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Design and Analysis of Various Cross-Section Shapes of Automotive Bumper

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ABSTRACT

Automotive bumper is used in Automobile industry to absorb the impact for the sake of driver's and passenger's safety. The importance of this equipment has been stressed in the coming years with the advancement of the technology to increase the safety factors of the automobile increasing its value. Various devices and materials are used in the form of impact absorbing substance. The device is supposed to absorb the Crash energy by its self-destruction so that less amount of the impact force is transferred to body of the vehicle. The purpose of this research is design and analysis of best c/s of bumper for given selected material using ANSYS software. Tensile and compression test perform on sample model to validate the ANSYS results.

Index Terms: Automotive bumpers, Bumper analysis, Bumper design, Crash energy Absorption, Design C/S bumper .

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I. INTRODUCTION

The rate of motor vehicle accidents globally is alarming and naturally increases as the number of vehicles on the roads increases. The trend in the rate of road accidents is the same in many countries in that 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.

Past research and experiences had indicated that during collision of vehicle important role played by bumper, which absorbs maximum impact energy. Size and shape of bumper affects its impact energy absorption.

Automobile bumper subsystem is the frontal and rear structure of the vehicle that has the purpose of energy absorption during collision. Usually, bumper subsystem consists of bumper transverse beam, stays, impact-absorbing materials connected to the structural components and a cover, that has both aesthetic and protection purposes. Among those elements, the bumper beam is the main structural component; it is expected to be deformable enough to absorb the impact energy, in order to reduce the risks of injury for pedestrians and other vulnerable road users, but, at the same time, it should also have sufficient strength and stiffness to give place to small intrusion of the engine compartment hence, to protect the nearby vehicle components.

II. LITERATURE REVIEW

Prof. F B Sayyad and A D Deshmukh, [1] they proposed that the designer should be aware that in order to reduce the weight, the safety of the car passenger must not be sacrificed. In development of bumper systems for the automotive industry, iterative Finite Element (FE) simulations are normally used to find a bumper design that meets the needs of crash performance. Praveen Kumar. A, Sameer Belagali, Bhaskar, [2] performed analysis on the automotive bumper to check the crashworthiness for the passenger safety. The bumper beam analyzed for the steel and composite material with the basic bumper design in the first stage, and then front part is modeled with the honeycomb and foam type in the second stage to compare the deformation and energy absorbed during the impact. Dnyaneshwar B. Kahane, K.V.Chandratre, [3] investigated Energy is absorbed during buckling and damage to main frame is avoided. In this study crash box of different geometry is studied for energy absorption capacity experimentally and analysis done on (FEA) and results of this study are compared. Study of different designs of crash boxes are undertaken to optimize the design for maximizing energy absorption capacity, minimizing critical buckling force. Ajay D. Katore, Prof. Sachin Jain, [4] proposed that the greatest demand facing the automotive industry has been to provide safer vehicles with high fuel efficiency at minimum cost. Current automotive vehicle structures have one fundamental handicap, a short crumple zone for crash energy absorption. Sagar P Dhamone, Dr Arun kumar P, [5] investigated that Different impact attenuation systems in the vehicle were studied with emphasis on the bumper modeling, material consideration, automatic machine handling, Robotics sensor for Bumper can achieve the desirable properties such as low weight, high fatigue strength, accessories in automation, improvement in quality of products. Improvement of the structural adhesive help to increases the difficulties in crash simulations of adhesive- bonded vehicle structures. Brad E. Paden, Paraic M. Kelly, Jacob A. Hines, David Bothman, Ciaran Simms, [6] investigated the head motions produced by the four concepts are modeled as one or two square acceleration pulses and are analyzed using the Head Injury Criterion (HIC). The computed bumper lengths are a fraction of the overall length of a locomotive and are thus feasible for practical implementation. One concept involves an oblique impact and the potential for rotational head injury is analyzed.

