Effect Of Carbon Fiber Reinforcement On Square Aluminum Cross Section For Automotive Applications

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Abstract

The studies on thin- walled structures have concentrated on structural optimization substantially for enhancing crashworthiness and light weighting, whilst fairly little attention has been paid to analysis of cost effectiveness of an optimized structure. How to develop cost-effective products has always been a primary thing pursued by enterprises in different ways. To address this issue, this study aims to interpret a methodical approach for exploring the goods of colorful material grades and structural dimension (e.g. wall consistence) on cost effectiveness relative to crashworthiness performance. Crashworthiness of a material is a measure of its capability to absorb energy during a crash. A well-designed crash box is necessary in guarding the expensive vehicle factors. A square, cold-blooded ray of aluminum/ CFRP was subordinated to dynamic axial cargo. Mixes are effective, to deal with tensile loads, than essence. Nowadays, essences are replaced with mixes owing to their advanced strength to weight rate and are considerably used in automotive operations. Modeling and analysis of compound crash box was done on CATIA V5R21 & ANSYS workbench. Manufacturing of mongrel crash box will be done using open molding system. Testing of mongrel crash box performed on UTM for bending test.

Keywords- Crash boxes, impact, FEA, Impact Energy.

I. INTRODUCTION

The functional cost of either passenger vehicles or line is directly commensurable to the quantum of energy consumption. The energy consumption, in turn, is commensurable to the gross vehicle weight. Hence any reduction in the weight of the vehicle can bring in functional edge. Hence manufacturers have been trying to use advanced and featherlight material similar as CFRP mixes to achieve low weight to high strength rate (1). Thin- walled CFRP tubes are also used as energy absorbers in both aerospace and ground transport vehicles in place of essence(2). In the case of motorcars, many parameters are of significance to compare the effectiveness of the tubular designs. The most significant among these is the specific energy immersion capacity (ocean) of the tube which also considers the material with which the absorber is made up of.

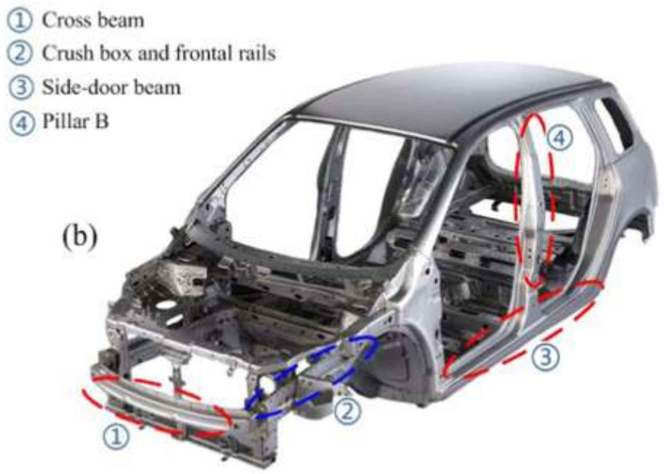


Fig 1- Crash box used in automobiles

A crash box is a vital element located between the side- rails and the cushion guarding passengers as well as the corridor that are precious to repair like cushion hood and radiator from serious damage during a anterior crash(1). They're designed to meet the low-speed impact regulations listed by the Research Council for Automotive Repair (RCAR) (2). Aluminum is a feather light relief that delivers excellent energy immersion compared to traditional accoutrements like sword. Important exploration has been done to prove the crashworthiness of Aluminum (3). Fiber corroborated polymers though precious are used for light weight vehicles to ameliorate its strength and crashworthiness with minimum increase in weight. Due to the presence of else acquainted filaments mixes have better energy immersion characteristics than essence (4). But essence are ductile while mixes are brittle therefore mixes cannot be used as collapsible crash boxes to absorb energy despite its graces. A mongrel ray is a essence tube carpeted with a particular polymer compound therefore retaining the rigidity of essence and energy immersion of mixes while adding the overall strength, stiffness and crashworthiness (5). Multitudinous experimenters conducted axial crushing trials on mongrel shafts. Crashworthiness of these was delved while considering different cross sections, accoutrements and different exposure of the filaments and ply (5- 17). An experimental analysis however necessary, is precious not to mention time consuming with a lot of query. Modeling and analysis software is a perfect mileage to constrict down the total number of cases so that experimental confirmation can be done for the most important and positive cases.

II. LITERATURE REVIEW

G. Balaji et al.(1) Experimental and numerical evaluation is performed on a square concave aluminum column, an aluminum honeycomb filled column, an aluminum column filled with concerted carbon fiber and an aluminum honeycomb at constant haste of3.06 mm/ s to dissect the axial crushing miracle at low speed axial loads. To validate experimental labors, numerical simulation is performed using PAMCRASH unequivocal finite element law. The goods of honeycomb core and carbon fiber corroborated aluminum honeycomb were anatomized experimentally and numerically. A decent agreement between experimental and numerical results is observed. The goods of distortion modes and force- relegation angles on these different structural columns were studied. Experimental and numerical results showed the square aluminum column filled with carbon fiber corroborated aluminum honeycomb was the most crashworthy combination, where the maximum increase of energy immersion, specific energy immersion and crush force effectiveness were over to60.6,27.8 and17.4 independently, compared with bare aluminum concave column.

