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Analysis and Experimentation of Crash Box

Omkar Garud[1], Krishna S. Pawar[2], Prashant K. Thorat[3], Amit M. Waghmare[4], Sagar P. Chopade[5]
[1, 2, 3, 4,5]Mechanical Engineering, SRTTC FOE Pune, Maharashtra, India

Abstract*: A separate component in vehicle which is mounted in between main frame and front bumper of the car is called Crash box. The Crush Box is a thin-walled deformable structure attached between the vehicle bumper and the chassis. The Crush box is quite more important for absorbing the impact energy. In case of front car crash collisions, crash box is expected to deform and absorb crash energy that can be transferred to other cabin parts so that damage to the occupant cabin and occupant is minimized. The design of such structures for progressive crush is very important because if these structures deform at very high crushing forces there is high risk to bio-mechanical damage to the vehicle occupants. Hence it is important that the design of such structures should be to maximize the energy absorption while maintaining the peak force below an allowable threshold. Here, progressive crush is a mode of axial crush that initiates near the tip of the crash box and then progresses towards rear. Crash box structure provides safety and comfort to the passenger at the time of front impact. It works as safe guard for the costly components behind the bumper like engine hood and cooling system. In this project plane crash box geometry with varying thickness is studied for the energy absorption. Study is based on analytical, experimental and numerical work. Various parameters like width, thickness, taper which affects on the crash box performance are studied. Crash box crushing behavior is analyzed by using quasi static method. Experimental test is performed on UTM machine. Quasi-static simulation is performed using ABAQUS. Good agreement obtained in the results of analytical, experimental and numerical method. By varying the parameters and application of beads different designs are proposed and simulated for the maximum energy absorption. Application of various positioned beads show good influence on the energy absorption.
Keywords: Crash Box, Front collision, FEA analysis, Energy Absorption.

I. INTRODUCTION

Road transport is the dominant mode of transport in India, both in terms of traffic share and in terms of contribution to the national economy. To meet the demand for road transport, the number of vehicles and the length of road network have increased over the years. A negative externality associated with expansion in road network, motorization and urbanization in the country is the increase in road accidents and road crash fatalities. Traffic safety and car accidents have become a major topic for automotive research during recent years. The number of road users worldwide is continuously increasing, making the severe injury and mortality of people from car accidents a primary concern. With increase in number of vehicles every year, there is increase in number of accidental death.

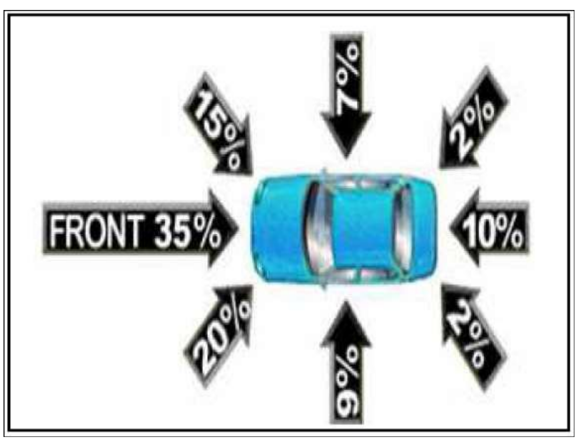

Fig. 1 Car Crash Illustration

Frontal car crash cause more deaths and injuries as compared to any other kind of car crash. The number one concern for drivers and passengers is safety. People expect driving or riding in cars to be very safe. A vehicle is expected to provide adequate protection to driver and passengers in a serious accident. To protect the occupants of a car, there are many new tangible safety features such as airbags, crash box, seat belts, and ABS brakes. Surviving a crash is all about kinetic energy. When your body is moving, it has a certain amount of kinetic energy. After the crash, when you come to a complete stop, you will have zero kinetic energy. To minimize risk of injury, you would like to remove the kinetic energy as slowly and evenly as possible. In frontal collisions, the body structure performs different functions. Nowadays thin walled structures have become very popular as energy absorbers because of their desirable energy absorption capacity, quite light weight and low cost. They are widely used in automobile, aerospace, defense and other industries. The front is designed to act as a crumple zone, managing and absorbing crash energy by collapsing in a controlled manner, so that the impact affects the car and not the occupants. Since the prototype laboratory tests are very costly in the design process, computer operation has been strongly demanded. In the last ten years or so, CAE (computer aided engineering) has developed a new branch Crash Simulation. The successful applications of finite element methods in this area are the key. The simulations are cheaper and faster than the real tests. Only a small number of real tests are performed for validating the simulation results and because the law requires them. Crashworthiness is a measure of the vehicles structural ability to plastically deform and yet maintain a sufficient survival space for its occupants in survivable crashes. This project aim is to study the Crashworthiness of a crash energy absorbing car structure.

