# Title: Experimental and Analytical Investigation for Impact Behavior of Different Shapes of Crash Box

**Dnyaneshwar B. Kahane[1], K.V.Chandratre[2]**

*[1]Student, Department of Mechanical Engineering, G.E.S.COE, Nashik, kahane.db@gmail.com*
*[2]Asst.professor, Department of Mechanical Engineering, G.E.S.COE, Nashik*

## ABSTRACT

***Crash box is a device mounted between front bumper and main frame of car in order 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. 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.***

***In this study, crushing behavior of crash boxes is determined at deformation. Crushing of boxes is simulated using ANSYS. Results of study showed good co-relation between simulations, experimental results. Parts with different designs are simulated using numerical method and optimized design with increased energy adsorption capacity, elastic strain and minimum deformation is proposed.***

***Keywords: Crash box, Crushing load, Energy absorption, FEA, ANSIS.***

---

## I.INTRODUCTION

Crash box is a device mounted between front bumper and main frame of car in order 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. In this study crash box of different geometry is studied for energy absorption capacity experimentally and results of this study are compared for calculating accuracy of FEA method. Study of different designs of crash boxes are undertaken to optimize the design for maximizing energy absorption capacity, elastic strain and minimizing deformation and minimizing cost of the component. [6].

**Fig-I crash box [6]**

During last decade large number of article have considered crash performance of thin walled metallic column used in automotive and aerospace application, as a crash absorbing element in automotive application crashworthy structure absorb impact energy in control manner thereby bringing passenger compartment to rest without subjecting occupant to high deceleration. Crash box absorb energy progressively folding and bending as column wall collapse. Rate of energy dissipation is concentrated over narrow zones. Remaining structure remains rigid. [4]

Also protect expensive vehicle component. Numerous previous works have attempted to determine material of crash box. They considered low carbon steel, low alloy steel and aluminum alloy. Different cross section gives different impact strength. [11]Composites with specially design lay-up sequences can absorb much more energy than metal. However

Composites are brittle so it is impossible to apply composite structure as collapsible absorber. In superlight weight electric vehicle hybrid material is considered. Impact analysis of different shapes cross section achieved using ANSYS. Finite element software & result compare experimentally& theoretically correlate and the result. [11]

CRASHWORTHINESS:-Crashworthiness is an ability of structure to pretend its occupants during an impact. This

Is commonly tested when investigating safety of aircraft and vehicle depending on nature of impact and vehicle involved. Different criteria are used to determine the crashworthiness of structure. Were assessed using computer models[6]

## TYPES OF CRASH BOX:-

**Carbon Fiber Crash Box:-**Carbon fiber reinforced polymer or often carbon fiber is extremely strong and light fiber reinforced plastic which contain carbon fiber. Polymers that are usually used for binding are mainly thermo set resin. Epoxy is one of the thermo set resins. Sometimes in some cases other thermoplastic is also used. Such polymers are polyester or nylon. The required strength and rigidity of a carbon fiber reinforced polymer is obtained from reinforcement which is measured stress and elastic modulus accordingly. Unlike isotropic material like steel and aluminum CFRP has a directional property.


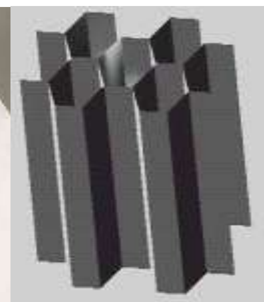

**Fig.II circular carbon fiber crash box Fig. III Structure of honeycomb crash box [7]**

CFRPs demonstrate excellent corrosion resistance; the effect of moisture at wide range of temperatures can lead to the degradation of mechanical properties of CFRP, particularly at matrix-fiber interface. Carbon fiber crash box are light weight compare to other conventional crash box made of steel. Carbon fiber normally used in super cars in normally, but now many car makers and modifiers are starting to use it for replacement body parts on everyday cars. [7]