Sayyad, Abhay singh Diliprao Deshmukh, [7] investigated that the different countries have different performance standards for bumpers. Under the International safety regulations originally developed as European standards and now adopted by most countries outside North America also. Lande P.R, Patil R.V, [8] the aluminum Honeycomb sandwich panel is structure which has very slight to weight ratio. Mohammed Rasool Naji, Girish Narayanrao Kotwal, [9] investigated that The core layer is the hexagonal aluminum honeycomb, adhered to the face plate and the sole plate by adhesive glue. The diversionary honeycombs can bear the pressure coming from the plates which provide the superior flat and rigidity, if the plates are very large. The panels are light weight and saves energy. A.T. Beyenea, E.G. Korichob, G. Belingardib, B. Martoranac, [10] investigated that the design of vehicle subsystem for lightweight and for safety seems to lead the designer toward opposite directions. As composite materials has completely different failure behaviour than the conventional metallic materials, the direct adoption of the traditional metallic energy absorbing geometry may lead to a catastrophic failure and yield higher peak loads. Xiaosong Huang, [11] proposed that carbon fiber is defined as a fiber containing at least 92 wt % carbon, while the fiber containing at least 99 wt % carbon is usually called a graphite fiber . Carbon fibers generally have excellent tensile properties, low densities, high thermal and chemical stabilities in the absence of oxidizing agents, high creep resistance, good thermal and electrical conductivities. They have been extensively used in composites in the form of woven textiles, continuous fibers, and chopped fibers. Arun Kumar D T [12] investigated that the most widely used plastic next to polythene. Polypropylene as it is cannot be used in many applications. The strength of plastic needs to be improved in many applications. Addition of reinforcement materials like carbon fibers with an organic compound like maleic anhydride improves the strength of polypropylene.

III. MATERIAL PROPERTIES AND ANALYTICAL CALCULATIONS

Carbon-fiber-reinforced polymer or often simply carbon fiber, is an extremely strong and light fiber-reinforced polymer which contains carbon fibers. The polymer is most often epoxy, but other polymers, like polyester, vinyl ester or nylon, are sometimes used. The composite may contain other fibers, such as agamid e.g. Twaron ,Kevlar, aluminium, or glass fibers, as well as carbon fiber. Carbon fiber is commonly used in the transportation industry; normally in cars, trains. And boats . Although carbon fiber can be relatively expensive, it has many applications in aerospace and automotive fields, such as Formula One car. Aluminium alloys are alloys in which aluminium (Al) is the predominant metal and some other typical alloying elements which use are copper, magnesium, manganese, zinc and silicon . There are two mainly classifications, namely as casting alloys and wrought alloys, both of which are further subdivided into the two categories, one is heat-treatable and other is non-heat- treatable. Aluminium alloys are widely used in engineering structures and components where corrosion resistance or light weight is required.

Table 1 : Properties of Material

	Al Alloy	Carbon fiber
Young's Modulus	7.1e+4 Mpa	70 e3Mpa
Poisson's Ratio	0.33	0.10
Density	2770 kg/m^3	1600 Kg/m^3
Ultimate tensile strength	310Mpa	600Mpa
Yield Strength	280Mpa	228Mpa

Surface area of various cross-section :

1) Surface area of rectangle:

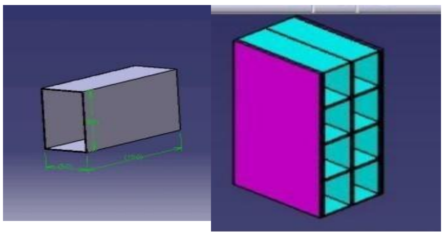
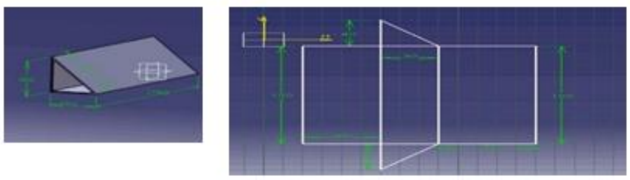


Fig.1 : Rectangle cross-section

=2lw+2wh+2
lh
=2*150*50+
2*150*80+
2*50*80
=47000mm2

2) Surface area of Right angle triangle



area of left rectangle	Area of center rectangle	Area of right rectangle
=40*150	=150*30	=50*150
=6000mm^2	=4500mm^2	=7500mm^2

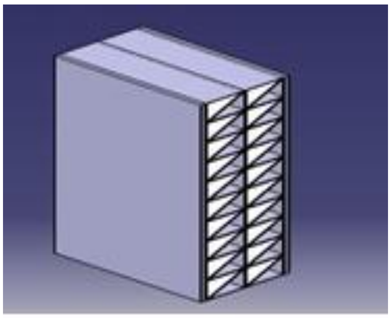


Fig.2: triangular cross-section

Area of two triangle

=2*(1/2 *40*30)

=1200mm^2

Total area

=6000+4500+7500 +1200

=19200mm^2

area of triangle is half of rectangle ,so taken 2 triangle in consideration.