GurpinderS. Dhaliwal et al.(2) mongrel compound laminates have been extensively regarded as a family of largely damage tolerant accoutrements with a high weight- saving eventuality. The main interference to full application of Hybrid Composite System in the automotive assiduity is their structural response as compared to monolithic accoutrements like Steel or Aluminum (AL). The main thing of this exploration is to probe the stiffness, weight savings, cargo carrying capacity, failure Modes of Al/

carbon fiber corroborated polymer(CRFP) mongrel compound system and validate the experimental results with computational Model. Mama

Quanjin et al.(3) The study aims to probe the effect of different infill pattern structures on the energy-absorbing characteristics of single hair crack carbon fiber- corroborated plastic tubes, single polylactic acid and cold-blooded carbon fiber- corroborated plastic/ polylactic acid tubes underuse-static axial contraction condition, which were fabricated using hair winding and cumulative manufacturing ways. The infill pattern structure plays an important part on the energy- absorbing characteristics in the inner single PLA and cold-blooded CFRP/ PLA tubes. Hair crack mongrel CFRP/ PLA tubes have implicit for enhancement of the energy- absorbing characteristics compared to inner single PLA and external CFRP tubes.

Nasir Hussain et al. (4) In case of a crash due to collision of vehicles, effective impact energy immersion by the vehicle safety structure is significant as it reduces the damage to the vehicle and its inhabitants. Factors made of compound accoutrements have a more complex mode of distortion, unlike essence, which in general deform with buckling or bending modes. The distortion mode of the element made of a compound is of great significance as the energy immersion position depends on it. Distortion mode can be modified by introducing special geometric features known as triggers in the design of the crash box. A detector can also be useful in achieving needed distortion mode and thereby helpful in attaining target energy and force values. The relative merit of crash boxes with different combinations of cross-sections and detector types for these parameters was assessed. The stylish performing combinations made from colorful notch triggers and different cross sections of crash boxes have been linked.

Gangadhar Biradar1 et al.(5) in this exploration it represents prosecution of crash confine the vehicle crash value operations, likewise its impact on energy absorbing limit by expanding its separator consistence and the conduct of the crash box at different pets. The Energy at mounding point is around 27,775 N- m. From the below classified rates, we can see that by expanding the mass of the blockish cross-area crash box to 4 mm energy consumed can be expanded to 25000 N- m which is exceptionally near energy at mounding point for illustration toward the morning of the effect 27775 N- m. At different pets the conduct of the crash box was comprehended, advanced the speed advanced the energy immersion and the energy are moved at a quicker rate to different pieces of the vehicle. The most significant finish of this examination is the adaptation in separator consistence for illustration 4 mm is absorbing further energy than 2 mm while 4 mm separator consistence can be employed in the vehicle gave it fulfills different factors, for illustration, the plan and mass of the crash box contemplations.

Se- Jung Lee et al.(6) in this paper it presents a plan strategy to decide the cross-sectional measures to ameliorate the energy adaption capability of the crash box. In the original step, the cross-sectional measures for the applied plan are resolved in two different ways. One is a parameter study exercising separate plan with a symmetrical cluster. The cross-sectional rudiments of the crash box are chosen among the accessible cross-segments videlicet a circle or a polygon. Three new feathers of crash box are recommended, with point by point shapes from the proposed plan fashion. When planning the structure of a vehicle, crashworthiness of the anterior structure ought to be considered to limit rubberneck injuries, to dwindle the effect energy moved to the vehicle body and to dwindle the fix cost of the vehicle. In a low- speed crash, damage to the vehicle and passenger injuries ought to be dropped as the crash box ingests the effect energy to the topmost. Calculated structure exercising topology streamlining with ESLSO gives an altogether new cross-area state of the crash box. The three crash boxes with new cross-sectional measures are acquired and these have high energy retention capacity and light mass. For crashworthiness improvement of the crash box, the parameters of strain energy, topmost clasping cargo and dislodging are employed as the responses.

Liu Yan- jie et al.(7) In the paper it presents auto crash box at low- speed impact by exercising Finite Element Method. The FE model of the cylinder was approved by looking at the exploratory issues and FE model outcomes. However, it's needed to be fell with retaining crash energy antedating other body corridor with the thing that the damage of the primary lodge figure is limited and trippers might be safe, If there should arise an circumstance of anterior crash mishap. Crash- box typically was made a cerebral refined walled tube. Results show that on normal the difference of these was outside 10 percent.

The respectable relationship of results acquired show that the numerical examinations are reliable. Crash- box of carbon sword and aluminum emulsion accoutrements are allowed about, it demonstrates that the peak impact power and topmost energy adaption have certain impact to energy retaining member with colorful accoutrements. The application of aluminum emulsion accoutrements, it demonstrates that accoutrements have certain impact to crash worthiness of energy retaining part.

Pawel Kaczyenski et al.(8) in this paper it presents the consequences of semi static and dynamic crushing experimental of tensed energy absorbing factors made of AZ31 magnesium combination wastes. Also, many inquiries concerning the energy immersion of thin walled structures made of AZ31B magnesium blend and application of applicable geometric shape permits to control the procedure of dynamic crushing and initiates another instrument of energy retention that's dynamic crushing. During the ruinous of void crash boxes, there was no impact of the strain rate fair and square of energy consumed. Strain rate impact was seen during the pounding of the aluminum head, which was described by 53 further noteworthy crashworthiness during the static tests. Thus, aluminum filled exemplifications consumed more energy during the semi static tests. Interaction impact between the crash box (magnesium compound), and its stuffing (aluminum head) have been watched. The energy consumed by filled crash boxes was 50- 70 advanced than the total of powers consumed by aluminum head and crash box singly.