**Aluminum Honeycomb Sandwich Crash Box:-**As from the name we know that it has geometry of honeycomb which minimizes amount of material used. Due to this it causes to lower its cost and weight. The aluminum honeycomb is produced by expansion process. This type of construction consists of two thin facing layers separated by core material. The aluminum honeycomb panel provides light weight, high rigidity and high structural stability. [7]

**Steel Crash Box:-**Steel front crash box mostly used in off road vehicles which has coating to influence the corrosion life of crash box. Steel is often e-coated and then printed or powder coated. Steel crash box is made up of a bare steel and then e-coated and then powder coated. Steel crash box are coated with zinc which improves the life of steel by discouraging or preventing corrosion. In past steel crash box was very thick to which it increases the weight. Now days because of new technology gauge of steel decreases and its strength increases. [7


**Fig. IV steel crash box [7] Fig.V structure of metal foam crash box [7]**

**Metal Foam Crash Box:-**The metal foam has cellular structure which consists of a solid metal as well as it has pores which makes it an ultra-light material. The aluminum and its alloy have low density due to which it is used as metal foam. Crash box made up of metal foam possess high compressive strength. Generally there are two types of foam open and close type. In automotive industry for making of crash box mostly closed type is used which provides optimal energy absorption. Many automakers make use of aluminum foam crash box which is placed between impact beam front rails of car. During collision at low speed of about 15km/hr they deform and absorb all energy thus protecting all valuable parts of front of the car frame. [7]

## LITERATURE SURVEY:-

**1. Ince F. et al. [2011]:** In this study impact behavior of crash boxes made of steel and aluminum material are investigated experimentally and numerically. The crash test is performed by using drop test unit. Crash test is modeled using ANSYS finite element software. Result of crash tests are compared with finite element result. Impact force during crash is also compared with forces obtain during finite element method. Results are found to be in an agreement. The impact behavior of hybrid box made of steel and aluminum is also investigated numerically. Analyses are performed changing parameter such as aluminum to steel weight ratio. Crash box optimized based on deformation to obtain minimum weight.

**2. Qureshi O.M. and Bertochi E. [2011]:** in this study, crash behavior of thin walled box beams with sinusoidal relief pattern is studied. Reference specimen is selected for which analytical formulation is done and Finite element analysis software for numerical solution HYPERMESH mostly used software in automotive industry is used. for 5mm size of mesh impact test is get done, then graph of reaction force verses displacement are plotted and By assuming more models optimized model is selected. Many types sinusoidal pattern were embedded in box beam surface and their performance as crash absorber was assessed.

**3. Kim H.C., et al. [2014]:** crashworthiness characteristics and axial collapse with damage proportion behavior of an aluminum/CFRP hybrid square hollow section beam were investigated under dynamic axial crushing load. Low speed impact test is preferred to RCAR regulation preferred to five lay-up sequences and two different thicknesses. Both tip end of hybrid specimen were clamped by specially designed Jig to assign similar boundary condition with auto body crash test modes. Different direction carbon fiber offer different characteristics and together all they show different characteristics mixed. Energy absorbed improves up to 30% to 38% that improve by improving thickness of CFRP.

**4. Rusinek A., et al. [2008]:** The aim of study on dynamic loading in adiabatic condition of deformation is to analyses effect of elastic wave propagation Combined with plastic behavior on collapse site or rectangular tubular structure made of steel. To demonstrate strong coupling between the effects of strain rate sensitivity with process of an elastic wave reflection on boundary condition, series of numerical simulation was performed. It shows that numerical study that strain rate sensitivity influences the position of the first collapse site. First collapse initiation of structure defines level of power absorption. Since process of folding may be combined with bending of structure in this non-axial case energy absorption Wp decreases & effectiveness of structure to energy absorption is insufficient.