3) Surface area of Hexagon :

=6ah+3 √ 3 a2

=6*45*150+3 √ 3 *452

=51022mm

This area approximate same as area of rectangle.

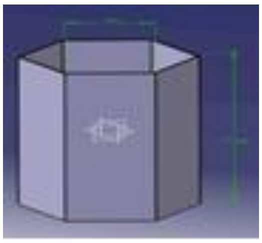


Fig.3:Hexagonal cross-section

IV. METHODOLOGY

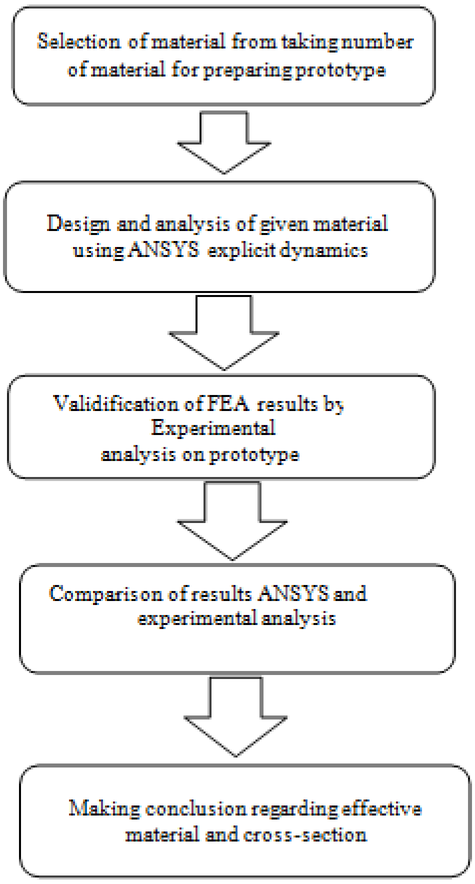


Fig.4 Flowchart of Methodology

V. FINITE ELEMENT ANALYSIS USING ANSYS EXPLICIT DYNAMICS

The design of products that need to survive impacts or short-duration and high-pressure loadings can be greatly improved with the help of ANSYS explicit dynamics solutions. These specialized problems require advanced analysis tools to accurately predict the effect of design considerations on product response to sever readings. Understanding such complex phenomenon is especial important when it is too expensive or impossible to perform physical testing.

Three Steps In The Finite Element Calculation

1. Pre-Processing

Create and discretize the solution domain into finite elements. This involves dividing the domain into subdomains i.e. 'elements', and selecting points, called nodes, on the inter-element boundaries or in the interior of the elements.

i. Assume a function to represent the behavior of the element. This function is approximate and continuous and its known as "shape function".

ii. Develop equations for an element.

iii. Assemble the elements to represent the complete problem.

iv. Apply boundary conditions, initial conditions, and the loading.

2. Solving

Solve a set of linear or nonlinear algebraic equations simultaneously for obtaining nodal results, such as displacement values or temperature values depending on the type of problem.

3. Post-Processing

This stage involves processing the nodal data to get other information such as values of principal stresses, heat fluxes etc.

