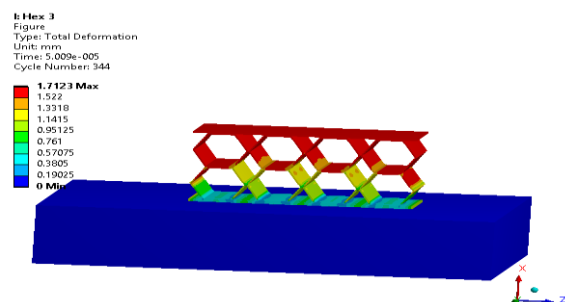


Figure -4: Deformed Hexagonal Section

#### d) Aluminium

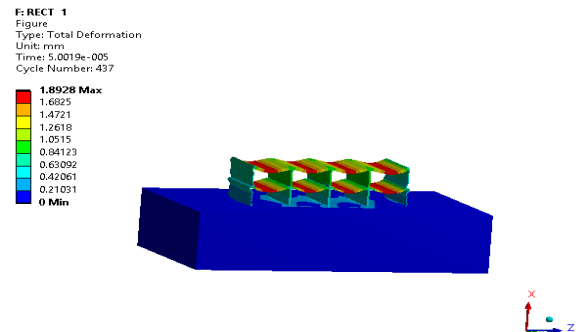


Figure -5: Deformed Rectangular Section

#### e) Glass Epoxy

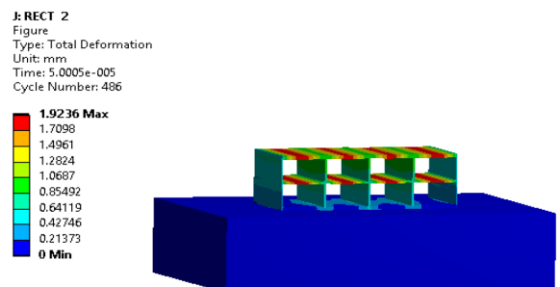


Figure -6: Deformed Rectangular Section

f) Carbon fiber

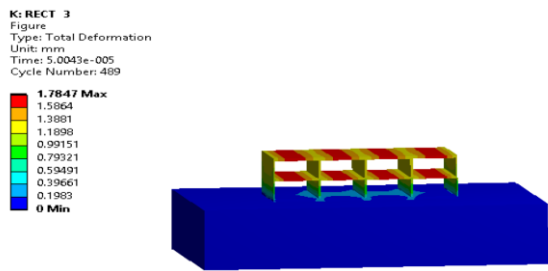


Figure -7: Deformed Rectangular Section

g) Aluminium

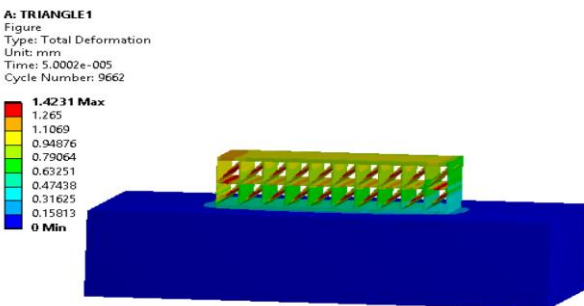


Figure -8: Deformed Triangular Section

h) Glass Epoxy

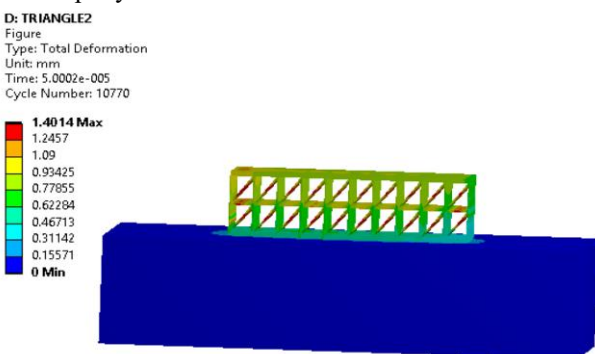


Figure -9: Deformed Triangular Section

i) Carbon Fiber

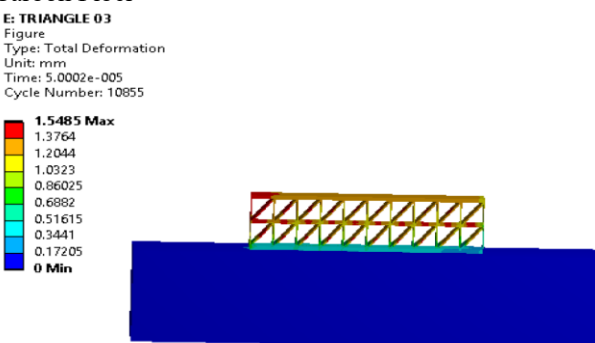


Figure -10: Deformed Triangular Section

**FEA Results:**

Currently, automotive industry relies on finite element analysis (FEA) in development of product. Analyzing the energy absorption in real impact is quite complicated and depends on

different parameters. The influence of design parameters on the weight, costs or functional properties of new car models can be determined using the FEA. FEA is a suitable method to analyze the energy absorption during impact to determine the approximate deflection behavior during an impact. Weight and impact behavior parameter were compared for composite and aluminum material.