A. Crash Box Principle

Crash box, which is equipped at the front end at car frame, is one of the most important automotive parts for crash energy absorption. In case of frontal crash accident, for example, crash box is expected to be collapsed with absorbing crash energy prior to the other body parts so that the damage of the main cabin frame is minimized and passengers are saved their lives. 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. 2.

Fig. 2 Crash box in the position of body

When low-speed collision occurs, crash box absorb impact energy and reduce the peak force of the impact. 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 KE were absorbed. In term to achieve the passenger comfort by ensuring there safety and to provide safe guard for the costly components behind the bumper like engine hood and cooling system we have to increase effectiveness and performance by increasing energy absorbing and deformation capacity of the crash box.

II. OBJECTIVE

As we all know, safety of a vehicle has been a primary area of interest and research since many years. There has been an ongoing search for better energy absorbing structures. Researchers have been trying to modify various parameters on materials and carry out research on them to determine their energy absorption capabilities.

A. The objective of this project is to find the effect of impact on different types of Energy Absorption tubes.
B. To investigate effect axial crush behavior of various structures energy absorption aluminum tubes through finite element analysis and experimentation

III.METHODOLOGY

In the design of metallic energy dissipating structures, the concept of a space frame composed of thin walled prismatic columns, has been identified as a very efficient impact energy absorbing system. In this structure types, energy absorption normally take place by a combination of progressive folding and bending of the column. For light weight designs, low density metal filler, such as aluminum honeycomb or foam, has the potential for increasing energy absorption of a thin-walled prismatic column. The increase of energy will be absorbed by the large compressive deformation of the filler. Recent developments of cost-effective processes for the production of low density cellular materials, such as aluminum foam, have cleared the way for using it in energy absorption devices to reinforce a space frame structure. There is a various methods that can be used to improve energy absorption capacity of crash box. As discussed above there are large number factor which affect the energy absorption capacity of the crash box. Instead of these filler material we can use the other filler materials such as various low density polyethylene materials. Other parameter which affects energy absorption is the shape. We have performed experiments and stimulation on various shapes and cross-sectioned crash box.

IV. FEA ANALYSIS

To check various parameters such as energy absorption capacity, various stress induced and to check whether the scope is available or not for the further improvement we have done some FEA simulation on the ABAQUS CAE software for the crash box designed in catia software for various models.

Dimensions of the model are 64x39.8x100 (length x width x height). The Figure 3 shows the model of the crush box as per the designed values used in current applications.

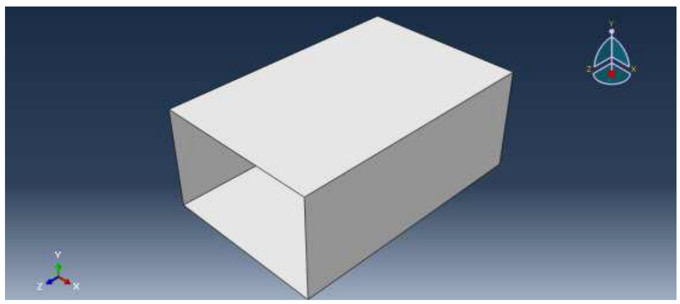

Fig. 3 CAD model of Crash Tube (Test no. 1)

A. Material Properties

Material specification of mild steel used for the analysis is listed below in Table 1.

TABLE I MECHANICAL PROPERTIES OF ALUMINUM

Property	Value
Density (kg /m^3)	2.78
Modulus of Elasticity (GPa)	68.3
Poisson's Ratio	0.34

B. FEA Boundary conditions

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. For this we have done assembly of the crush tube with two undeformable plates at the top and bottom of the tube. BC contains one end of the tube fixed at the lower plate and other side i.e. top side contains velocity conditions.

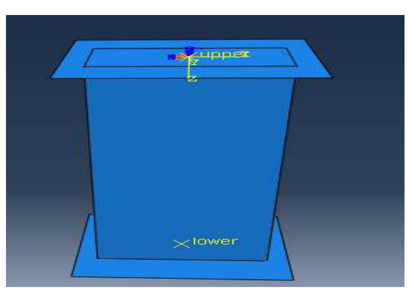

Fig. 4 Boundary Conditions

C. Simulation Result

Using the above inputs and the use of the abaqus CAE software various results obtained are as shown in Figures.

