To Study the Implementation of Biomimetics in Crash Safety and its Experimentation

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Abstract: *Crashbox is deformable or made to deform, this component is considered important in order to absorb the impact energy. In case of frontal collisions, it is expected to deform and absorb crash energy which can be transferred to other parts is minimized. Hence, designing process of such crash box should maintain the peak force below an allowable threshold. Various filler materials are explored and their energy absorption ability. Crash box geometry is studied. Experimental analysis includes test on UTM machine and S.E.A is done. In order to improve overall design specifications biomimetic concepts are utilized. Biomimetic structures are mainly inspired from honey comb (trabecular) and beetle skin are confronted. A comparison between the Conventional Crash box and Biomimetic crash box is done on basis of crashworthiness based on compressive force – displacement curves. Similarly, other structures such as fruit seeds, cattail, (human tibia), bamboo, etc is studied.*

Keywords: *Crash box, Crashworthiness, Biomimetics, Structural design, frontal impact, S.E.A, fillers.*

1. INTRODUCTION

The collisions and the type of impacts lead to the accidents having greater impacts. Consequently, research on buffering and energy absorbing structures and the related materials has always been a research hotspot for engineers and scientists. Hence, a cheap, but energy absorbing component having good performance, constituting thin-walled tubes are been used in numerous devices and vehicles.. As inexpensive they are in great demand and studied widely. The study of honey-comb structures and cell structures have taken speed in the intention for the development of energy-absorbing structures and components. Whereas in order to obey the theory of 'fittest will survive' various organisms in order to survive in natural environments and its critical conditions have undergone evolutions over centuries leading to the extraordinary natural structures having the excellent personalities that provides perfect references and inspiration for the development of new materials and design. The term 'biomimicry' comes into the picture, it is simply innovation inspired by nature. The source of inspiration from centuries is the biological forms, behaviour, morphologies, anatomies, their mechanisms and modes of adaptation to the environment1.

1 The Principle of Crash Box:

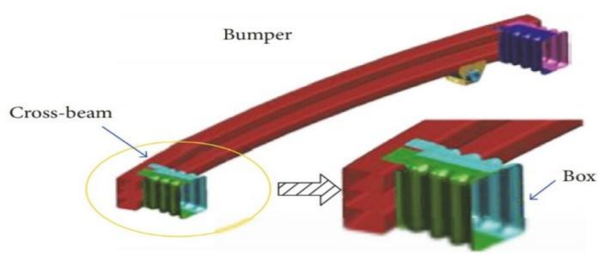


Fig 1. The Crash Box Position

In case of crash energy absorption one of the most important part in automobile is the crash box, it is located at the frontal end of car frame. The crash box must do following: i)Critical buckling force needs to be minimized ii)Energy absorption must be high iii)It should be light in weight. The Bumper together consists of fascia, cross-beam and the crash box. During the frontal collisions generally, crash box should collapse simultaneously absorbing the impact energy before it reaches to the other body parts. This results in reduction or minimization of damage to the main driver cabin and passengers. Hence, the generated energy of frontal collision is retained in the crash box in the form of permanent deformation. Position of crash-box shown in Fig.1.

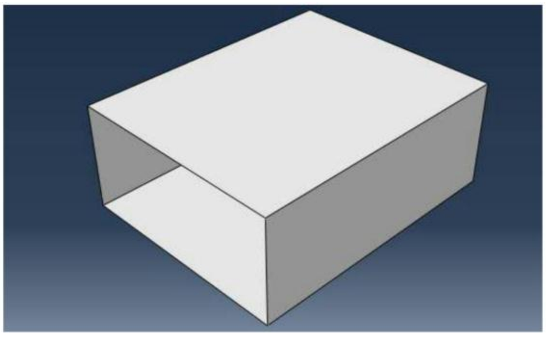
3. OBJECTIVE

1. The Objective of this paper is to study bionic designs of various impact absorbing models and their inspiration from biological structures and their experimentation

4. CONVENTIONAL CRASH BOX

In order to get the information regarding energy-absorption capability, the stresses induced as well as scope for further improvement and development the FEA analysis is done. The Conventional crash box (CONV crash box) commonly used in modern vehicles generally have a singular tube and they have a leading line of deformation, for example;