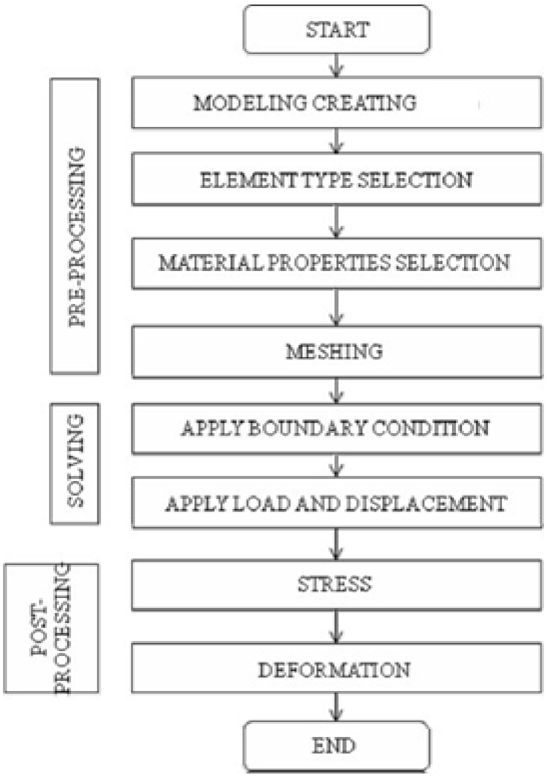


Fig 5 : Structural Analysis Flow Chart

Boundary Conditions :

The Velocity generated from the action of bumping velocity are applied at the region where top of the hexa Section are touching to Bumper. Following boundary conditions are applied on the bumper. Total Downward Direction velocity 33330 mm/s as a worst loading scenario.

- Analysis Hexa Bumper Al alloy :

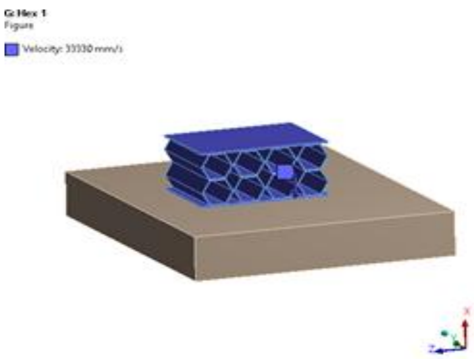


Figure 6: Boundary conditions for baseline Hexa Bumper model

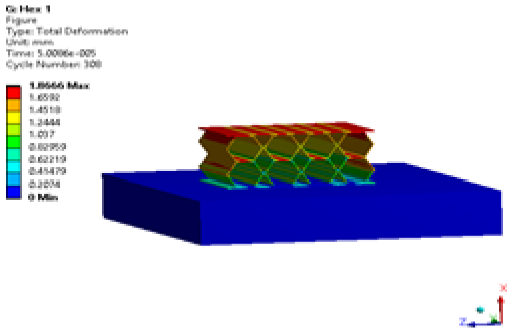


Figure 7: Total deformation plot for baseline Hexa Bumper

Fig. 7: show that the maximum displacement shown by the baseline Hexa Bumper design is 1.8666mm.

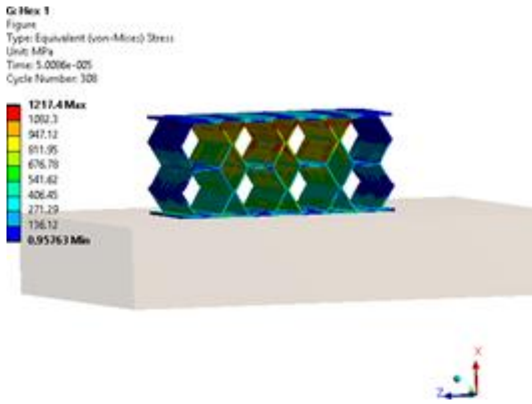


Figure 8:Von-Misses stress plot for baseline Hexa Bumper

Fig. 8 :show that the maximum equivalent stress observed in the baseline Hexa Bumper is 1217.4 MPa.

Table 2 : FEA result

Sr. No.	Description	Deflection(mm)	Von-Mises stress (MPa)
1	Hexa Section Aluminium alloy Carbon Fiber	1.8660 1.7123	1217.4 484.98
2	Rectangular Section Aluminium alloy Carbon Fiber	1.8928 1.7847	1560.4 506.63
3	Triangular Section Aluminium alloy Carbon Fiber	1.4231 1.5486	1595.6 514.52

FEA Results :

Result show that Hexagonal structure show better stress carrying capacity than rectangle and triangular structure . So we construct Hexagonal structure model for testing and find out which material is most suitable for that structure.