**5. Toksoy A.K. and Guden M. [2010]:** The crushing behavior of partially aluminum closed cell foam filled commercial 1050H14. Aluminum crash boxes were determined at quasi static & dynamic deformation velocities. Quasi static & dynamic crashing of boxes is stimulated using LS-DYNA. Result show that partial foam filling tended to change the deformation mode of empty boxes form non-sequential to sequential folding mode. In general experimental & simulations result show similar mean load value & deformation modes. The SEA empty, partially & fully foam filled boxes were predicted as function of box wall thickness between 1mm to 3mm foam filler relative density between 0 & 0.2, using analytical equation developed for load analysis indicates that both fully& partially foam filled boxes were energetically more efficient than empty boxes above a critical foam filler relative density partially foam filling, however decreases the critical foam filler density at increasing box wall thickness.

**6. Peroni L., et al. [2008]:** Aim of study is progressive collapse behavior of same thin walled closed section structural section made form deep drawing steel & joined with different joining system .solution taken of different continuous joining technologies. Non conventional for automotive construction are examined & compared to usually spot welding. Different type of adhesives & laser welding considered. Collapse influence by loading rate, material used, static & impact loading condition were examined. Even weaker adhesive gives excellent result. Adhesive gives continuous correction of sheets absorbs much energy.

Laser welding gives better result compare to spot welding, improved stability in laser compare to other joining.

**7. Li N., et al. [2015]:** In this study occupant responses & injuries are important consideration in design & assessment of roadside safety devices such are barrier. In previous work occupant responses & injury risk are evaluated vehicle responses but in this case responses taken by incorporating crash test dummies into vehicle, simulated by finite element method.

Finite element model of ford F250 pickup truck & hybrid3, 50Th percentile crash test dummies were employed. This includes sled test & full frontal impact test. Crash simulations were performed in two longitudinal barrier system 1) rigid concrete barrier 2) semi rigid w-beam guardrail. Both vehicle & occupant responses are taken. MASH criteria may under estimate the occupant injury risk and

CEN criteria overestimate risk. Accurate assessment based on occupant responses in addition to vehicular responses.

**8. Boria S., et al. [2015]:** This is the study of impact behavior of composite crash structure in this attention focused on material distribution & gradual smoothing & lamination process vehicle impact test is carried out dynamic analysis conducted numerically using LS-DYNA & experimentally. Numerical analysis was conducted using both shell& solid element in order to reproduce not only brittleness of composite structure but also effective delamination phenomenon analyses show good capacity to reproduce crashing process.

**9. Ma Q.H., et al. [2013]:** In this study paper domestic A-class car bumper as object of study, CAE model was established by using HYPERMESH software and for calculation finite element method used. Bumper studied in C-NCAP & E.C.E R42 two different standards. Bumpers optimized by changing structure size of way. Increase in thickness improves safety performance. Smaller maximum acceleration of collision bumper give smaller degree of vehicle & safety performance is higher. if collision bumper absorbed more energy in process, bumper safety is higher.

Bumper thickness increases weight by 87% for 4mm & safety increases by 34%. For 3mm increase thickness weight increase 38% & safety performance increase 14.4% .bumper thickness increase to 3mm balance the wt& performed.

**10. Chaudhari C.D., et al. [2013]:** this paper focused on 40% offset bumper beam crash test analysis with obstacle based on objective & comparable safety performance by EURONCAP. Bumper is fixed with internal & external crash boxes to absorb energy developed. Model built using CATIA & discredited with HYPERMESH while the stress behavior of bumper beam system to assist for safety design of vehicle component. Shows that highest stress areas in front of bumper and at crash box indentation those dissipate more energy so these indentions of crash box perform well to minimum damage to bumper

## RESEARCH GAP:-

Based on analysis of literature survey it can be seen that most of research work is done on. Designing crash boxes based on different material like hybrid material.

-Most of researchers have taken the composite as an only alternative.

-Also work done on effect of boundary condition and absorption capability based on -welding types.

-But very few researchers have worked on increasing absorption capacity by changing geometry.