1. Test – Dimensions of the model are 90×50×100 (length×width×height), thus fig1 shows model as per specifications.



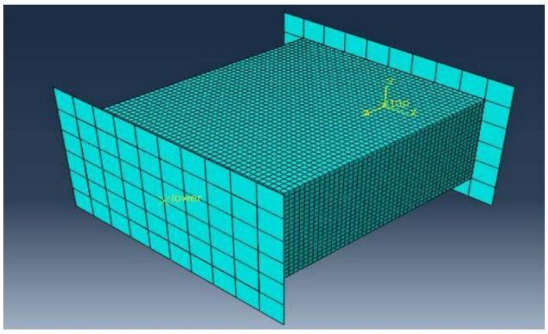
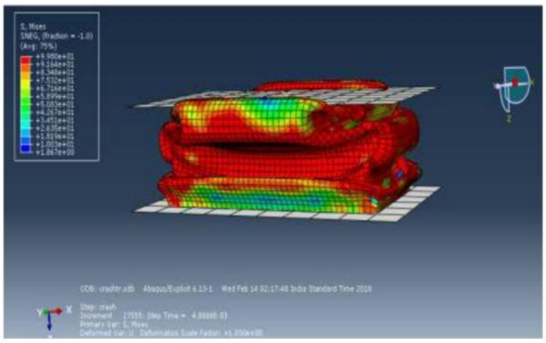


Fig2: Crash Tube CAD model Fig 3: CONV crash box assembly (using CAD)

Material Properties: Mild Steel

Simulation Result:



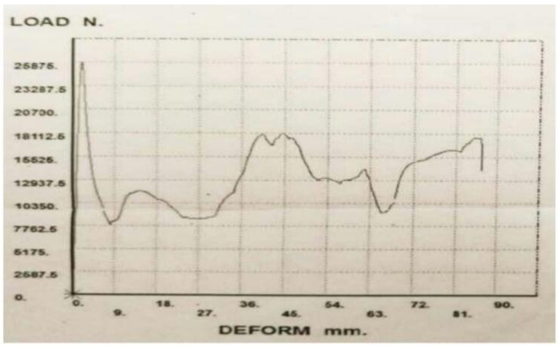


Fig 4:Deformed Shape and stress plot Fig 5 Load vs Defr

Experimental Analysis

In quadilateral cross-section the mean crushing pressure can be calculated as:

Pm $= K \times \sigma \times b^{1/3} \times t^{5/3}$, Pm- Mean Crushing Pressure, σ= Maximum Yield Stress

K= 13.06, t= thickness

5. CASE STUDY: BIONIC DESIGN CRASH BOX

The realated studies are extended to bionic structures such as honey-comb and cell-wall structures for developing more better impact-absorbing models. The hiearchical strucutre of honeycomb where its cell wall is replaced by triangular lattice configuration which show better energy absorption characteristics. The beetle's elytra has unique fuction to protect the main body,its the inner 3D structure of beetle's elytra is evolutionalized structure characterized by higher rigidity and low weight. Process included i.specimen selection ii.eleectron mircroscopy iii.Microstructure of beetle and honeycomb. Beetle elytra consists of upper and lower skin with honeycomb shaped walls with numerous trabeculae forming a sandwich plate with solid or hollow trabeculae. Beetle Elytron Plate (BEP) was developed it had trabeculae throughout the mid-sections and had distinct properties of those having trabeculae at end of the walls which lead to development of End-trabeculae Bettle Elytron Plate (EBEP)

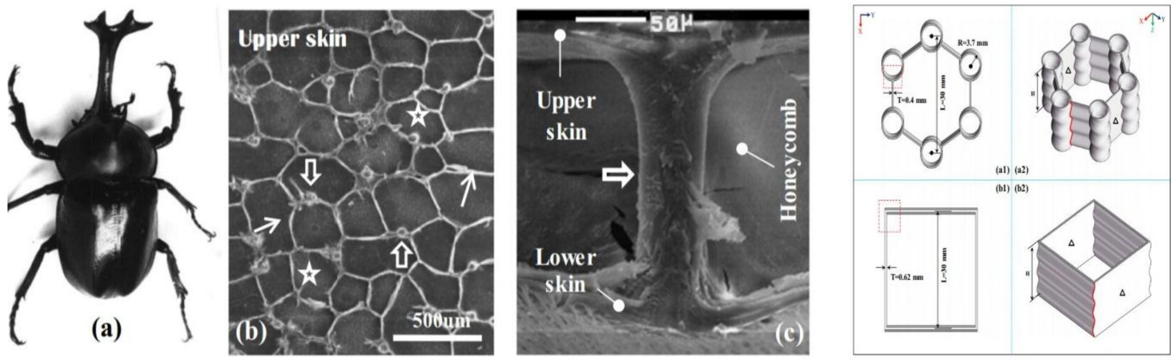


Fig 6: **a**.Beetle **b**.Microstructure **c**.Trabeculae7; Biomimetic crashbox & CON crashbox

6. MODELLING & SAMPLE DESIGN

This section study of a type of biomimetic trabecular honeycomb having hexagonal morphology & is thin walled which adapts the inner biological setup of bettle's elytra and using concept of honeycomb plates is developed. It is named as EPEB crashbox for convinience. CON crashboxes have leading line of deformation, both CON and EBEP crshboxes possess sine wave deformation having orientation parallel to X and Z plane shown in fig 7(in red) whereas some walls parallel to X and Z plane doesn't have lines of deformation (shown in Δ in fig7a2,b2).