So we prepare prototype hexagonal cross-section using Al alloy and composite material.

VI. EXPERIMENTAL ANALYSIS

Test perform on UTM .A universal testing machine (UTM), also known as a universal tester ,materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. Load frame - Usually consisting of two strong supports for the machine. Some small machines have a single support.

Load cell - A force transducer or other means of measuring the load is required. Periodic calibration is usually required by governing regulations or quality system.

Cross head - A movable cross head (crosshead) is controlled to move up or down. Usually this is at a constant speed: sometimes called a constant rate of extension (CRE) machine. Some machines can program the crosshead speed or conduct cyclical testing, testing at constant force, testing at constant deformation, etc. Electromechanical, servo-hydraulic, linear drive, and resonance drive are used.

Means of measuring extension or deformation - Many tests require a measure of the response of the test specimen to the movement of the cross head. Extensometers are sometimes used.

Output device - A means of providing the test result is needed. Some older machines have dial or digital displays and chart recorders. Many newer machines have a computer interface for analysis and printing.

Tensile Testing :

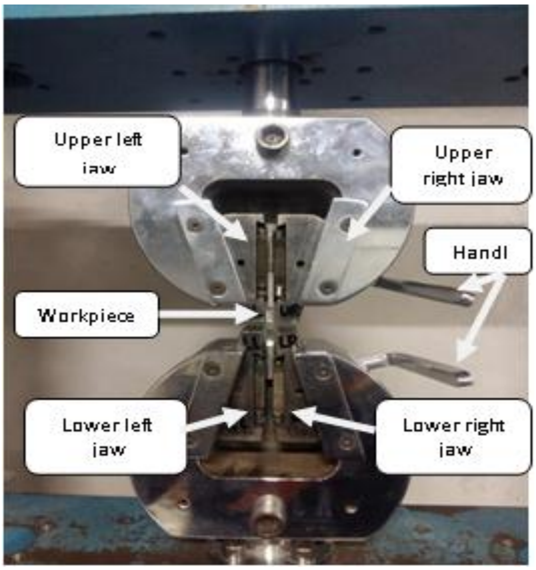


Fig 9: Tensile testing using UTM

Al alloy Sample:

Test Specimen: Properties of test specimen for Al alloy tensile test listed in table 2.

Parameter	Value(mm)
Length	100
Width	10
Thickness	4

TABLE 3: Properties of test specimen Al alloy

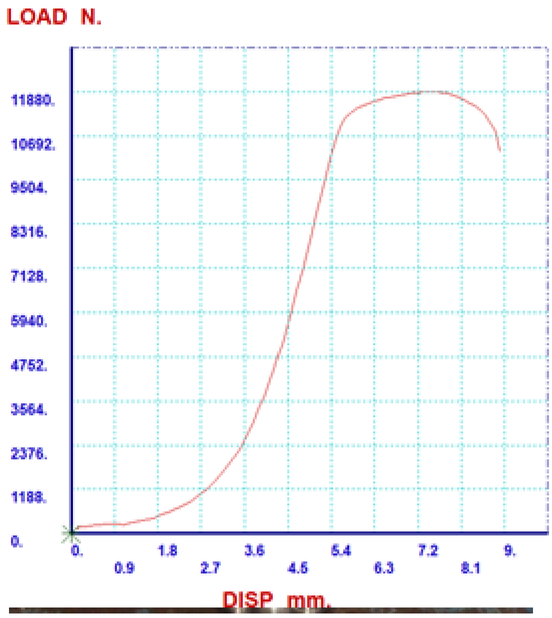


Fig.10: Tensile test-Load vs Deformation graph for Al alloy

Al alloy test sample take 11880 N up to deformation of sample 7.2 mm without failure. Al alloy strength from tensile test resulted as 349.34 MPa. Composite material

Test Specimen: Properties of test specimen for Composite material tensile test listed in table 2.