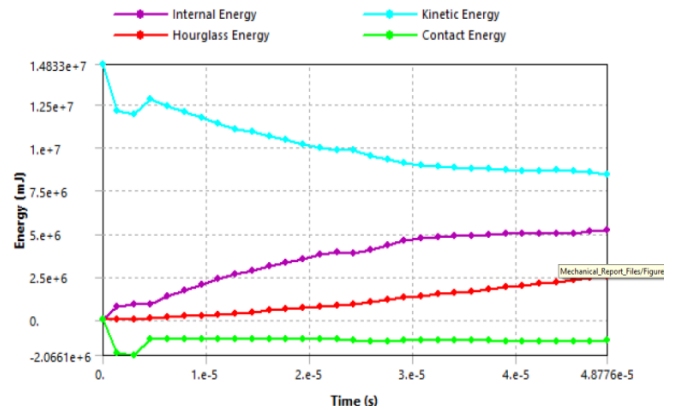


Figure 11. Energy graph for Hexagonal section

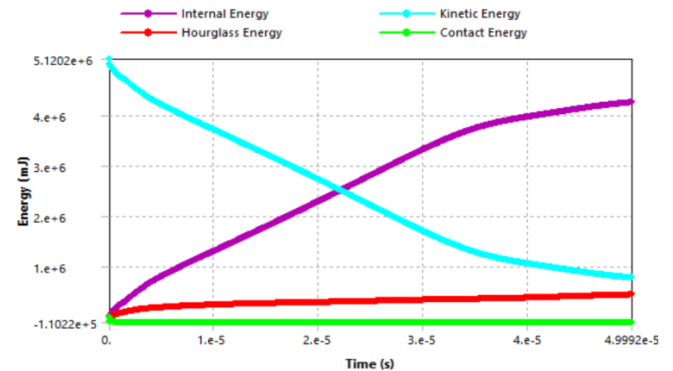


FIGURE 12. Energy graph for Rectangular section

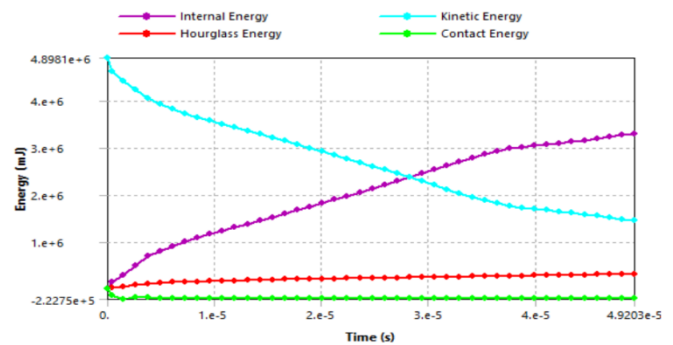


FIGURE 13. Energy graph for Triangular section

The above energy graphs we can see that the conservation of energy is substantiated. It is observed from the graphical values that the kinetic energy of the entire system drops upon collision due to sudden drop in the velocity of moving car. It is observed by the deforming structural components, increases simultaneously, thus keeping the total energy constant.

Below table show the FEA results for all threes shapes with all three materials considered.

**TABLE 2:** FEA Results

Shape	Material	Mass (kg)	Deflection (mm)	Von-Mises stress (M Pa)
Hexagonal Section	Aluminium alloy	2.11	1.866	1217.4
	Glass Epoxy	2.0461	1.8863	1458.8
	Carbon Fiber	2.0581	1.7123	484.98
Rectangular Section	Aluminium alloy	0.6145	1.8928	1560.4
	Glass Epoxy	0.5934	1.9236	1775.8
	Carbon Fiber	0.5969	1.7847	506.63
Triangular Section	Aluminium alloy	0.139	1.4231	1595.6
	Glass Epoxy	0.1342	1.4014	2933.2
	Carbon Fiber	0.135	1.5486	514.52

**Table 3:** Impact Test results

Material	Impact strength (kJ/m <sup>2</sup> )
Al	1579
Composite Material	252.79

### 3. ANALYTICAL ANALYSIS

Absorbed energy: Absorbed energy is energy absorbed by component during its plastic deformation. Are a under load–displacement curve is absorbed energy.

$$E = \int_0^{\delta_{max}} P(\delta)d(\delta)$$

$$P_m = \frac{E}{\delta_{max}}$$

$P_m$  – Mean crushing load,  
 E - Absorbed energy,  
 $\delta_{max}$  - Total displacement.

This Equation is derived by equating large number of experimental data. Mean crushing load is evaluated by means of following formula:

$$P_m = K \sigma_o b^{\frac{1}{3}} t^{\frac{5}{3}}$$