-Very few of researchers have focused on physical aspects of crash box.

And effect of change in fatigue life with change in shape of crash box is less observed. This research gap is used in defining and formation of problem statement and objective of project.

## PROBLEM DEFINITION:-

Past research and experiences had indicated that during collision of vehicle important role played by crash box, which absorbs maximum impact energy. Size and shape of crash box affects its impact energy absorption. Hence problem statement is "to find out optimum shape of crash box for maximum energy absorption and minimum critical deformation."

## EXISTING DIMENTION OF CRASH BOX:

Existing crash box used in many sedan cars is may be slightly vary, here we are considering crash box of vehicle ford aspire. The existing crash box is a square having 2 mm thickness and of dimension of 100mm x 100 mm, and length of 160mm. having ribbing slots at 30mm, 60mm and 100 mm from top.

Ribbing Slot dimension are width of 10 mm and depth of 4 mm.Material of existing crash box= mild steel.

## CALCULATION FOR OTHER CONSIDERED SHAPE OF CRASH BOX.

By keeping same length of crash box as of the existing, because length is very important consideration while designing crash box. So keeping same length L=160 mm and volume of crash box. We considered three shapes which are rectangle, circular, and hexagonal.

Volume of existing square crash box = A x A x L

=100 x 100 x160

=1600000 mm^3

=1600 m^3

So let us find shape of rectangle

=L x B x H
=consider width of 80, we get
1600000=160 x 80 x H
H=125 mm
Same way for circular and hexagon we can calculate:
Diameter 115 and side of hexagon 62.

TABLE I: calculated dimensions of diff shapes of crash box.

| Dim.\ shape | Square | Rectangle | Circle | Hexagon |
|---|---|---|---|---|
| Length | 100 | 125 | ---- | 62 |
| Diameter | ---- | ---- | 115 | ---- |
| Width | 100 | 80 | ---- | ---- |
| Height | 160 | 160 | 160 | 160 |

CALCULATIONS FOR FINDING IMPACT FORCE:
Let us consider mass of vehicle is 1000 kg and car is having velocity is 56kmph i.e 15 m/s ( As per RCAR bumper test andnew car assessment program (NCAP) frontal barrier impact test) then generated kinetic energy equal to:

= ½ x M x V^2
=0.5 x 1000 x 15.5 ^2
K.E =120125 J

In this case kinetic energy is equal to work, and work
W= F x d, so F x d=120125 J, i.e F=120125/d. in this case consider distance before accident between car and object is = 2m, now we get F=120125/2. F=60062.5 N

So with this input data let's find out strain energy and deformation from analysis by using analysis software ANSYS 12.0.

**FEA RESULTS:**

With the above dimensions and with fine meshing we get results for crash boxes are as per below:

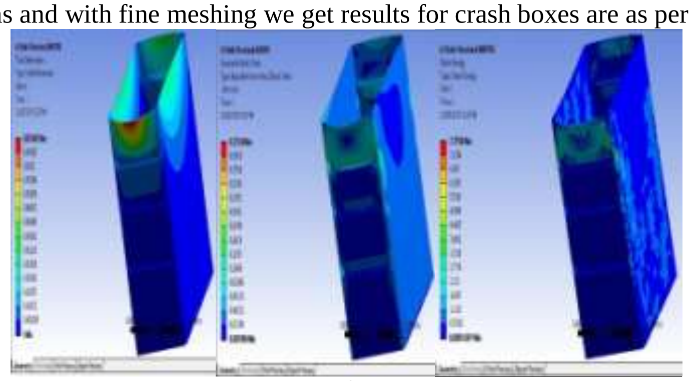

**FIG.VI. ansys result for square crash box.**

For square crash box deformation is 72 mm and elastic strain is 0.3253 m/m. for rectangular deformation is 77 mm and