TABLE 4 : Properties of test specimen Composite material

Parameter	Value(mm)
Length	200
Width	20
Thickness	10

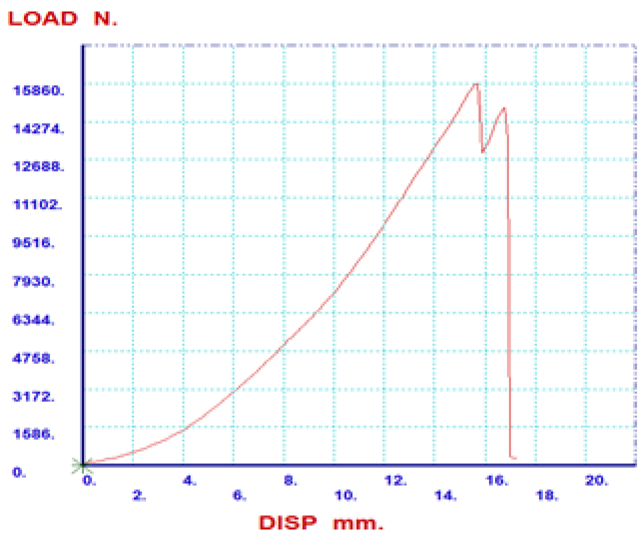


Fig.11: Tensile test-Load vs Deformation graph for Composite material

Composite material test sample take 15860 N up to deformation of sample 16 mm and after that it fail by fracture. Composite material strength from tensile test resulted as

267.48 MPa.

Compression Testing :

Test Specimen: Properties of test specimen for compression test listed in table5.

TABLE 5 : Properties of test specimen for compression test

Parameter	Value (mm)
Length	12.7
Width	12.7
Thickness	25

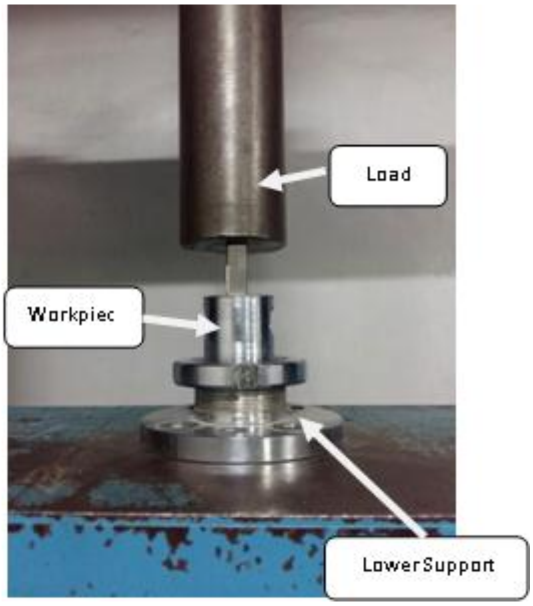


Fig 12: Compression testing using UTM

Al alloy Sample:

Following graph plot between Load vs Deformation for Al alloy hexagonal cross-section under compression. It show that load bearing capacity at various deformation .

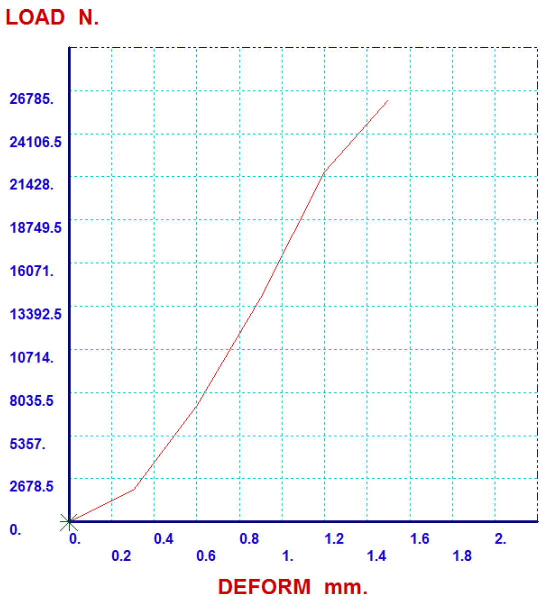


Fig.13: Compression test Load vs Deformation graph for Al alloy.

Above graph show that Al alloy hexagonal cross-section sample take load up to 26783.40 N at deformation 1.40mm without failure.

