ISSN 2395-1621

Optimization of facesheet of sandwich structure against bending

#1Gongane Akshay H., #2F.A. Shaikh

[1]aksgoon@gmail.com
[2]firoz_ahmed49@yahoo.co.in

#1Department of Mechanical Engineering, SPPU, Pune
Vishwakarma Institute of Information Technology, Pune

ABSTRACT

The use of sandwich structure continues to increase rapidly due to the wide fields of their application, for instance: satellites, aircraft, ships, automobiles, rail cars, wind energy systems, and bridge construction to mention only a few. The sandwich composites are multi-layered materials made by bonding stiff, high strength skins facings to low density core material. The main benefits of using the sandwich concept in structural components are the high stiffness and low weight ratios. In this study static behavior of honeycomb sandwich composites are investigated through three-point bending tests. The objective of the project is to maximize bending stiffness and strength. An optimum design is to be finding out for both bending stiffness and strength as design parameters. For this fiber orientation of plies and facesheet thickness are variables, while core thickness is taken as constant.Material properties of carbon fiber facesheet are find out by experimental test according to ASTM standards. These material properties are used in FE model directly for simulation.A Finite element analysis of 3-point bending is to be carried out with HyperMesh 12.0 and Radioss solver software.

***Keywords*—Finite element analysis, composite material, 3 Point bending test, honey comb, facesheet (skin)**

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

Sandwich construction is of particular interest and widely used in many structures, because the concept is very suitable for lightweight structures with high in- plane and flexural stiffness. Sandwich panels typically consist of two thin face sheets or skins and a lightweight thicker core. Commonly used materials for face sheets are composite laminates and metals, while cores are made of metallic and non-metallic honeycombs, cellular foams, balsa wood or trusses. The face sheets are typically bonded to the core with an adhesive, and carry most of the bending and in-plane loads. The core provides the flexural stiffness and out-of-plane shear and compressive strength.

Important issues in sandwich structures are the quality of the structure, the failure mechanisms that are developed under various loading conditions, effects of nonlinear material behavior and effects of geometric nonlinearities.

The facing skins of a sandwich panel can be compared to the flanges of an I-beam, as they carry the bending stresses to which the beam is subjected. With one facing skin in compression, the other is in tension. Similarly the honeycomb core corresponds to the web of the I-beam. The core resists the shear loads, increases the stiffness of the structure by holding the facing skins apart, and improving on the I-beam, it gives continuous support to the flanges or facing skins to produce a uniformly stiffened panel. The core-to-skin adhesive rigidly joins the sandwich components and allows them to act as one unit with a high torsion and bending rigidity. [1]

In the previous research research work of optimization of sandwich structure minimum weight or minimum cost was objective with respect to bending or torsional stiffness. Analytical procedure is followed to find out optimum fiber orientation, optimum thickness of both facesheet and core. But with such optimization procedure everytime it is not possible to manufacture this sandwich because of some manufacturing constraints and unavailability of some fiber orientation.In this paper optimized sandwich structure is achieved by considering manufacturing constraints of sandwich. FEA results shows that optimized sandwich structure can be manufacture and results can be experimentally validated.

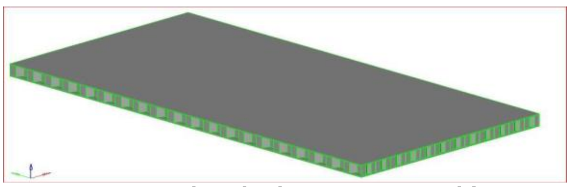

Fig. 1 Honeycomb sandwich structure CAD model

I. LITERATURE REVIEW

S. Belouettar et al, reviewed that the analysis of the experimental results of the static four point binding tests permit to make the following statements: the sandwich composite stiffness increases when increasing the core density and the load to failure increases with increasing cores densities; the maximum loads are higher in the L-direction than in the W direction for low densities and almost of the same order of higher core densities values and the maximum deflection is higher in L configuration than in the W for the same sandwich core. [2]

