

# Studies on Cellular Geometrical Refinement of Fold Core Composites for Enhanced Impact Resistance

Shwetha B M<sup>[1]</sup>, Pradeepkumar K Chikkamath<sup>[2]</sup>, Shamanth Kambodi Surendra<sup>[3]</sup>

Assistant Professor, Department of Aeronautical Engineering, Shree Devi Institute of Technology, Mangalore  
Karnataka, India<sup>[1][2]</sup>

Master Student Aeronautical Engineering, Linkoping University, Linköping, Sweden<sup>[3]</sup>

**ABSTRACT:** It is the trend in recent past to reduce the weight of any component without compensating the strength this trend has become a boon to aerospace industry, the use of advance sandwich structures is the one among these techniques which serves the required phenomenon by structural design pattern. The fold core design is the pattern of sandwich structures where the core of the sandwich structures is of the pattern of folded sheet that can give the same strength as that of conventional materials used in fact some extra properties like higher impact resistance. In the present study the fold core structure made up of aluminum sheets is mimicked with finite element solution software using LS Dyna and the geometrical optimization is carried out for different fold core structures and the impact strength of the structures is studied by comparison of the impact of metal ball made up of steel at lower velocities and the energy absorption of these different structures is compared and the best of the geometry is concluded by amount of kinetic energy absorbed by the core material at lower velocities using LS Dyna crash impact simulations. The results of present study concludes that the rounded corners of these fold core structures give better results of impact strength.

**KEYWORDS:** Aluminum, Fold core, Ls-Dyna, Low velocity, Metal fragments.

## I. INTRODUCTION

Weight reduction is one of the important design considerations of present engineering and transport structures for aerospace and automotive applications. In this circumstance, the sandwich design standard is playing a key part, as it permits for considerable higher weight-specific bending stiffness related to a uniform structure. A sandwich structure characteristically comprises of two thin and stiff skins, divided by a lightweight cellular core. The main drive of the core is to improve the bending stiffness by splitting the skins, to transmit transverse shear loads and to endure compressive loads normal to the sandwich superficial. In circumstance of transversal impact loads, the core has to provision the skins from local bending and it has to avoid main destruction and dissemination by great energy absorption ability.

Honeycomb sandwich structures are artificial or natural structures which have structure of honeycomb to minimize the material and to reduce weight and cost of the material. The honeycomb structures geometry varies widely but hallow cells formed in mid of thin vertical walls are common in all these form of structures. The columnar and hexagonal shapes are common in cells. The shape of the Honeycomb structures offers with reduced material density and with high relative compression and shear properties.

Composite sandwich structures with cellular cores are used in various light weight applications, e.g. in aerospace, automotive, marine or civil engineering. So based on this framework, honeycomb core structures made from aluminum or Nomex aramid paper have a top rank when it comes to weight specific mechanical properties.

However, honeycomb sandwich structures when it comes to the aircraft applications undergo from drawbacks like humidity inclusion in the closed cells which will lead to the increase in structural weight and lessening of mechanical properties and exclusive sporadic manufacturing process.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

In order to overcome these disabilities in modern years, alternative sandwich core structure have been urbanized by folding to three dimensional open zigzag structures of composite prepreg sheets, which are referred to as Fold core structures. The basic principal of these Fold core structure is that of flat sheet of a material is folded to a three dimensional structure in an origami like manner without stretching the material. This folding can be performed in diverse sporadic and unremitting processes with several different materials and in a verity of geometry, optimized for the specific application.

## *A. Materials used in present study*

In our study in order to analyze the diversity between the conventional carbon fiber reinforced plastic (CFRP) and aramid which is used as a core material in the later part of the studies we have come up with the modern aluminum core and glass fiber reinforced plastic as a face sheet which enables us in providing light weight and high strength for withstanding loads.

## *B. Aluminum Core*

Aluminum has been an important aerospace structural material in the development of weight-efficient airframes for aircraft since the 1930s. The aircraft capable of flying at high speeds and high altitudes would have been difficult without the use high strength aluminum alloys in major airframe components such as fuselage and wings. Compared with other aerospace materials, such as magnesium, titanium, steel and fiber reinforced polymer composite, aluminum is used in greater quantities in the majority of aircraft. Aluminum accounts for 60-80% of the airframe weight of most modern aircraft, helicopters, and space vehicles. The amount of aluminum alloy used in modern fighters varies considerably between aircraft types, although many are built almost entirely using aluminum. In general, the percentage of the airframe made using aluminum is lower for military attack aircraft than for civil aircraft.