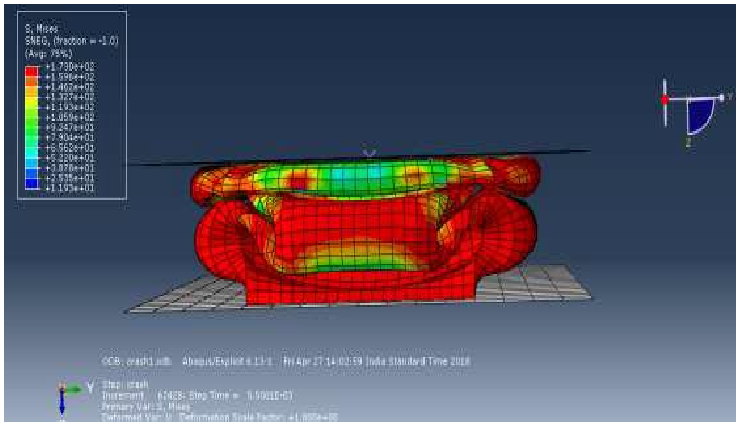

Fig. 5 Deformed Shape of The Crush Tube (Test no. 1)

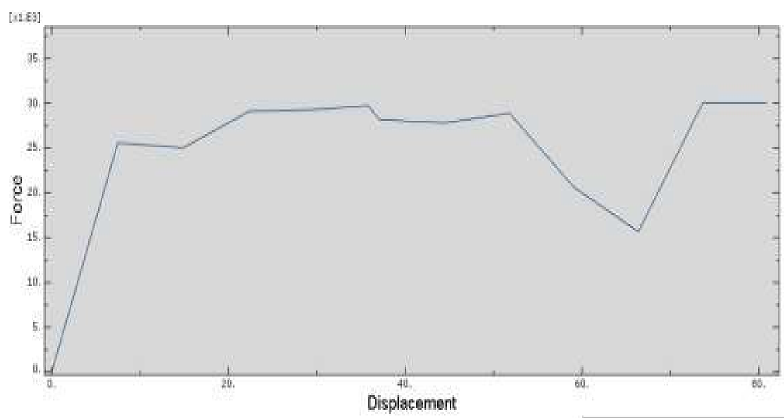

Fig. 6 Deformation Vs Force Plot (Test no. 1)

1) *Test No 2:* Dimensions of the model are 80x40x100 (length x width x height). The Figure 7 shows the model of the crush box as per the designed values used in current applications.

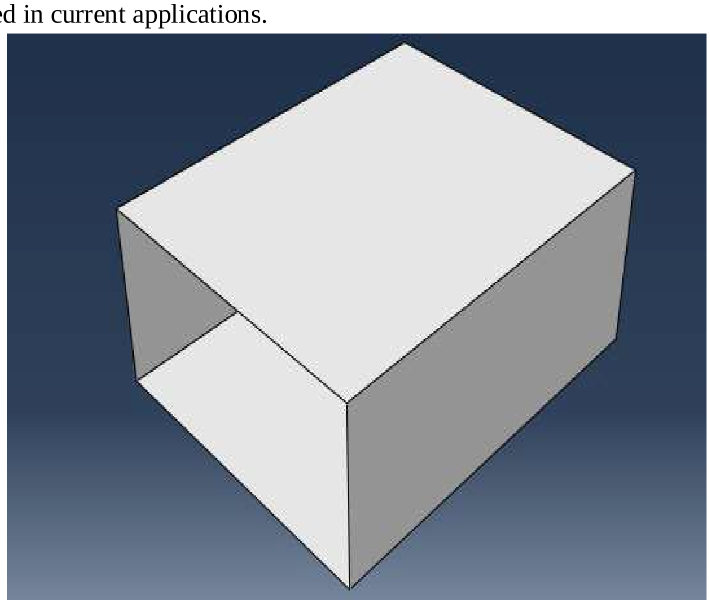

Fig. 7 CAD model of Crash Tube (Test no. 2)

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D. Material Properties

Material specification of mild steel used for the analysis is listed below in Table 1.

TABLE III MECHANICAL PROPERTIES OF ALUMINUM

Property	Value
Density (kg /m^3)	2.78
Modulus of Elasticity (GPa)	68.3
Poisson's Ratio	0.34

E. Meshed Crash Box Assembly

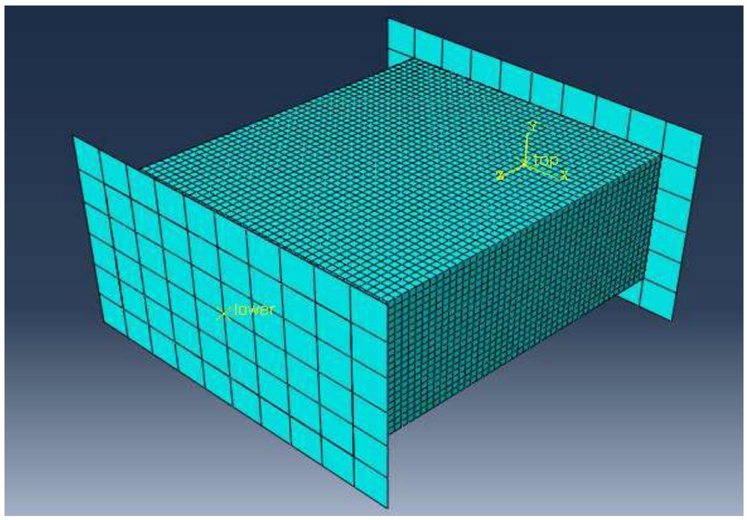

Fig. 8 Meshed CAD Assembly (Test no. 2)

F. Simulation Result

Using the above inputs and the use of the abaqus CAE software various results obtained are as shown in Figures.