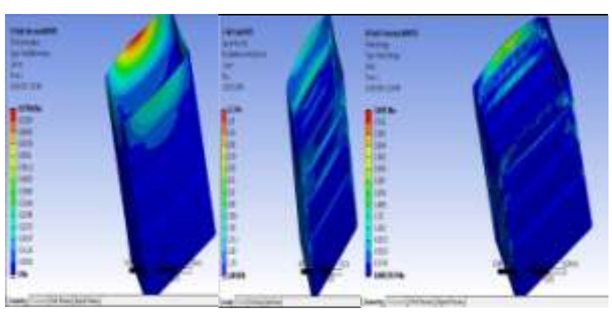

**FIG.VII ansys result for rectangle crash box.**

Elastic strain is 0.2417m/m.

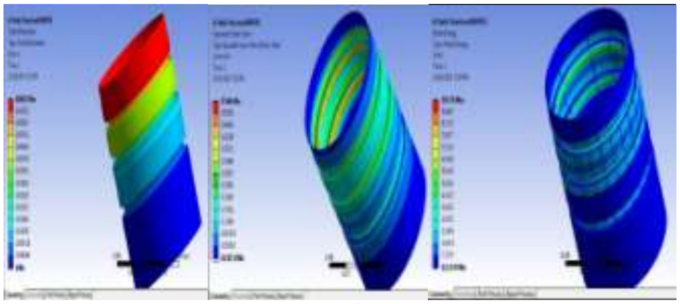

**FIG. VIII.ansys result for circle crash box**.

Respectively for circular crash box we get 68 mm and 0.5466m/m and for hexagonal 62mm 0.6164 m/m.

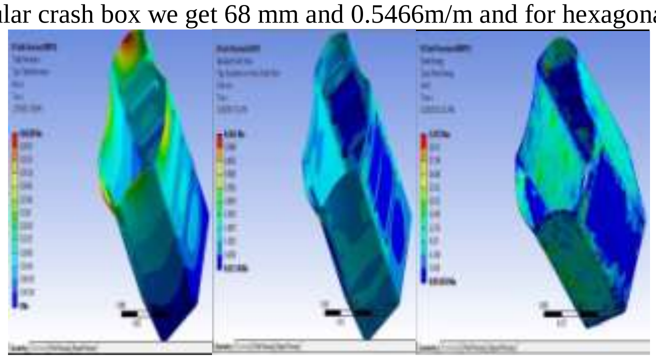

**FIG.IX.ansys result for square crash box.**

TABLE II: FEA ANSYS FEA

| Shape of crash box | deformation | Elastic strain | Strain energy |
|---|---|---|---|
| Square | 72 | 0.32533 | 7.7758 |
| Rectangle | 77 | 0.24174 | 3.8491 |
| Circle | 68 | 0.5466 | 10.176 |
| Hexagonal | 61.2 | 0.6164 | 33.95 |

From the ANSYS results we can say that hexagonal shape crash box is give minimum deformation and maximum elastic strain for same load of force 60062.5 N. now same result is has to validate with experimental. Experiment is has to be done by drop weight impact testing.

## IMPACT TESTING:

When two objects collide, damage is often done to one or other of them. How well something resists damage is called its impact resistance. An impact test measures how much energy is absorbed when an object fractures or breaks under a high speed collision. It's an important property. The safety of many consumer products depends on their resistance to breaking. [17]

**Drop weight test.-**A mass is dropped from vertically on to a test specimen. A tube or rail is used to guide the falling mass. Since the mass either stop dead on the specimen or breaks it,.However, the energy absorbed by a specimen when its break can be estimated: The mass is dropped from increasing height until the specimen fractures. The impact energy is the kinetic energy of mass at impact. Energy absorbed by test specimen is the impact energy required to just break specimen. Mini tower is bench top instrument used for low energy application such as packaging films and thin or brittle plastics.

Features-1) Impact energy is adjusted by lifting height and the number of weights.2) the buffer is equipped to absorb the residual energy after breaking specimen to protect the weight and anvil from destroying. Also install the safe outfit, such as safety net, safe pin for maintenance and hanger locking.