Isaac M. Daniel et al, performed an experimental study on the behavior of composite sandwich beams under four-point and three-point bending. The sandwich beams were prepared with unidirectional carbon/epoxy face sheets and aluminum honeycomb core. Strains in the face sheets and the core were measured with strain gages and moireÂ gratings. The bending behavior of the beams, whether loaded under four-point or three-point bending, is governed by the face sheets. Therefore, the moment/strain relations for the face sheets display the same type of non-linear behavior as the composite material itself, i.e. a stiffening non-linearity in tension and a softening non-linearity in compression. The contribution of the cores to the bending stiffness is neglected.[3]

Bezazi et al, have investigated that sandwich structure has better mechanical properties than its components in terms of stiffness and load at failure. The load–displacement behavior of the sandwich panels during static loading revealed three distinct phases, and the final failure was not obtained until a sudden fall of the load.[4]

J.C.M. Theulen et al, have minimized the weight of the sandwich for given bending stiffness or strength. Analytical calculation shows that for minimum weight sandwich of specified stiffness core weight should be twice that of faces, independent of material used. Also for minimum weight sandwich of specified bending strength, weight of core and facesheet approximately equal.[5]

Kaveh Kabir et al, investigated sandwich panels with very thin aluminium face sheets under three-point bending loading conditions. The effect of the strength of the face sheets, foam core thickness and bending span length on the failure modes, deformation behavior and failure loads are studied. Experimentation concludes that face yielding occurs when low-strength face sheets are utilised and core yielding occurs when strong face sheets are used.[6]

Craig A. Steeves et al, have optimized sandwich beams by minimizing an objective function such as weight or cost, against a set of constraints such as structural sti7ness or strength. He designed the geometry of a sandwich beam in three-point bending to achieve minimum mass, against the constraint of a prescribed structural load index which is a common optimization task for sandwich beams. Failure mechanism maps have been constructed to reveal the operative collapse mode as a function of geometry of sandwich beam, and minimum weight designs have been obtained as a function of an appropriate structural load index.[7]

Xiang Li et al, develop a minimum weight optimization method for sandwich structure undertorsion. The optimum solutions show that at optimum design the core weight accounts for 66.7% of the whole sandwich structure. Optimum face skins thickness and lay-up angle relation, Optimum weight and lay-up angle relation are developed by studying different dimensions and optimum core thickness, face skins thickness and minimum weight approximately calculated.[8]

Xiang Li et al, presented optimum solutions for the combined requirements of both bending and torsional Stiffness. Based the optimum design results, a sandwich structure subjecting to multiple design constraints in terms of torsion and bending stiffness, three design cases are identified and their pertinent optimum solutions are derived. [9]

Mustafa Akbulut et al, proposed an optimization procedure to minimize thickness (or weight) of laminated composite plates subject to in-plane loading. Fiber orientation angles and layer thickness are chosen as design variables. Static failure criteria are used to determine whether load bearing capacity is exceeded for a configuration generated during the optimization process. The laminate consists of plies having the same thickness. The objective is to find the optimum design of the laminate to attain the minimum possible laminate thickness with the condition that it does not fail.
For different materials, fiber orientation angles in the optimal lay-up designs may be different for the same loading case. Thus, one may not generalize the results obtained for a particular material to others. A design process for composite materials should not be based on intuition or experience because sometimes, when one component of loading is increased, load bearing capacity of the optimized laminate may increase. [10]

Mark Walker et al, describes a methodology to select the best material combination and optimally design sandwich laminates with fibre reinforced skins and low density cores for minimum cost. The objective of the optimization is to minimize the laminate cost by selecting the skin and core material combination, layer thicknesses and skin fibre angles optimally, subject to load and mass constraints. As the optimization problem contains a number of continuous (ply angles and thicknesses) and discrete (material combinations) design variables, a sequential solution procedure is devised in which the optimal variables are computed in different stages. In the first, the skin and core thicknesses and the skin fibre angles are determined optimally for each candidate. Thereafter, the cheapest candidate is selected. The methodology and its benefits are demonstrated using graphite, glass or kevlar/epoxy facings, and balsa or PVC cores.[11]

FINITE ELEMENT ANALYSIS

Honeycomb and facesheet both are modelled in Catia V5 and are then imported in Hypermesh 12. Dimensions of sandwich panel for modelling are referred from ASTM D7249 and D7250. In the first iteration of optimization of facesheet of sandwich Carbon fibers of orientation [45,90,-45,-90,45,90,-45,-90] selected for the both upper and lower facesheet. There are 8 upper facesheets and 8 bottom facesheets. For making layers of facesheet 'Pcomp' is used and for core 'Pshell' is used. Element size is 2 mm. Manual meshing is done for both facesheet and honeycomb. Quad element is used for both facesheet and honeycomb. Thickness of each ply is taken as 0.15mm.