Omkar Garud et al.(9) In this paper it presents crash box figure with changing consistence for the energy adaption and different parameters like range, consistence, strain which influences on the crash box prosecution are examined. The plan of similar structures for dynamic crush is significant handed that these structures distort at high smashing powers there's high hazard to bio-mechanical damage to the vehicle tenants. Then, dynamic pound is a system of vital crush that starts close to the tip of the crash box and subsequently advances towards back. Trial test is performed on UTM machine. Semi stationary recreation is performed exercising ABAQUS. Application of different situated points show great impact on the energy withholding. Good understanding discovered in the middle of investigative, test and numerical disquisition bring about the crash confine there’s proliferation mean crushing cargo, and assimilated energy when we change cross area from blockish to round or including a many irregularities like holes in blockish cross separated tubes. The crash box profile is bettered and can satisfy the necessary pretensions. Also, we arrive at the resolution that conformed energy supplements with proliferation in consistence.

Dhananjay Desai et al.(10) In this composition it present exploration on aero plane crash box figure for the energy retaining. Different parameters like range, consistence, strain which influences on the crash box prosecution are concentrated. Crash instruction smashing conduct is examined by exercising semi static fashion. Exploratory test is performed on UTM machine. By shifting the parameters and use of droplets colorful structures are proposed and recreated for the topmost energy assimilation. Operation of different positioned droplets show great effect on the energy immersion. Trial and numerical recreation by exercising ANSYS Explicit Dynamic examination is performed on aero plane crash box. In the crash box there’s proliferation mean smashing cargo, utmost reduced pounding cargo and consumed energy. It's concluded that consumed energy supplements with proliferation in consistence and with drop in strain edge. Likewise proliferation in number of sides of box influences basically on the energy immersion. Plan G1 is assessed as stylish plan as it has high energy assimilation with low introductory holding cargo.

Gabriel Jigaa et al.(11) The crash box is a vehicle design point that enhances impact performance and reduces damage to the vehicle body at impact speed. It can reduce form costs during collisions. This paper conducted numerical simulations on colorful crash- box models to find the optimal shape to reduce energy immersion by the side- member. The impact haste was 16 km/ h, and the stylish gets was achieved with an aluminum locker filled with PU. The blockish locker was the most inimical due to its large distortions, causing total damage to the vehicle structure. The sword locker was another option, with a0.4 difference in side member distortion. The internal energy was 4000 J, making it one of the most effective. The shock consumption during impact was 110 msec. still, there was a significant distinction between the sword blockish locker and the aluminum locker filled with PU froth. To reduce vehicle damage during collisions, the energy should be as low as possible (below 500 J, varying between vehicles).

R Raman et al(12) The addition of CFRP layers to a pure Aluminum ray increased its Specific Energy immersion and Crush Force Energy. The Al/ CFRP (0°/ 90)° mongrel ray offers the stylish conditions for maximizing both ocean and CFE. ABAQUS analysis results align with experimental results, making it an accurate tool for assaying crashworthiness of accoutrements, indeed mixes. In the Al/ CFRP(45°/-45°) n instance, both ocean and CFE bettered slightly, while the peak crushing cargo increased due to the scissoring effect of ± 45° carbon filaments.
Qiang Liu et al (13) the study delved the crashworthiness characteristics of CFRP square tubes filled with aluminum honeycomb. It explored cargo relegation angles, failure modes, and the impact of cell range on crushing parcels. Three distinct failure modes were observed stable progressive end- crushing (I), unstable original buckling(II), and collapse in themed-length(III). The average ocean of the filled tubes was lower than 70 for modes II and III, representing unstable failure modes. The peak cargo and absorbed energy increased by over 10 compared to bare CFRP tubes. The filled tubes with a 6 mm cell range of the aluminum honeycomb had slightly advanced ocean than the bare tubes. The energy immersion capability of the honeycomb- filled CFRP tube was advanced than the concerted effect of the bare CFRP tube and aluminum honeycomb alone, due to the commerce effect. The medium- viscosity stuffing tube showed the topmost stuffing effect, with an increased absorbed energy of471.43 J, original to8.93 of the total absorbed energy.

JunYuan Zhang et al (14) this paper examines the crushing performance of aluminum/ CFRP square tubes under axial lading using experimental and simulation styles. The results show that cold-blooded square tubes with single angle- bias (0) 4 and (45) 4 fall off from the aluminum tube, performing in Lower Ocean compared to pure aluminum tubes. In cold-blooded tubes with anti-symmetric angle- bias, CFRP and aluminum fold in stable symmetric mode, adding ocean up to 11 compared to pure aluminum tubes. The study also confirms that thin- walled tubes made up of identical accoutrements can ameliorate ocean by adding mass. Simulation results show that energy immersion decreases with the number of layers, with better immersion when the number of layers is n10. still, for cold-blooded tubes with identical aluminum consistence and small CFRP layers, the enhancement in ocean isn't apparent due to the drop in energy immersion capacity neutralize by the increase in mass. The enhancement in ocean comes from the increased mass of the tube and replacing aluminum amalgamation with CFRP.