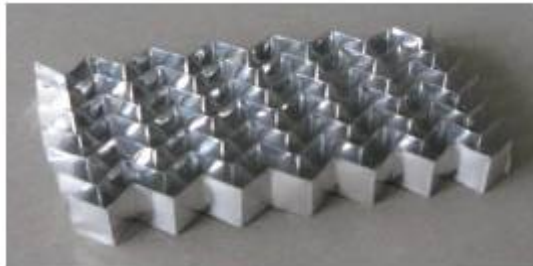


Fig. 1 Foldedcore Structures made from Aluminum

## *C. Fiber-Reinforced Polymer Composites*

For Fiber Reinforced Polymers the matrix materials must be meet some requirements in order to be suitable to the fiber reinforced plastic. The bonding and saturation of matrix material with fiber reinforced plastic must be within suitable period of curing. The chemical bonding of the matrix adhesive should be maximum with fiber reinforced plastic. The matrix should able to cover the reinforcement to prevent from notches and cut which would leads to the reduction of the strength and transmission of loads to the fibers. To prevent the failure of fibers should be kept separately and if failure occurs the deboning of matrix from fibers for same reasons. To maintain chemical and physical stability of matrix material that should be plastic while molding and reinforcement process. Material that should be plastic while molding and reinforcement process.

## II. LITERATURE REVIEW

Kiran chelluru [1], " Finite element simulations of Ballistic impact on metal and composite plates" (2004) the thesis submitted to Department of Mechanical engineering And the faculty graduate school of Wichita University has

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

concluded that, the parameters such as projectile velocity, projectile mass, projectile geometry boundary conditions, target thickness, target yield strength and target failure and friction between the target and projectile has to be considered for ballistic impact simulations.

S. Heimbs, T. Mehrens, P. Middendorf, M. Maier, A. Schumacher [2], "Numerical Determination of the Nonlinear Effective Mechanical Properties of Folded Core Structures for Aircraft Sandwich Panels" (2007), has explained impact simulations with such kinds of cellular structures necessitate information of the standardised properties, subsequently a detailed cell wall modelling approach is unpractical for large sandwich structures. One way to determine these nonlinear effective mechanical properties is extensive experimental testing under compressive, tensile and shear loading.

S. Heimbs, P. Middendorf, C. Hampf, F. Hahnel, K. Wolf [3], "Experimental and Numerical Analysis of Composite Folded Sandwich Core Structures Under Compression", (2008) in this review the performance of such a sandwich assembly with a fold core made of carbon fibre-reinforced plastic under low velocity impact is studied experimentally and numerically. At first the core properties under compressive and transverse shear loads are characterised building a basis for the validation of the simulation models. Low velocity impact tests under various energy levels are described with respect to the evaluated damage of face and core and are finally simulated with LS-DYNA. Chang Qi, Shu Yang, Dong Wang, and Li-Jun Yang [4], "Ballistic Resistance Of Honeycomb Sandwich Panels Under In-Plane High-Velocity Impact" (2013), explains parametric studies were then approved out to illuminate the effects of both macroscopic and microscopic parameters on the ballistic retorts of the axenic Honeycomb Sandwich Panels. The numerical results show that the perforation resistant abilities of the axenic HSPs improve as the standards of the macroscopic parameters rise. However, the microscopic parameters demonstrate the non-monotonic properties on the panels' ballistic measurements

### III. MODELLING AND SIMULATION

The model development was finished on a parametric basis reducing the pre-processing work and offering an efficient way of investigating different folded core geometries. Design of the fold core structure has been done using CATIA V5 Software. By using hyper mesh, meshing has done with the size of 10 for wall geometry and core geometry. Using Ls-Dyna material has been assigned for core using piece wise linear plasticity and wall using by elastic properties. Aluminum is core material and Glass Fiber reinforced Plastic is Face sheets with wall thickness of 0.8 mm and core of 1.0mm. Contact between core and wall, is surface to surface contact with termination time of 1.8sec. The Model has constrained the outer node of the core geometry in X,Y,Z directions there will not be any rotational moment. Transversal low velocity analysis has been done using model of metal ball with diameter of 10 mm at different 1 velocities. The Imp actor was modeled as a spherical rigid body.