7. EXPERIMENTAL METHOD

The investigaton of the two crashboxes were done by the compression experiments. Experiments were stopped at ultimate yeild point. Evaluation of energy-absorbing chracteristics of the boxes were done with the help of following formulas.

$E=\int_0^S F dz$; $F_{AV}=\frac{E}{S}$; CFE$=\frac{F_{AV}}{F_P}$;

E= Absorption energy, F=Compression force; z=displacement, S=total displacement

F(AV)=Mean compressive force, F(p)=Max Force, CFE=Compressive Force Efficiency

SEA(specific energy absorption) gives the energy absorption characteristics of structure is given as ratio of (entire energy absorberd by structure) to (Structure mass) E/M

First formula is used for calculating the entire energy absorption ability during compression process,the second one is used for calculating the average compression force.,thus third formula CFE is used for eshtablishing relationship between whole energy absorption and peak force. Hence, above formulas are utilized for evaluating the mechanical and structural properties of two crash-boxes.

8. FORCE –DISPLACEMENT CURVE

Fig 7; Graph shows the force-displacment curves for the test performed on two crash boxes. It can be seen form the curve that the dominant energy absorbtion took place after yield limit (point A). Hence,characteristics between two crashboxes (Biomimetic & CONV) will be studied on basis of the curve after point A. After point A the force that CONV crash box has to withstand falls down suddenly at point B, but a little increment till point C was seen, after that force decreased, and hence after that there was no increase in force upto level of point C. Hence, the efficiency of CONV crashbox was reduced greatly. Thus, forces from points (B-C) fluctuated in lower magnitude of force. Hence, CON crashbox wasn't able to bear any load once it had reached the displacement value of 12mm.

Whereas, the yeild limit of bionic Biomimetic crashbox reduced upto point B it was in form of C-type curve this occurred after point A limit was attained. In contrast with CONV crashbox the lowest point B which corresponds to lowest load that is observed in the entire curve of compression process thereafter. Then the force value increased from B to C and remained almost stable from Cto D. This means of 20% compression ratio it has a rise and force-displacement curve is almost stable, having higher force values. At the end part of force-displacement curve due to compression of the material after entire crushing, a rising force is generated, however it omitted in the calculation and analysis. 14.49mm is the displacement value considered for calculations is final one.The energy absorbed by Biomimetic crashbox was found to be 375.5J which was 5 times the energy absorbed by CON crashbox. By the second formula, the average compressive load for the EBEP crasbox was found to be 25.5kN this was due to its good energy absorbing (B-C) and (C-D), this value was 390.4% which was higher than CON crashbox (5.2 kN). By 3rd formula CFE of the Biomimetic crashbox is found to be 53.7%, that of CON crashbox was 20.4%. Hence if the design on the basis of larger deformation is considered,EBEP crashbox gives us the better guarantee of the main structure to be remained safe.

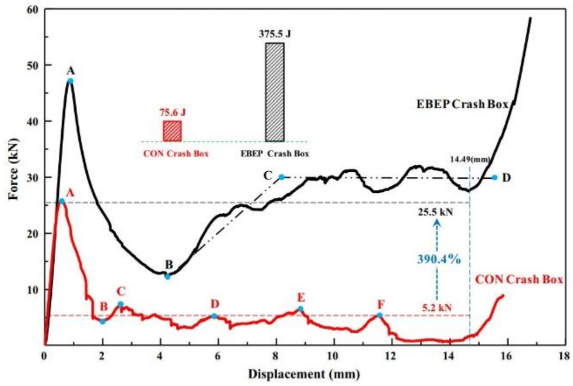


Fig 7: Force vs displacement graph

9. SIMILAR STRUCTURES

1. HUMAN TIBIA: The main bionic idea considering Tibia Bone as an example, it is a rigid strong bone externally and squishy bone internally. a bionic crashbox is comprising external concave structure shell and inner to be filled with material having -ve Poisson Ratio(NPR). As compared to +ve Poisson's Ratio, -ve Poisson's Ratio has good physical & mechanical properties, lower mass and high energy absorption