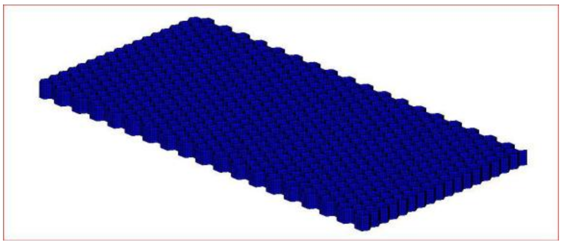

Fig.2Honeycomb Structure

Fig.3

Upper facesheet

Fig.4

Lower facesheet

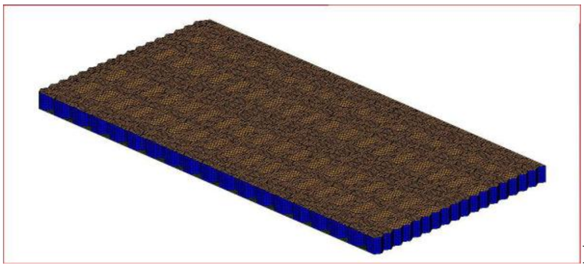

Fig.5

Sandwich structure

Table 1: Quality checks

Warpage	15
Aspect ratio	5
Skew	45°
Minimum length	1 mm
Maximum length	4mm
Tria minimum interior angle	20°
Tria maximum interior angle	120°
quad minimum interior angle	45 °
quad maximum interior angle	135 °
Jacobian	0.6

Boundary condition:

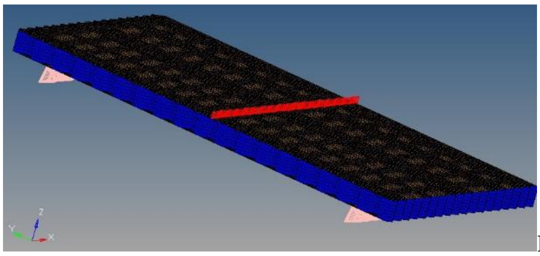

Fig.6

Boundary condition

Boundary condition is referred from experimental setup as given in ASTM 7249 and ASTM 7250.

SIMULATION RESULTS

A sandwich panel is analysed by FEA using Hypermesh and solved by Radioss. In FE analysis equivalent properties of facesheet and core used directly in the model. For modelling 'Pcomp' and 'Pshell' used for facesheet and core respectively. Simulation is carried out for load 2kN, 3kN….upto 10kN. Results of Maximum deflection and vonmises stresses are taken.

In the next iteration fiber orientation are changed and similar steps are followed. Simulation results using different fiber orientation shows that $[0/45/-45/90]_s$ this face sheet orientation gives more optimize sandwich structure. i.e. with this fiber orientation facesheet or even sandwich structure will be optimized in case of bending. Because deflection is minimum so structure becomes stiff as compared with other combination of fibers.

This simulation results gives the optimum fiber orientation results. Now to optimize the thickness of facesheet with this optimum fiber orientation, simulation is done with changing thickness of ply. For this iteration thickness of each ply is taken as 0.2 mm. Then simulation is done with 10 number of plies for each facesheet. The results shows that sandwich structure with 10 no. of plies having thickness of each ply is 0.2 mm have approximately same results with 8 no. of plies having thickness of each ply 0.15 mm. This shows that sandwich structure is optimized by considering fiber orientation and facesheet thickness as a variable.

Table 2: Deflection value for predicted sandwich panel

Load kN	Deflection mm				
	$[45/90/-45/-90]_s$	$[0/45]_{4s}$	$[90/90]_{4s}$	$[0/0]_{4s}$	$[0/90]_{4s}$
2	8.05e-1	8.323e-1	1.257	9.897e-1	7.984e-1
3	1.208	1.270	1.919	1.511	1.219
4	1.53	1.665	2.515	1.979	1.597
5	1.933	2.103	3.177	2.5	2.017
6	2.26	2.453	3.772	2.917	2.353
7	2.658	2.891	4.368	3.438	2.774
8	3.061	3.329	5.162	3.959	3.194
9	3.423	3.724	5.559	4.428	3.572
10	3.826	4.162	6.287	4.949	3.992