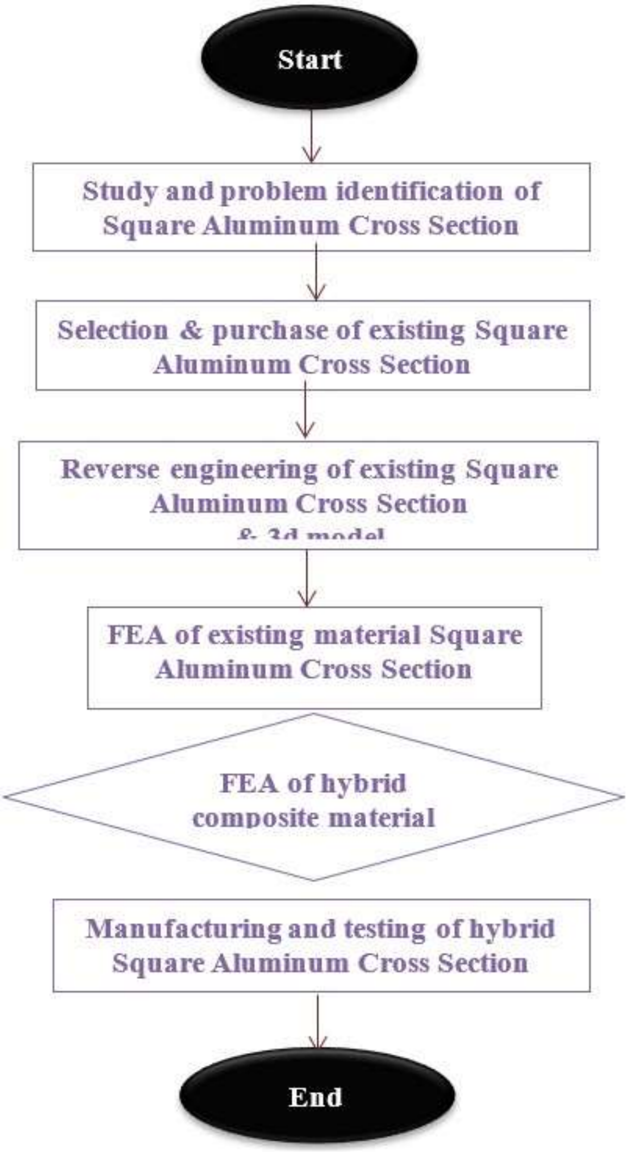
III. PROBLEM STATEMENT

The two most common forms of collision in auto crashes are anterior and lateral crashes. The crush box and auto anterior rails could probably suffer severe axial distortion during an anterior crash script, while the B- pillar, stave and roof rail, cross ray of the auto bumper, etc., experience side bending distortion under side crash. For this reason, both the axial and transverse crash characteristics should be considered in crashworthiness design

I. OBJECTIVES

- The present research work is to investigate the influence of composite reinforcement, on the bending strength, energy absorption and subsequent failure of hybrid composites crash box.
- Modelling and dynamic analysis of composite crash box was done on Catia V5R21 & ANSYS workbench.
- To perform experimental bending test on UTM and comparative study of optimized design of Hybrid Composite crash box.

II. METHODOLOGY



FINITE ELEMENT ANALYSIS

1. RECTANGULAR

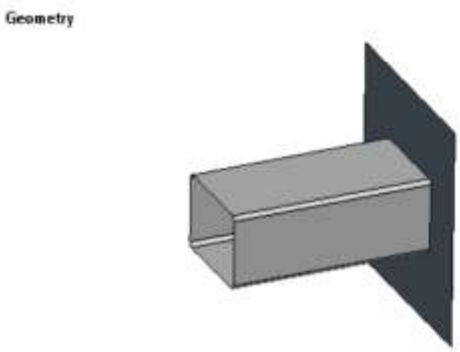


Figure Geometry of crash box

Material properties

Details of "Aluminum Alloy"

Common Material Properties	
Density	2.77e-06 kg/mm³
Young's Modulus	71000 MPa
Thermal Conductivity	table(T) = 0.14862 W/mm·°C
Specific Heat	8.75e+05 mJ/kg·°C
Tensile Yield Strength	280 MPa
Tensile Ultimate Strength	310 MPa

Meshing

As the main link of finite element analysis, grid division can best reflect the idea of finite element. The quality of the web site not only affects the efficiency of model analysis, but also directly affects the accuracy of analysis results. Therefore, according to the existing hardware, without affecting the accuracy of the calculation results, the method of dividing the mesh can be appropriately selected to save calculation time.

Statistics	
Nodes	5053
Elements	5023

Figure. Finite element mesh model of crash box

Final being piston mesh model, it contains 5053 bumps and 5023 rudiments. Element Types When shapes are complex or the range of length scales of the inflow is large, a triangular/ tetrahedral mesh can be created with far smaller cells than the original mesh conforming of quadrilateral/ hexahedral rudiments. This is because a triangular/ tetrahedral mesh allows clustering of cells in named regions of the inflow sphere. Structured quadrilateral/ hexahedral morass will generally force cells to be placed in regions where they aren't demanded. Unshaped quadrilateral/ hexahedral morass offer numerous advantages of triangular/ tetrahedral morass for relatively complex shapes.

• For simple shapes, use quadrilateral/ hexahedral morass.

• For relatively complex shapes, use unshaped quadrilateral/ hexahedral morass.

• For fairly complex shapes, use triangular/ tetrahedral morass with prism layers.

• For extremely complex shapes, use pure triangular/ tetrahedral morass.

Boundary condition

Under Static Structural analysis, 10m/ hr of haste is impact on the face of crashing box.