2.CATTAIL & BAMBOO PLANT:

Cattail is perennial and is inhabited in streams, ponds, lakes,etc.Its leaves has excellent mechanical properties due to evolved multiscale structures. Its chiral morphology's synergitic effect makes it survivable in the wind. Bamboo has tubular structure ,multilayered composite structure, hollowness,and vascular bundles which has good mechanical properties

10.EFFECT AND (S.E.A) OF FILLER MATERIAL

In achieving maximum energy absorption it is preferrable to fill the box with filler material having lower density generally aluminium honeycomb or aluminium foam hence so, energy will be absorbed by compression of the filler.This aluminium foam shows the behaviour of approximately straight elastic region which is then followed by plastic region, which is ended up by a densification upto strains during which the steep increase in stress is seen in stress strain curve, as shown in fig. 8. It is seen from S.E.A. of filler material can be divided into three distinct regimes in design aspect. First regime is the design of column of crash box having weight less than 0.5 kg, in this area column wall thickening gives the excellent specific energy absorption. Now if weight of column is greater than 0.5 kg, then the greatest specific energy absorption is given by aluminium foam filler type. Hence, this is obtained by using the aluminium honeycomb having density more than 3.2×10^{-8} kg/mm3. Hence , we conclude aluminium honeycomb having a rigidity ratio more than 1.2% gives the greatest specific energy absorption (SEA) shown in graph in fig 10.

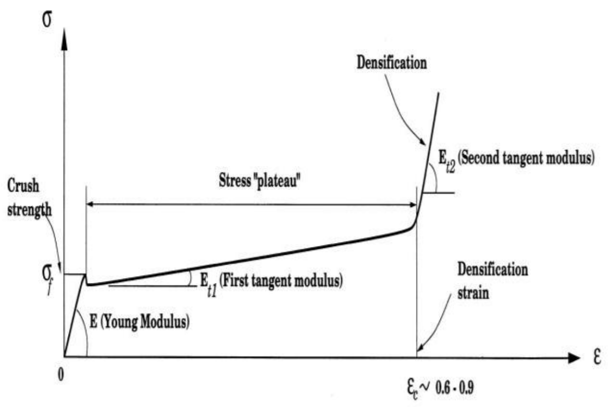


Fig 8. Stress vs strain curve of Aluminium foam

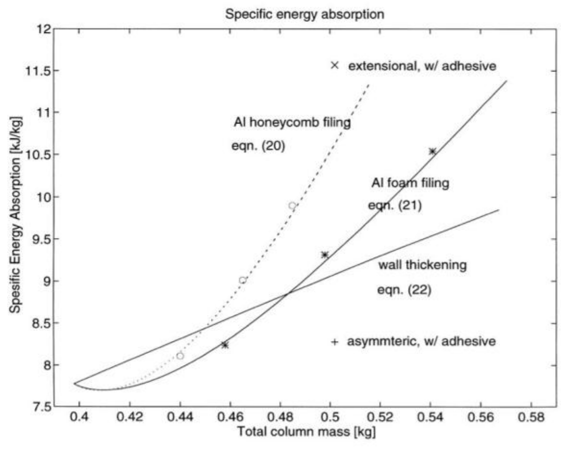


Fig9 . SEA vs Total column mass

RESULT & CONCLUSION:

In case of CONV crashbox there is increment in absorbed energy and average crushing force when the cross-section are changed from rectangular to circular.The results also showed that grooves can stabilize the deformation.As frontal collision causes high repair cost,so Al alloy of square cross-section had good crashworthiness. Externally stiffened tubes were efficient energy absorbers. The structure od beetle's elytra and honeycomb were analysed using FEM and their SEA was studied.The impact absorption capacity of Biomimetic and CONV crashbox is compared and analysed based on compaction experiments.From force displacement curves it is seen that energy absorbed by EBEP crashbox was found to be 375.5J which was 5 times the energy absorbed by CON crashbox.The SEA was developed for the box filled with fillers like aluminium honeycomb or foam leading to the result that Al honeycomb filling is more weight efficient than all other fillers.Hence, the designer must have knowledge of engineering and biology in order to draw analogy between two.Fuctional modelling such as BIOTRIZ provide methods for transferring design parameters from biology to engineering.Biomimetics is that prominent field that is achieving prominence in biology and engineering through variety of wide discoveries which can be seen from the publications doubling everyyear,nearly 3000 papers per year. Biomimetics is the alternative method to engineer material, products,services.It has evolved through combination and integration with modern science and engineering in helping to discover new materials.Our next stage would be to create economy that follows natural development and evolution.

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