-The 8100 series used for high energy application such as high and low energy metals.

-mass variable up to 600 kg

-impact energy variable up to 70200 J [17]

**Fig .X. Drop Weight Impact Machine, Model 8100 [17]**

CONCLUSION:

Herby we can say that after simulation in ANSYS we can say that hexagonal shape of crash box is optimum and gives maximum energy absorption and minimum deformation for same load, we can also validate results from experiment on drop weight impact testing.

EXPECTED OUTCOME:-

When it comes to R&D for automotive materials, in crash performance increment most effort goes to developing and using materials to make cars lighter and safer. Studies indicate that good impact absorption system can save life of passenger in vehicle as well as minimum damage to property.
The crash box impact sustainability is about 20 % to 30 % of vehicle total crash absorbing system. As we know that the safety percentage increase by 20% of vehicle and contributes to better quality and performance of the vehicle by selecting optimum shape.shape which will be satisfying the impact absorption of existing crash box will be selected. Though reduction or increment of material for each crash box is less but we know that vehicles safety increases and for each vehicle 2 crash box are needed means almost this will give definitely large increment in safety.

REFERENCES:

[1] Ince F., et al. “experimental and numerical study on impact behavior of box structure” Elsevier Science Direct 2011.
[2] Qureshi O.M., et al. “crash behavior of thin walled box beams with complex sinusoidal relief pattern”received 1 July 2011: received in revised form 30 November 2011: accepted 6 December 2011.
[3] Kim H.C., et al.“crashworthiness of aluminum/CFRP square hollow section beam under axial impact loading for crash box application” Elsevier Science Direct www.elsevier.com ,5 february 2014. .
[4] Rusinek A., et al. ”effect of plastic deformation and boundary condition combined with elastic wave propagation on collapse site of crash box” Elsevier Science Direct 2008.
[5] Toksoy A.K., et al. “partial Al foam filling of commercial 1050H14 al crash box: the effect of box column thickness and foam relative density on energy absorption” received 1 Dec 2009: received in revised form 4 Feb 2010: accepted 4 Feb 2010.
[6] Peroni L., et al. “comparison of energy absorption capability of crash boxes assembled by spot weld and continuous joining technique” international journal of impact engineering 2009.
[7] Li N., et al.”numerical study of occupant responses and injuries in vehicular crashes into roadside barriers based on finite element simulation” received 3 march 2014: received in revised form 1 may 2015:accepted 7 June 2015.
[8] Boria S., et al.”Experimental and numerical investigation on impact behavior of composite frontal crash structure” received 27 may 2014: received in revised form 6 march 2015: accepted 11 April 2015.
[9] Ma Q.H., et al. “Research on the crash safety of car bumper based on different standard” 2013.
[10] Chaudhari C.D., et al. “Crash test for 40% offset frontal bumper car analysis using CAE”2013
[11] Boria,et al.“crash analysis of impact attenuator for racing car in sandwich material”2008.

[12] Shrivastav V., Dr.Telang A."optimization of impact attenuator design using Finite Element Method for enhanced vehicle safety during collision" international journal of science and research, volume 5,8august2015

[13] 13)Nakazawa Y., et al."development of crash box for passenger car with high capability for energy absorption"2005.

[14] Valayil T.P., Dr.Issac J.C."crash simulation in ANSYS LS-DYNA to explore the crash performance of composite and metallic materials" international journal of science and research, volume 4,8august2013.3

[15] Biradar G., AnjanBabu V.A **"**automotive crash box performance analysis and simulation during frontal rigid barrier crash" international journal of science and research 2012.

[16] Zaarai H., et.al. "an experimental & numerical crashworthiness investigation of thermoplastic composite crash boxes" Elsevier Science Direct 2008.

[17] "An introduction to IMPACT testing" **www.TiniusOlsen.com**