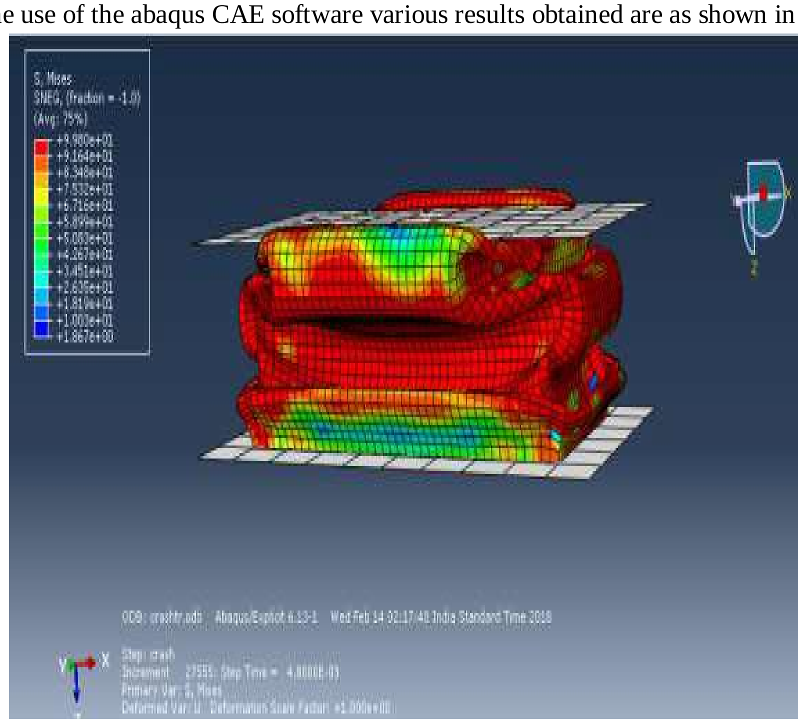

Fig. 9 Deformed Shape And Stress Contour Plot (Test no.2)

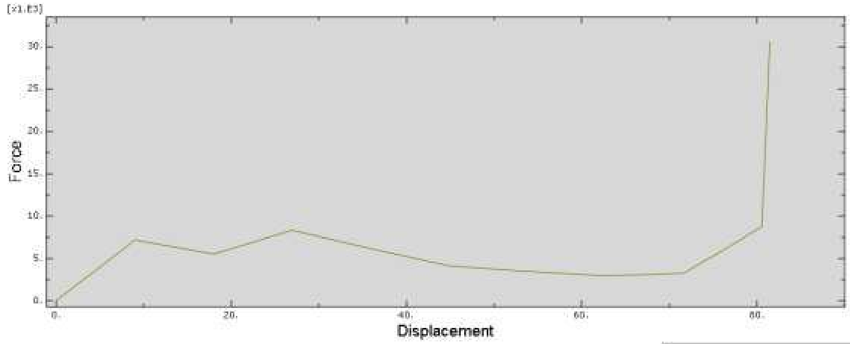

Fig. 10 Deformation Vs Force Plot (Test no. 2)

1) *Test No 3:* Dimensions of the model are 60x100 (diameter x length).The Figure 3 shows the model of the crush box as per the designed values used in current applications.

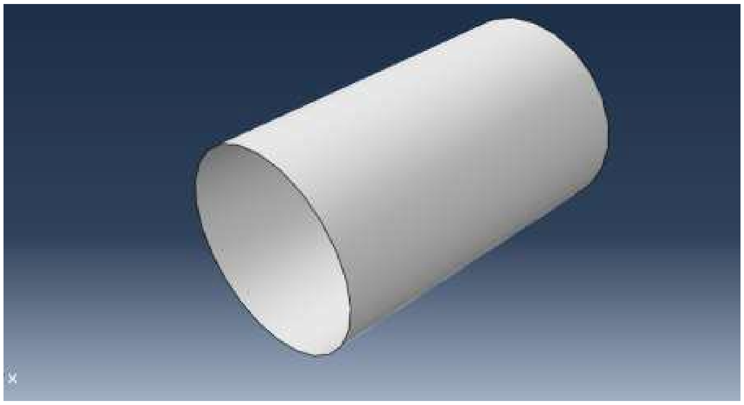

Fig. 11 CAD model of Crash Tube (Test no. 3)

G. Material Properties

Material specification of mild steel used for the analysis is listed below in Table 1.