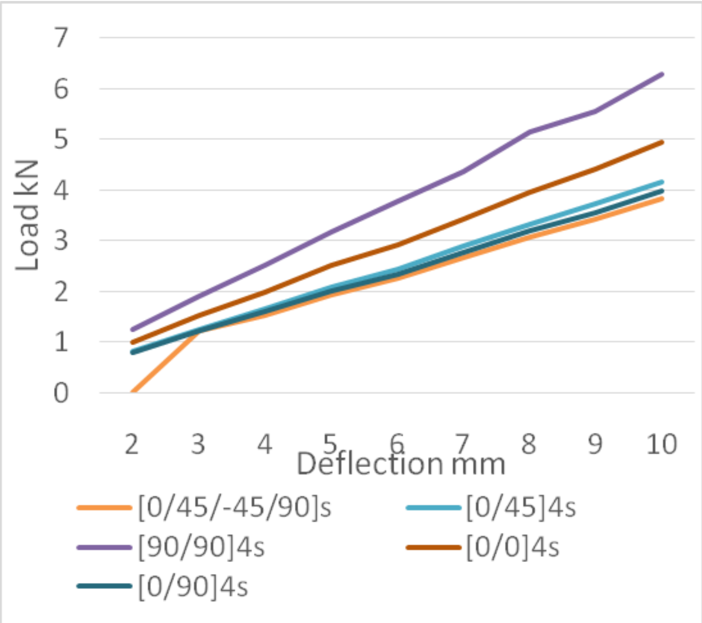

Fig.7 Comparison of Load vs. deflection

Deflection contours of optimized sandwich

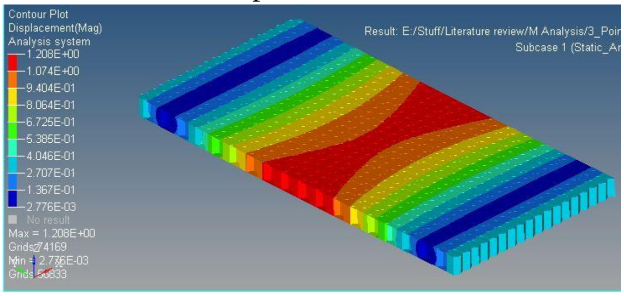

Fig.8 Deflection Contours for 2kN

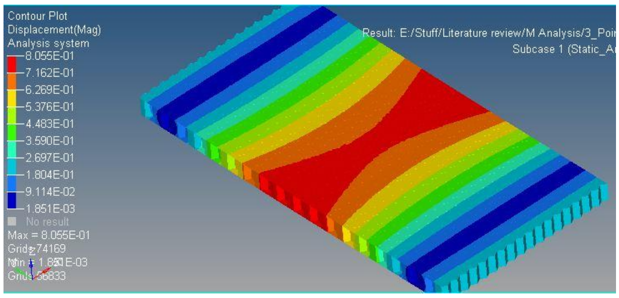

Fig.9Deflection Contours for3kN

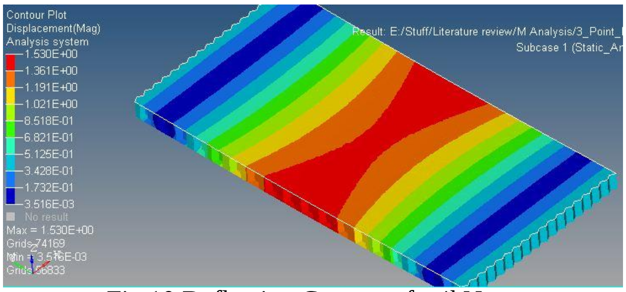

Fig.10 Deflection Contours for4kN

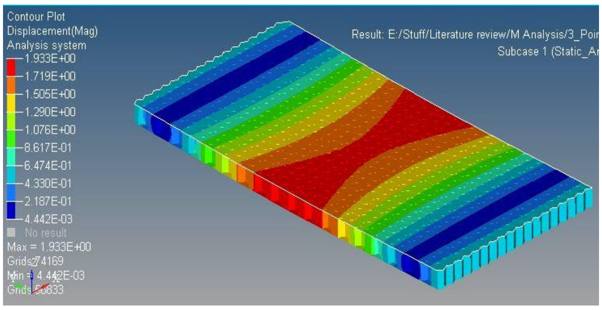

Fig.11Deflection Contoursfor5kN

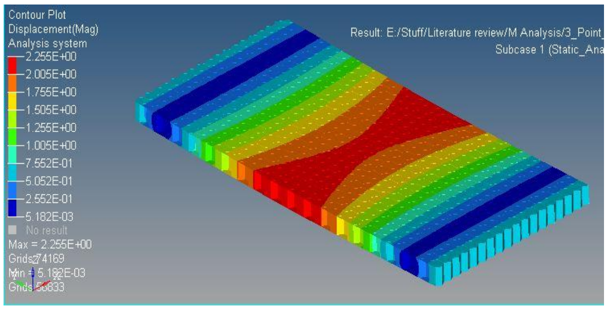

Fig.12 Deflection Contours for 6kN

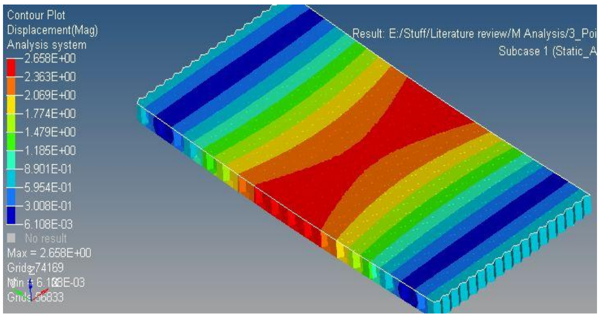

Fig.13 Deflection Contours for7kN

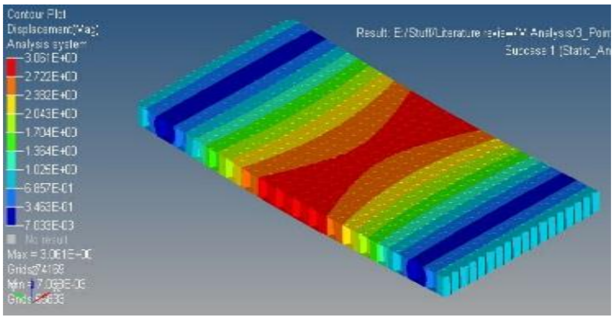

Fig.14 Deflection Contours for 8kN