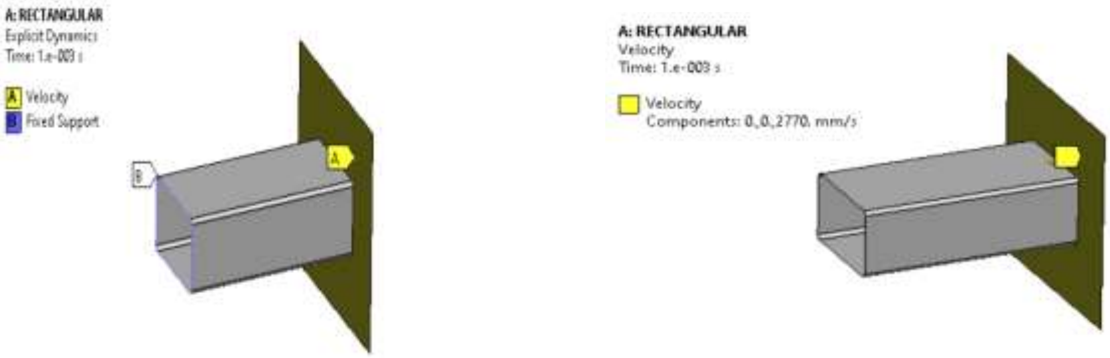


Figure. Boundary condition of crash box

Results:

1. RECTANGULAR

Total Deformation

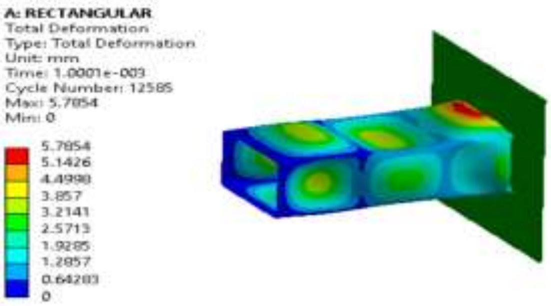


Figure. Total deformation of rectangular across section crash box

Equivalent stress

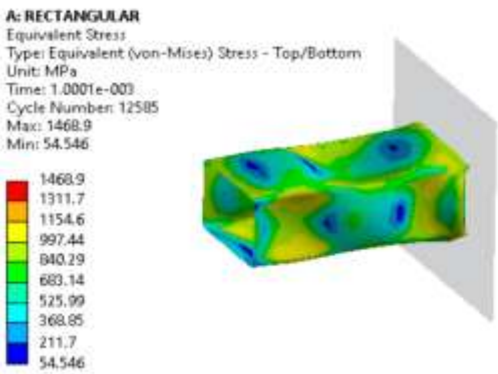


Figure. Equivalent Stress of rectangular across section crash box

Force Reaction

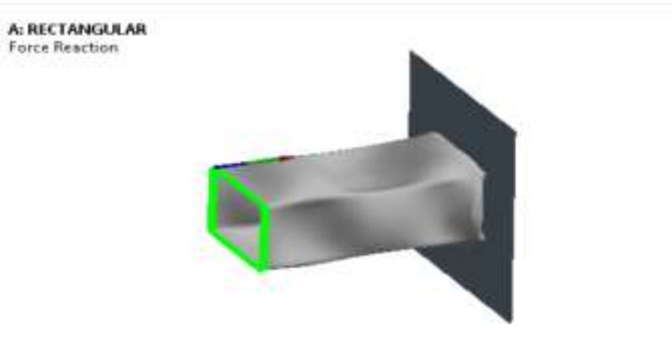
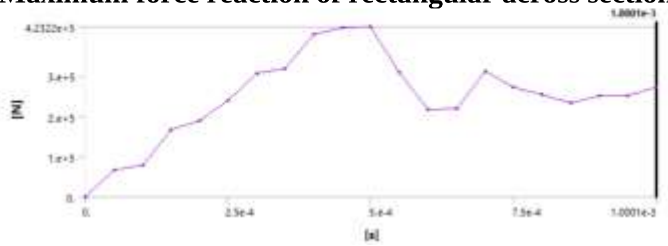


Figure force reaction of rectangular across section crush box

Maximum Value Over Time	
X Axis	4564.7 N
Y Axis	3634. N
Z Axis	0. N
Total	4.2322e+005 N

Maximum force reaction of rectangular across section crush box was



2. SQUARE

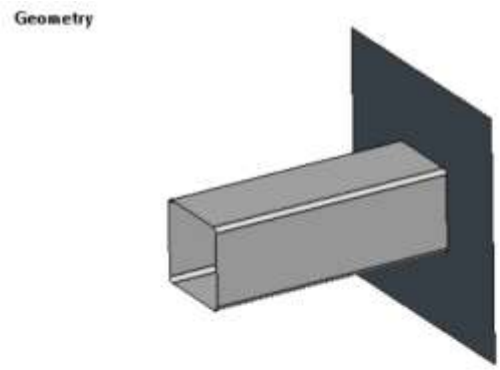


Figure. Geometry of crash box

Material properties

Details of "Aluminum Alloy"

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Density	2.77e-06 kg/mm³
Young's Modulus	71000 MPa
Thermal Conductivity	table(T) = 0.14862 W/mm·°C
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Tensile Yield Strength	280 MPa
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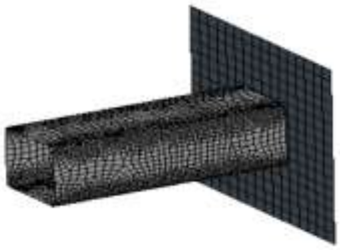

Statistics	
Nodes	4856
Elements	4822

Figure. Finite element mesh model of crash box

Final being piston mesh model, it contains 4856 bumps and 4822 rudiments. Element Types When shapes are complex or the range of length scales of the inflow is large, a triangular/ tetrahedral mesh can be created with far smaller cells than the original mesh conforming of quadrilateral/ hexahedral rudiments. This is because a triangular/ tetrahedral mesh allows clustering of cells in named regions of the inflow sphere. Structured quadrilateral/ hexahedral morass will generally force cells to be placed in regions where they aren't demanded. Unshaped quadrilateral/ hexahedral morass offer numerous of the advantages of triangular/ tetrahedral morass for relatively-complex shapes.