TABLE IIIII MECHANICAL PROPERTIES OF ALUMINUM

Property	Value
Density (kg /m^3)	2.78
Modulus of Elasticity (GPa)	68.3
Poisson's Ratio	0.34

H. Meshed Crash Box Assembly

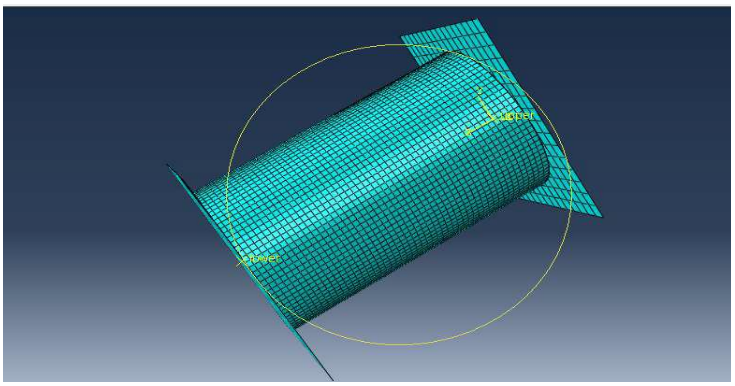

Fig. 12 Meshed CAD Assembly (Test no.3)

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I. Simulation Result

Using the above inputs and the use of the abaqus CAE software various results obtained are as shown in Figures.

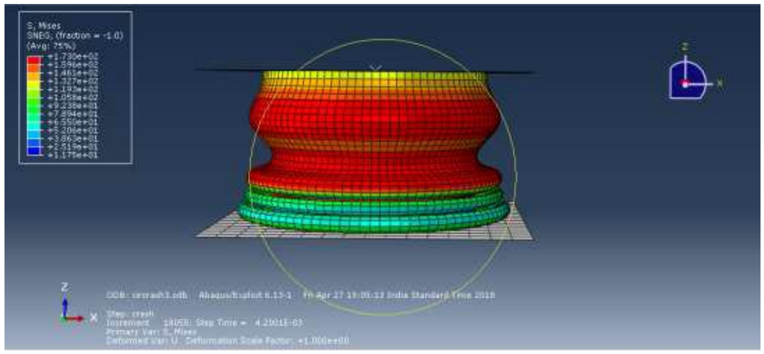

Fig. 13 Deformed Shape And Stress Contour Plot (Test no.3)

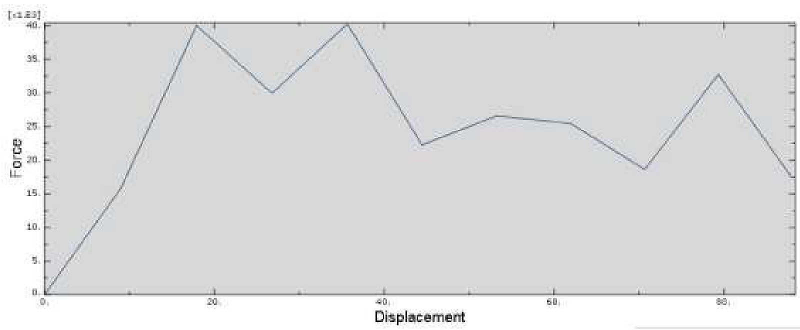

Fig. 14 Deformation Vs Force Plot (Test no. 3)

1) *Test No 4:* Dimensions of the model are 65x40x100 (length x width x height). The Figure 3 shows the model of the crush box as per the designed values used in current applications.

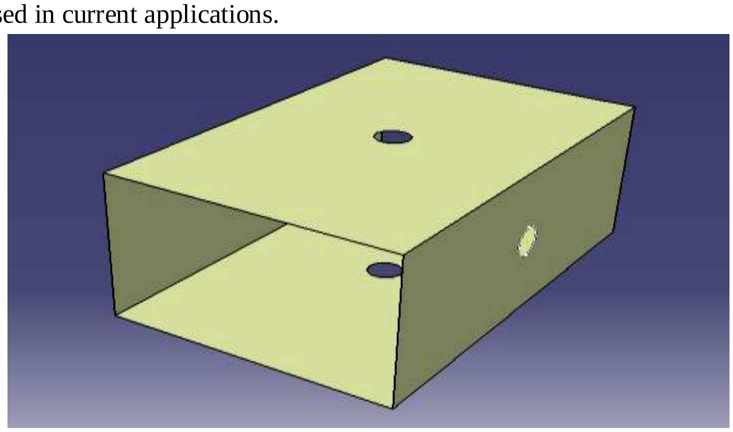

Fig. 15 CAD model of Crash Tube (Test no. 4)

J. Material Properties

Material specification of mild steel used for the analysis is listed below in Table 1.