Where,  $P_m$ , b and t are mean crushing load, width and thickness respectively.  $\sigma_o$  is yield stress. Value of b is taken as mean of box widths and K is a dimensionless constant. Value of K is proposed to be 13.06. (load  $P_m$  expressed in N, yield stress  $\sigma_o$  in MPa, and all dimensions are in mm).

### 4. RESULTS & DISCUSSION

By comparing FEA results, it is clear that Hexagonal section having better energy absorption capacity than Rectangular & Triangular section by considering Aluminium, Glass Epoxy and

carbon fiber. From analysis results, it is observed that the Hexagonal shaped crash box can store more energy than Rectangular & triangular shaped crash box. Since from the results, Aluminium shows better energy absorption characteristics, it is recommended that the frontal rails of an automobile passenger car be produced with Aluminium material. Along with the above said benefits, the Aluminium also boasts of being considerably lighter, thus gaining advantage on better acceleration and speed of the car. Added to it is the advantage of better fuel economy which is the playing card in today’s competitive passenger vehicle market. Also, with hybrid technology and electric vehicles paving the way for future, where weight reduction is a prime motive to aid the added weight of the extra drive mechanisms, Aluminium structured vehicles are the future of cost effective automobile passenger cars.

### 5. CONCLUSIONS

This analysis work for different shapes Triangle, Rectangle and hexagon with different material AL, Epoxy Glass, Carbon fiber were investigated for crash box. The following conclusions are drawn:

1. Crush box components absorbing energy are studied through basic types of different cross sections.
2. Triangular and Rectangular profile have significant Lower energy absorption than the other profiles.
3. More study on different composite materials and improvements in additional can achieve more improvement on deformation and energy absorption.

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