In order to separately validate the folded core model, simulations of the compression tests were performed before impact and after impact in ANSYS. In this study the influence of geometry of cellular was also investigated and found out to be significant. Furthermore, the impact resistance was over predicted in the FE-model, which could be explained by energy absorption of the fold core geometry. Such and other imperfections, which normally occur in all cellular structures, influence the mechanical behavior and have to be accounted for in a meso-scale FE-model. The model was calibrated accordingly.

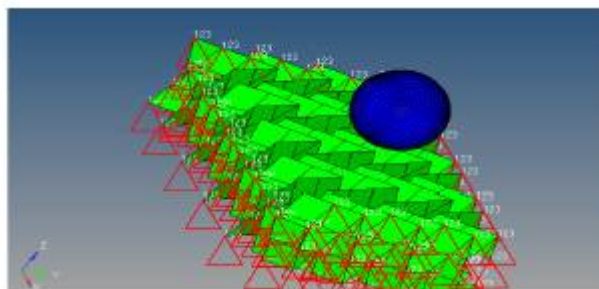


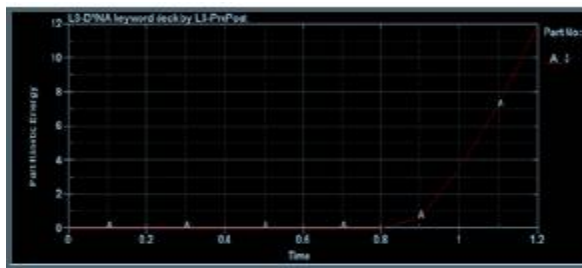
Fig. 2 The representative FE model of the core under projectile impact

## International Journal of Innovative Research in Science, Engineering and Technology

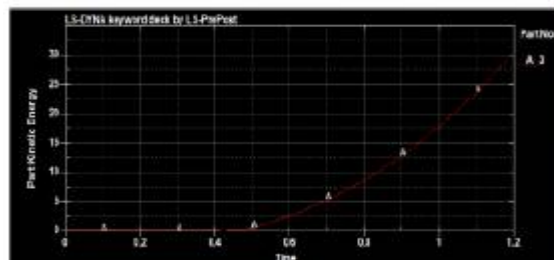
(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

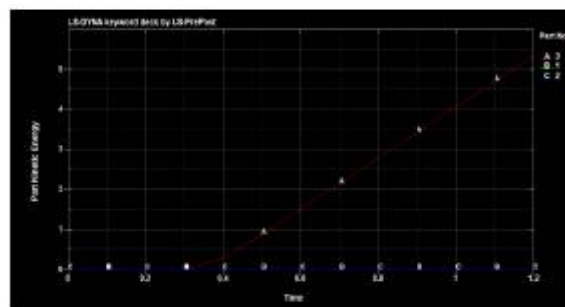
Simulation has been done for the different cellular geometries of foldcore sandwich structures with GFRP face sheets with a Steel ball (dia 10 mm impacting at velocity of 60m/s.) Kinetic Energy in 10<sup>-3</sup> J and Time in Microseconds.



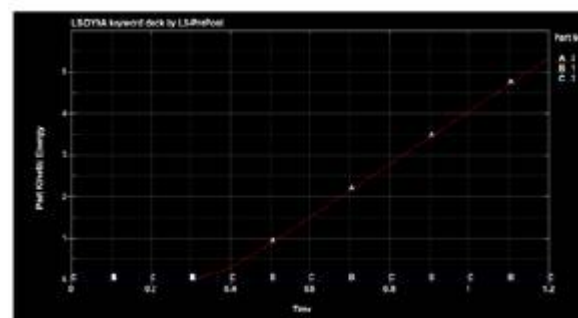
(A) Triangular (45° included) geometry



(B) Triangular (45° included with 3mm curve)



(C) Triangular (60degree included angle) with 3mm curve geometry



(D) Rectangle (90° included angle geometry A- Folded core B- Front face-sheet C- Back face-sheet

Fig. 3 Energy absorption Vs Time plot of core for the different geometries

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Simulation has been done for the different cellular geometries of foldcore sandwich structures without GFRP face sheets with a Steel ball (dia 10 mm impacting at velocity of 85m/s.)