TABLE IVV MECHANICAL PROPERTIES OF ALUMINUM

Property	Value
Density (kg /m^3)	2.78
Modulus of Elasticity (GPa)	68.3
Poisson's Ratio	0.34

K. Meshed Crash Box Assembly

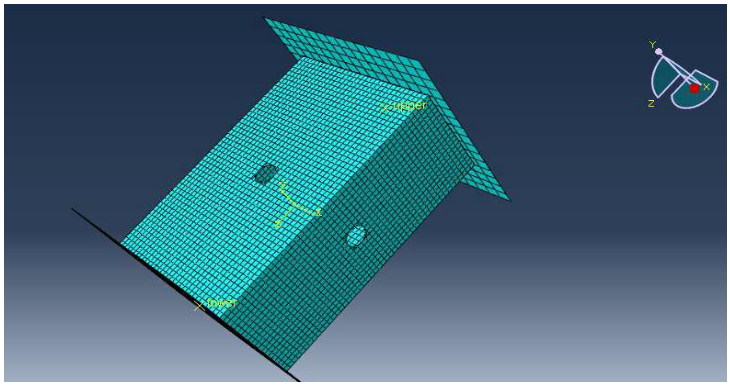

Fig. 16 Meshed CAD Assembly (Test no.4)

L. Simulation Result

Using the above inputs and the use of the abaqus CAE software various results obtained are as shown in Figures.

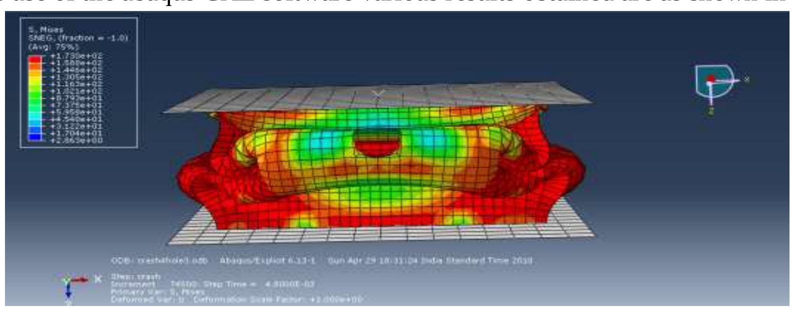

Fig. 17 Deformed Shape And Stress Contour Plot (Test no.4)

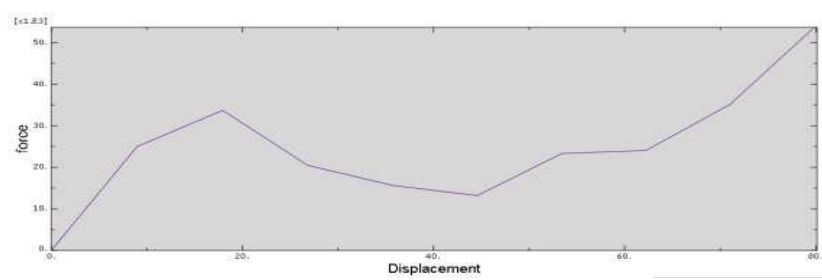

Fig. 18 Deformation Vs Force Plot (Test no. 4)

V. EXPERIMENTAL ANALYSIS

A. Test No 1

Fig. 19 Specimen After Complete Deformation (Test no. 1)

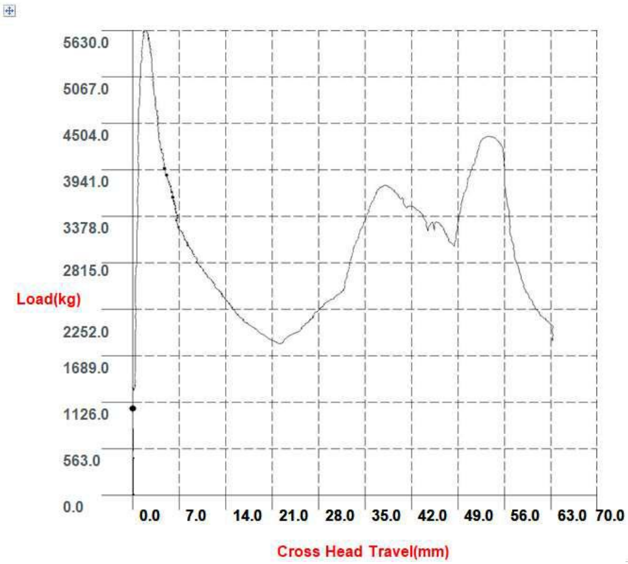

Fig. 20 Graph Of Load Vs Displacement (Test no. 1)

B. Test No 2

Fig. 21 Specimen After Complete Deformation (Test no. 2)