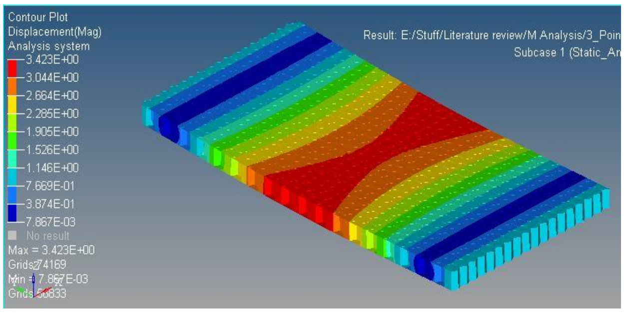

Fig.15 Deflection Contours for 9kN

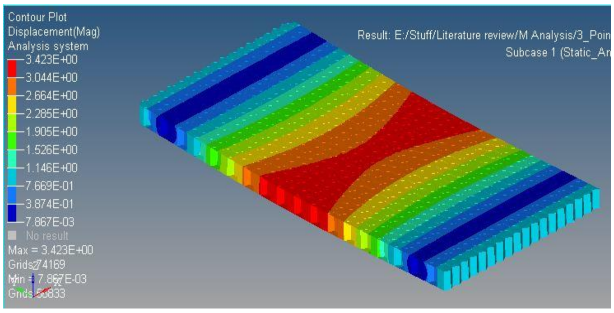

Fig.16 Deflection Contours for 10kN

II. CONCLUSION

Optimization of facesheet consists of fiber angle orientation and facesheet thickness as a variable. FE simulation of sandwich structure against 3 point bending for different fiber orientation and different no. of plies shows that sandwich structure with fiber orientation $[0/45/-45/90]_{4s}$ having 8 plies of carbon fiber is optimized sandwich structure. This results shows that optimized sandwich structure is morestiff against bending without affecting strength.

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