Composite Sample

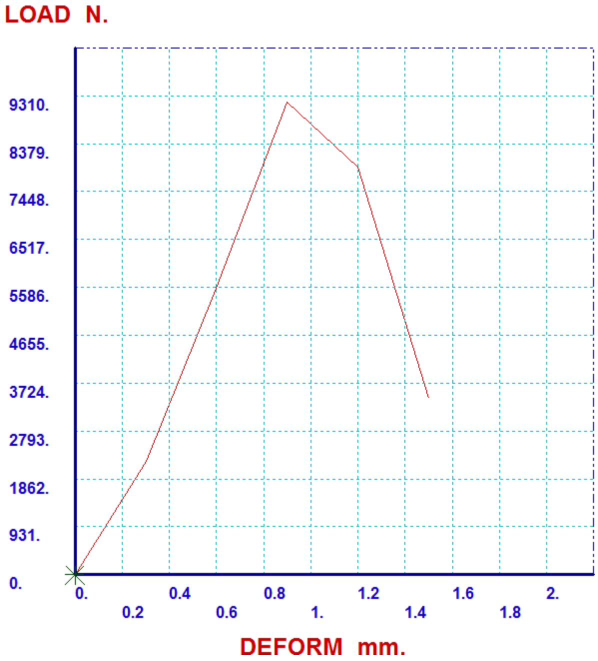


Fig.14: Compression test -Load vs Deformation graph for Composite material.

Above graph show that Composite material hexagonal cross- section sample take load up to 7918.40 N at deformation 1.20mm and after that it fail to withstand.

Table 6 :Compression Test Result

Sr. No.	Deflection in mm	Load at various deflection (N)	
		Al Sample	Composite Sample
1	0.15	558.60	940.80
2	0.30	1989.40	2195.20
3	0.45	4449.20	3777.90
4	0.60	7173.60	5566.40
5	0.75	10236.10	7389.20
6	0.90	13916.00	9192.40
7	1.05	17742.90	8879.80
8	1.20	21746.20	7918.40
9	1.40	26783.40	---

Impact testing :

TABLE 7 : Properties of test specimen Composite material

Parameter	Value(mm)
Length	110
Width	20
Thickness	10

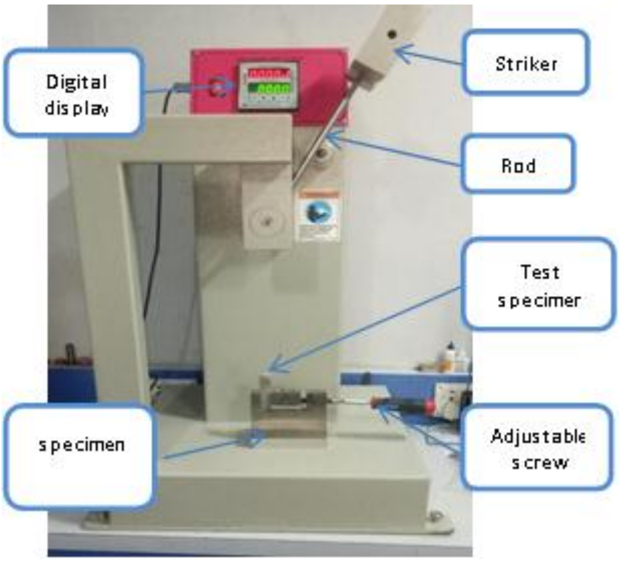


Fig 15: impact testing using izod impact tester

TABLE 8: Result of impact test of test specimen

Sr. No.	Test Specimen	Impact Value (J)	Izod impact strength (Kj/m^2)
1	Composite sample	17.20	252.79
2	Al alloy sample	27.29	358.19

Above impact test result table show that Al alloy sample is absorb more energy than composite sample. Above 3 test show that al alloy sample is better than composite sample. So we can say that Al alloy model withstand for given load and deformation without failure .

VII. CONCLUSION

From all the constraints the Al alloy hexagonal cross-section is best suitable cross-section for automotive bumper. This led to the conclusion that the chosen material of the bumper cross- section is safe and withstand to given stress condition well in its comfort zone.

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