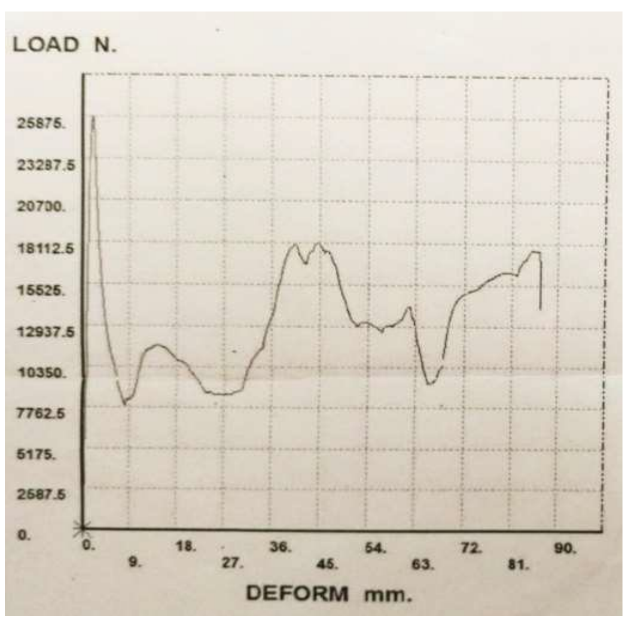

Fig. 22 Graph Of Load Vs Displacement (Test no. 2)

C. Test No 3

Fig. 23 Specimen After Complete Deformation (Test no. 3)

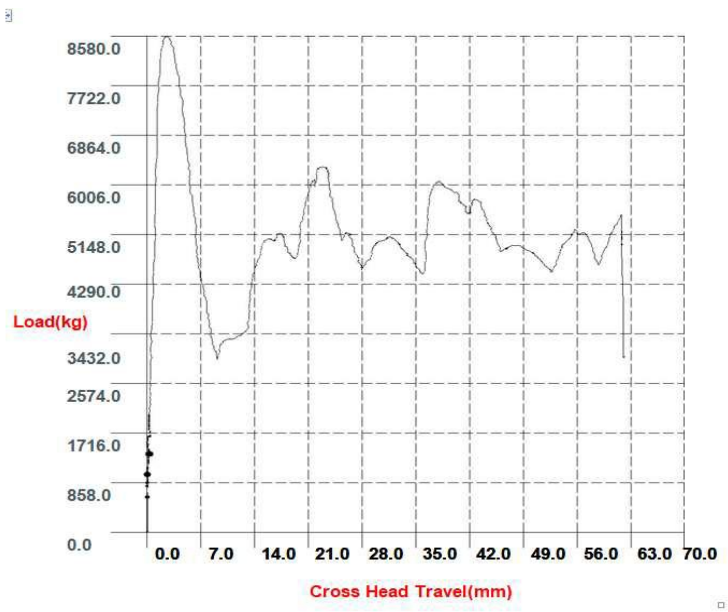

Fig. 24 Graph Of Load Vs Displacement (Test no. 3)

D. Test No 4

Fig. 25 Specimen After Complete Deformation (Test no. 4)

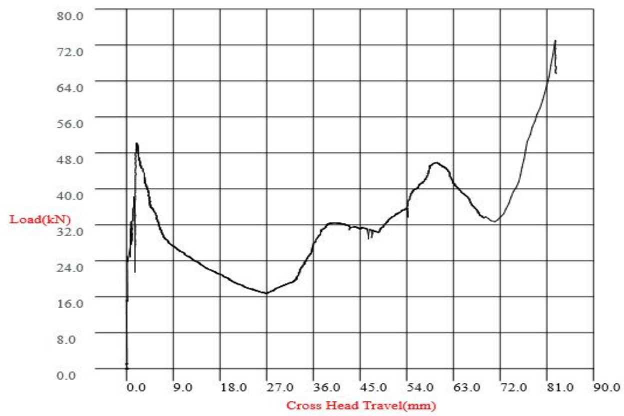

Fig. 26 Graph Of Load Vs Displacement (Test no. 4)

VI. ANALYTICAL CALCULATION

For any given sample of Rectangular Cross section Mean Crushing Pressure can be calculated with the help of following Equation,

$$Pm= K \times \sigma_0 \times b^{1/3} \times t^{5/3}$$

Where,

Pm= Mean Crushing Pressure
K==13.06
σo = Maximum Yield Stress
t = Thickness

For any given sample of Circular Cross section Mean Crushing Pressure can be calculated with the help of following Equation,

$$Pm= K \times \sigma_0 \times t^2 \times \left(\frac{d}{t}\right)^2$$

Where,

Pm= Mean Crushing Pressure
K==13.06
σo = Maximum Yield Stress
t = Thickness

VII. RESULT TABLE

Test	Peak Load (N)	Energy Absorbed		Percentage difference
		FEA (J)	Experimental (J)	
Test No 1 Rectangular c/s (65X40X100)	55230.3	2136.493	2347.454	9.87
Test No 2 Rectangular c/s (80X40X100)	25827.0	1015.854	1112.037	8.64
Test No 3 Circular c/s (OD=60 ID=56)	84169.8	2794.719	2901.177	3.66
Test No 4 Rectangular c/s with 4 holes (65X40X100)	52837.1	2852.349	3092.663	7.7