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340000444Boundary condition

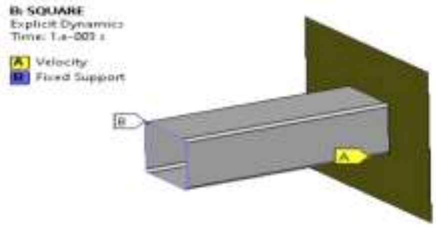


Figure Boundary condition of crash box

Results:

Total Deformation

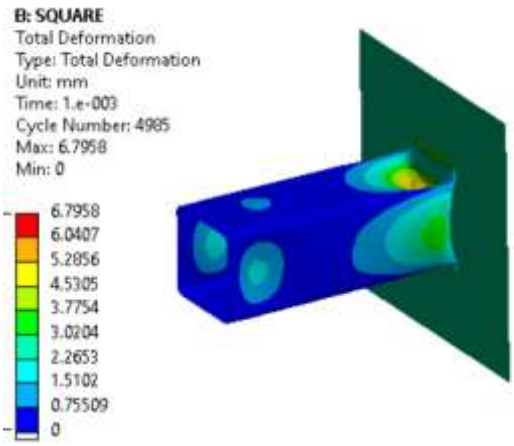


Figure. Total deformation of crash box

Equivalent Stress

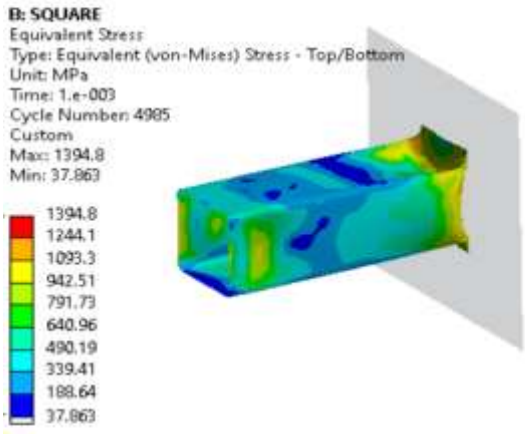


Figure. Equivalent Stress of crash box

Force Reaction

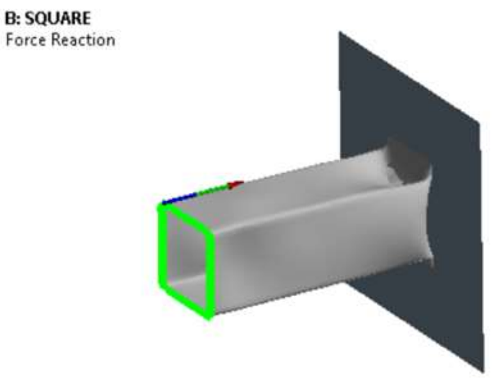
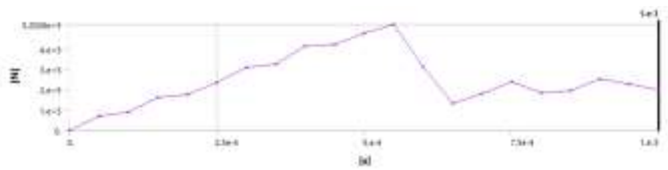
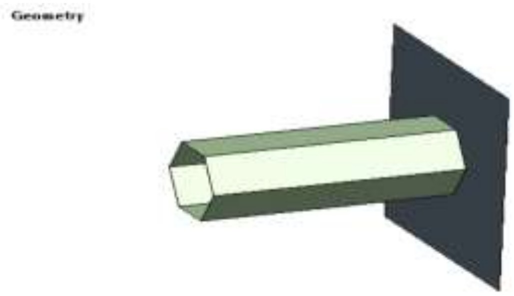


Figure force reaction of crush box

Maximum Value Over Time	
X Axis	5067.7 N
Y Axis	11045 N
Z Axis	0. N
Total	5.2026e+005 N



3. HEXAGON



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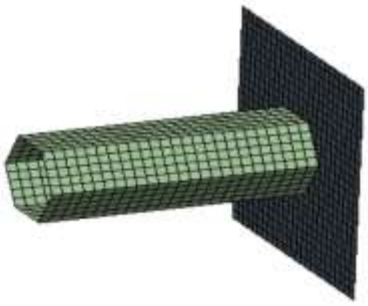

Statistics	
Nodes	1456
Elements	1375

Figure. Finite element mesh model of crash box

Final existing piston mesh model,it contains 1456 nodes and 1375 elements. Element Types

When geometries are complex or the range of length scales of the flow is large, a triangular/tetrahedral mesh can be created with far fewer cells than the equivalent mesh consisting of quadrilateral/hexahedral elements. This is because a triangular/tetrahedral mesh allows clustering of cells in selected regions of the flow domain. Structured quadrilateral/hexahedral meshes will generally force cells to be placed in regions where they are not needed. Unstructured quadrilateral/hexahedral meshes offer many of the advantages of triangular/tetrahedral meshes for moderately-complex geometries.

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- For moderately complex geometries, use unstructured quadrilateral/hexahedral meshes.
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- For extremely complex geometries, use pure triangular/tetrahedral meshes.