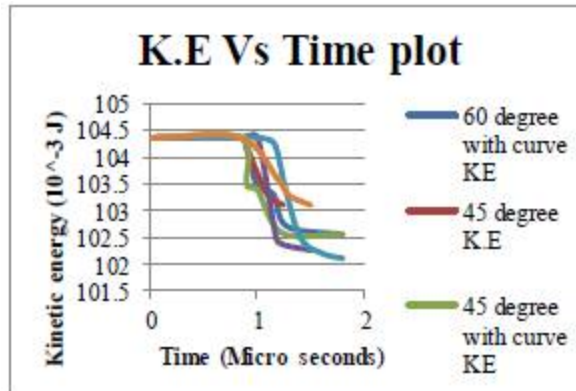


Fig.3 Kinetic Energy Vs Time plot of Metal ball

### Validation

Fig (5) shows the energy absorption for aluminum core for 45 degree, 60 degree, and 90 degree, which represents the increase in energy absorption by core with increase in time. Comparison of fig 5 with fig 4 we can validate that the energy absorption for the core structure depends on the cellular geometry of the folded core. Here Triangular ( $45^\circ$  included with 3mm curve) foldcore sandwich structure showing the better energy absorption of the impact of the ball

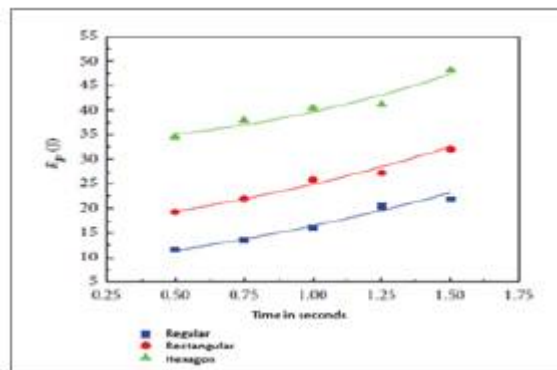


Figure 4: Energy absorption by core

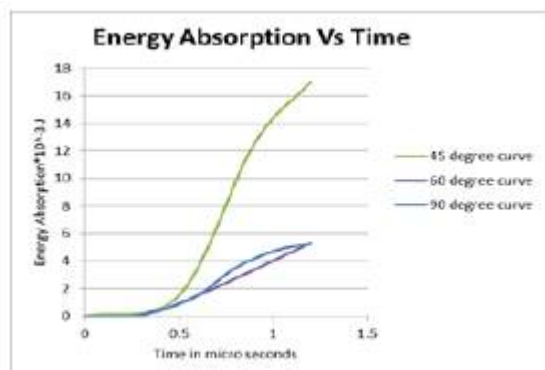


Figure 5: Energy absorption by core

# International Journal of Innovative Research in Science, Engineering and Technology

*(An ISO 3297: 2007 Certified Organization)*

Vol. 5, Issue 3, March 2016

## IV. CONCLUSION

In present study, triangular unit cell of angle  $45^\circ$  with 3mm outward from midpoint curve and cell length of 23mm geometry is showing good energy absorption due to the material density and curve restricting the load transmission to the adjacent cell of the core. As increase in relative density and thickness of foldcore and face sheets the residual velocity will decrease. Nonlinearity due to the residual velocity of the core with increased thickness, with respect to the impact velocity and core relative density.

## REFERENCES

- [1] Kiran chelluru [1], " Finite element simulations of Ballistic impact on metal and composite plates" thesis submitted to Department of Mechanical engineering And the faculty graduate school of Wichita University, (2004)
- [2] S. Heimbs, P. Middendorf, S. Kilchert, A.F. Johnson, M. Maierd "Numerical Simulation Of Advanced Folded Core Materials For Structural Sandwich Applications", Germany, 6th European LS-DYNA Users' Conference (2007)
- [3] S. Heimbs\*, P. Middendorf\*, C. Hampf†, F. Hähnel†, K. Wolf†, "Aircraft Sandwich Structures With Folded Core Under Impact Load", Porto 8th International Conference on Sandwich Structures (2008)
- [4] Chang Qi, Shu Yang, Dong Wang, And Li-Jun Yang, "Ballistic Resistance Of Honeycomb Sandwich Panels Under In-Plane High-Velocity Impact ", Hindawi Publishing Corporation, (2013)
- [5] Chang Qi, Shu Yang, Dong Wang, And Li-Jun Yang, "Ballistic Resistance Of Honeycomb Sandwich Panels Under In-Plane High-Velocity Impact ", Hindawi Publishing Corporation, (2013)