VIII. CONCLUSION

A. Experimental and numerical simulation by using ABAQUS Explicit Dynamic analysis is performed on plane crash box.
B. Good agreement found out in between analytical, experimental and numerical analysis result.
C. In the crash box there is increase in mean crushing load, and absorbed energy when we changes cross section from rectangular to circular or adding some irregularities like holes in rectangular cross sectioned tubes.
D. The crash box profile is improved and can fulfill the required objectives. Also we come to the conclusion that absorbed energy increases with increase in thickness.

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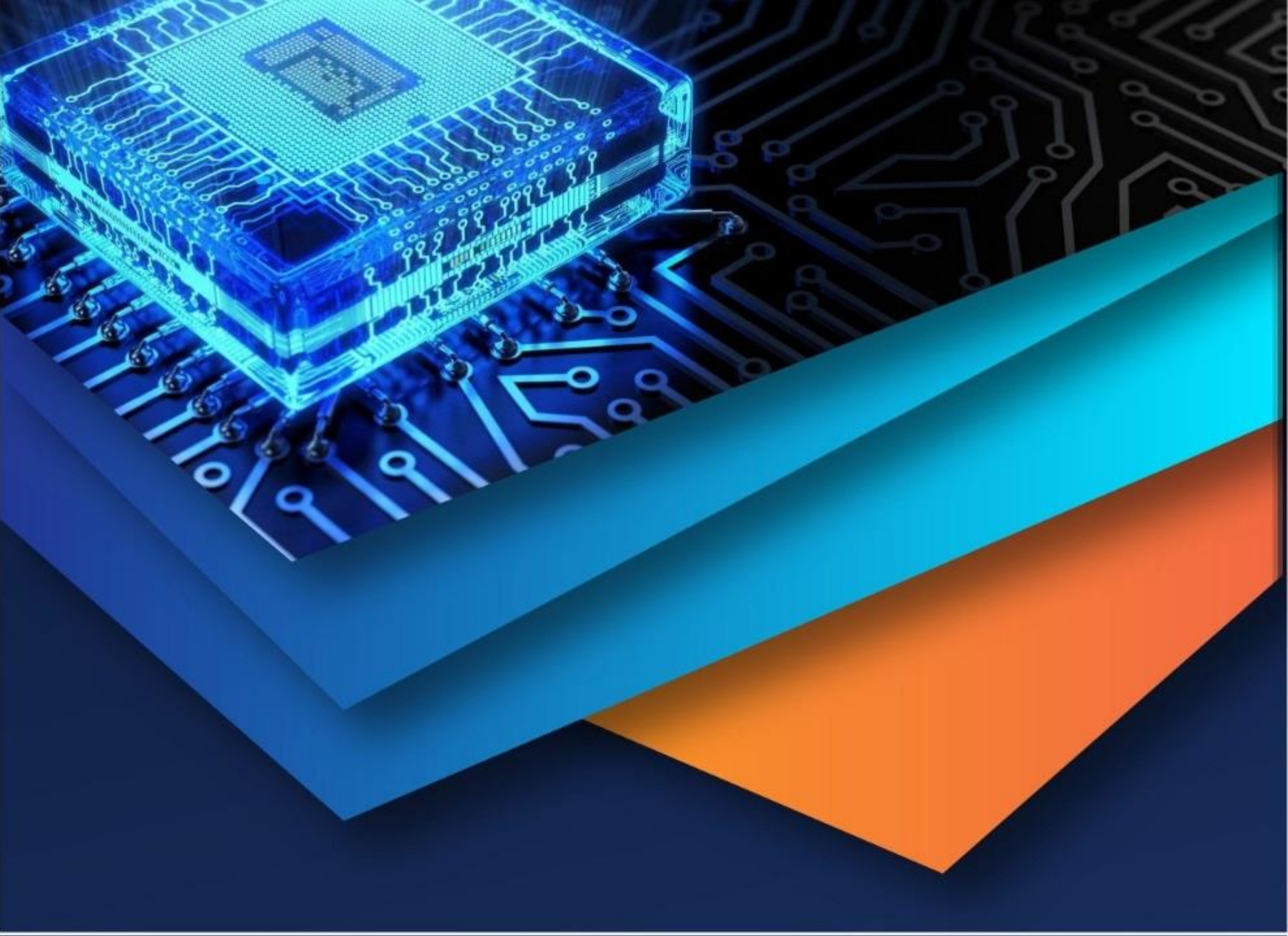

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