Boundary condition

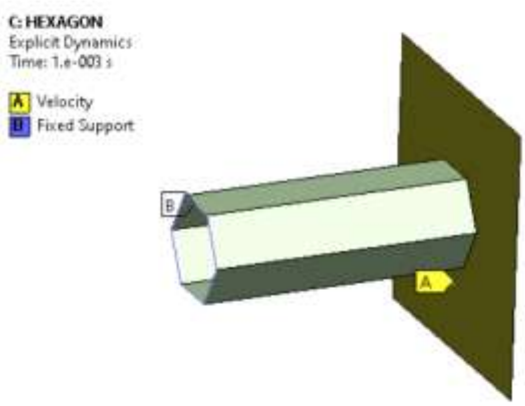


Figure. Boundary condition of crash box

Results:

Total Deformation

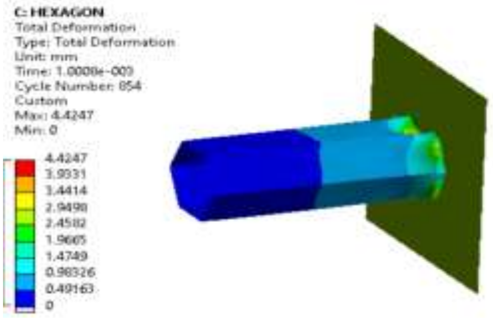


Figure. Total deformation of crash box

Equivalent Stress

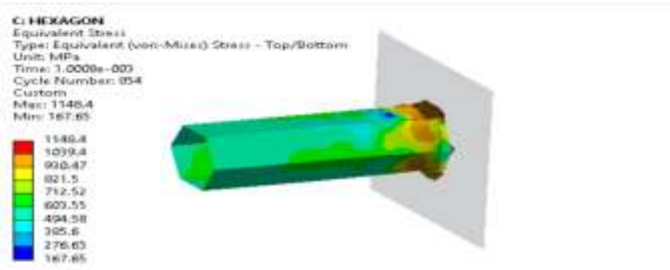
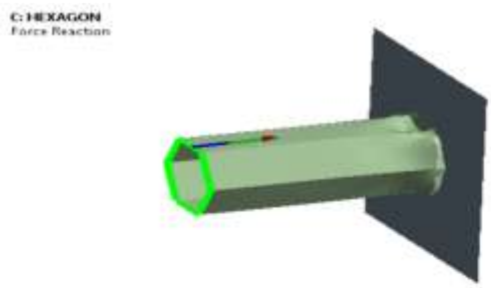


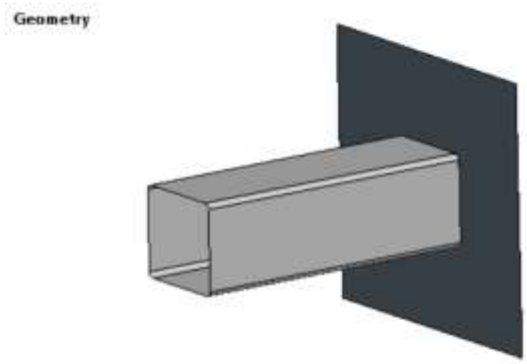
Figure equivalent stress of crash box



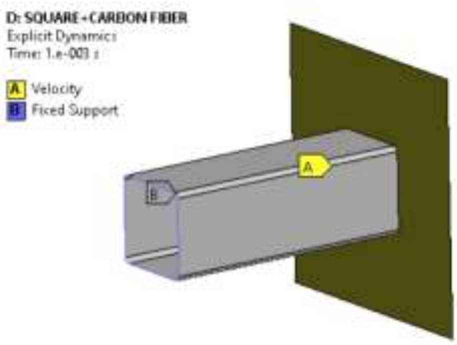
Force Reac

Figure Force Reaction of crash box

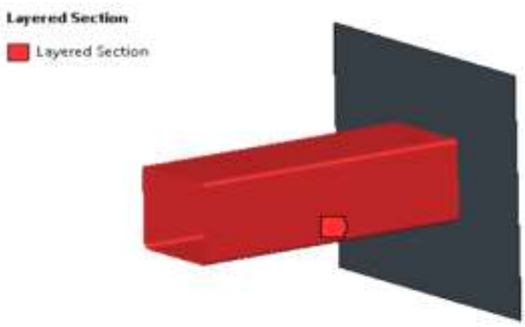
Maximum Value Over Time	
X Axis	2953.1 N
Y Axis	5494.9 N
Z Axis	0. N
Total	4.5745e+005 N



4. SQUARE+
Figure Geometry of crash box

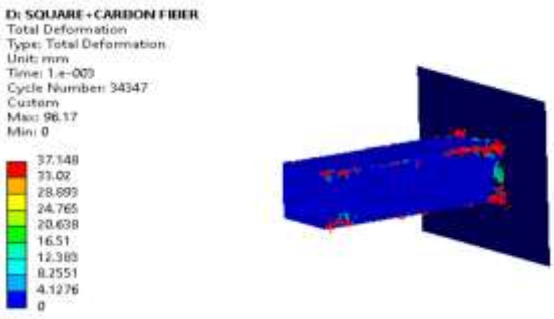


LAYERED SECTION

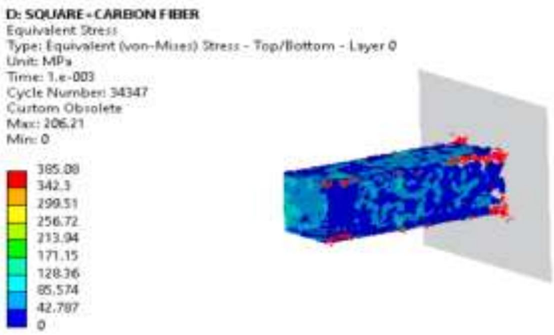


Results:

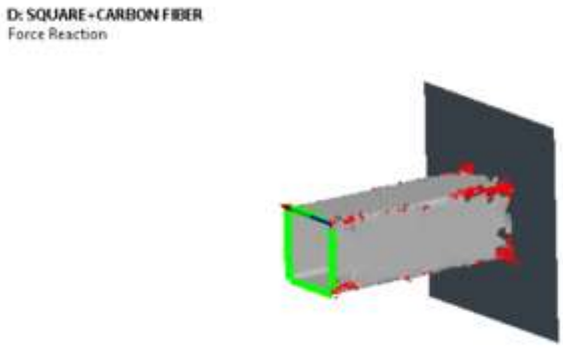
Total Deformation



Equivalent Stress



Force Reaction



Maximum Value Over Time	
X Axis	22690 N
Y Axis	26498 N
Z Axis	2.6113e+005 N
Total	5.288e+005 N

COMPARISION BETWEEN ALL CROSS SECTION

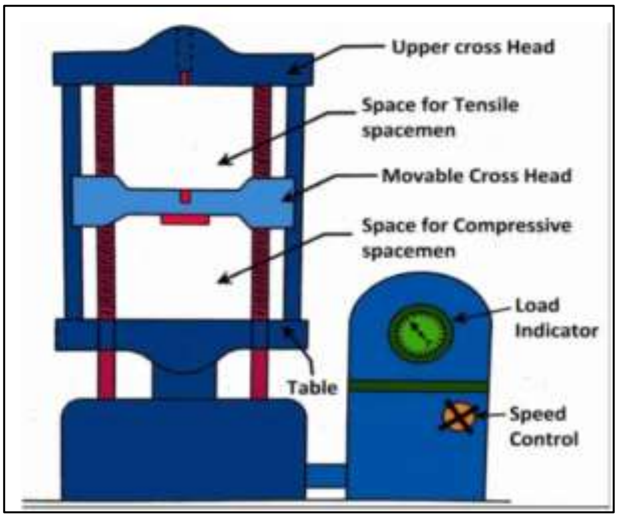
EXPERIMENTAL ANALYSIS

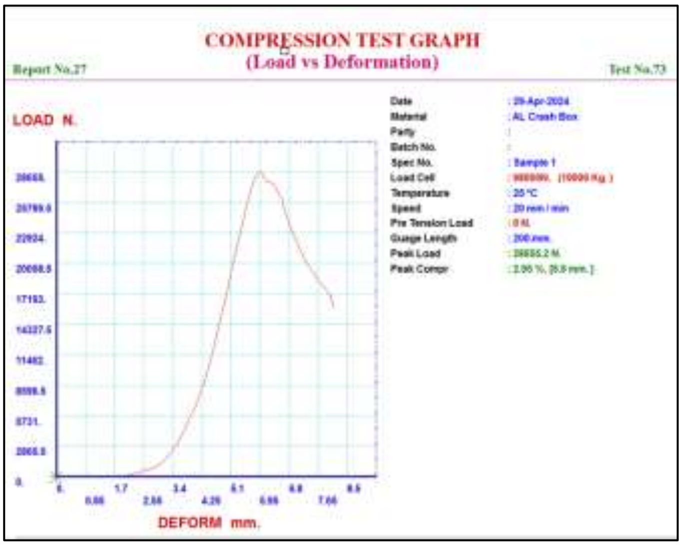
A Universal Testing Machine (UTM) is used to test both the tensile and compressive strength of accoutrements. Universal Testing Machines are named as similar because they can perform numerous different kinds of tests on an inversely different range of accoutrements, factors, and structures.

Universal Testing Machines can accommodate numerous kinds of accoutrements, ranging from hard samples, similar as essence and concrete, to flexible samples, similar as rubber and fabrics. This diversity makes the Universal Testing Machine inversely applicable to nearly any manufacturing assiduity.

The UTM is a protean and precious piece of testing outfit that can estimate accoutrements parcels similar as tensile strength, plainness, contraction, yield strength, elastic and plastic distortion, bend contraction, and strain hardening. Different models of Universal Testing Machines have different cargo capacities, some as low as 5kN and others as high as 2,000 kN.

CROSS SECTION	Force Reaction	Equivalent (von-Mises) Stress
RECTANGULAR	423.22KN	1468.9
SQUARE	520.26KN	1394.8
HEXAGONAL	457.45 KN	1148.4
SQUARE+CARBON FIBRE	528.8 KN	385.08





CONCLUSION

The incorporation of carbon fiber reinforcement into a square aluminum cross-section significantly enhances its mechanical properties, making it a promising candidate for various automotive applications. By combining the lightweight characteristics of aluminum with the exceptional strength and stiffness of carbon fiber, the hybrid structure demonstrates superior performance. This project has investigated the crashworthiness of aluminum crash boxes with rectangular, square and hexagonal cross sections. In the FEA simulation of the single part model, the square cross section shows higher reaction force and mean load than the other two cross sections. The simulation result shows that the square cross section shows the best performance as a crash box. From FEA analysis it concludes that carbon fiber reinforced square cross section has maximum reaction force that was 528.8 KN

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