International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 10, October- 2014

Analysis and optimization of Composite Sandwich Structures using Optistruct

Venkatesh. P[1]
[1] M. Tech Student,
Dept of Mechanical Engineering,
Malla Reddy College of Engineering & Technology,
Secunderabad -500100, India

P. Ravikanth Raju[2]
[2] Dept of Mechanical Engineering,
Malla Reddy College of Engineering & Technology,
Secunderabad -500100, India

J. Suresh Kumar[3]
[3] Dept of Mechanical Engineering,
JNTU College of Engineering,
Hyderabad-500085, India

Abstract - **The main aim of this paper is to focus on the application of optimization concept to composite structures. The present day optimization had spread its roots in engineering industries as a time and money saving tool. This paper brings out the effectiveness of Optistruct tool in bringing out the best possible composite structures that meets the required objective. A special type of composite structures called sandwich structures are modeled and optimized. The basic modeling is done with Ansys 11.0 and compared with experimental studies. Extensive optimization is done using Optistruct from Finite Element model developed using Hypermesh**.

Keywords: Optistruct, Composite sandwich, Constraint, Objective, Response

1. INTRODUCTION

The use of composites structures in aerospace and civil infrastructure applications has been increasing especially due to their extremely low weight which results in less fuel consumption, high flexural and shear stiffness and corrosion resistance. Optimization had given an opportunity to pick up the best available options with the imposed constraints and required objective.

Altair Optistruct uses the conventional optimization techniques and applies to the engineering analysis problems by taking the necessary inputs from the user. It has become efficient tool in engineering applications as it saves lot of time and money.

1.1 Composite Sandwich Structures

In its simplest form a structural sandwich, which is a special form of laminated composites, is composed of two thin stiff facesheets and a thick lightweight core bonded between them. A sandwich structure will offer different mechanical properties with the use of different types of materials because the overall performance of sandwich structures depends on the properties of the constituents. Hence, optimum material choice is often obtained according to the design.

Benefits of Sandwich structures

- High rigidity with higher strength to weight ratio.
- Smoother exterior
- High load carrying capacity
- Increased fatigue life
- Better fracture toughness characteristics
- Thermal and acoustical insulation
- High biaxial compression load bearing capacity

.

1.2 Sandwich Structure in Comparison with an I-beam

A sandwich structure operates in the same way with the traditional I-beam, which has two flanges and a web connecting the flanges (Figure 1). The connecting web makes it possible for the flanges to act together and resist shear stresses. Sandwich structure and an I-beam differ from each other that, in a sandwich structure the core and laminates are different materials and the core provides continuous support for the laminates rather than being concentrated in a narrow web. When the structure subjected to bending the laminates act together, resisting the external bending moment so that one laminate is loaded in compression and the other in tension. The core resists transverse forces, at the same time, supports the laminates and stabilizes them against buckling and wrinkling (local buckling). Figure 1 shows the structure of both sandwich panel and I-beam.

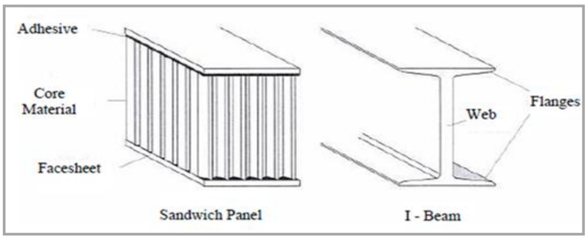

Fig.1. Sandwich Structure compared with an I-beam

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 10, October- 2014

2. FEA OF COMPOSITE SANDWICH

2.1. FE Modeling of Sandwich Structure

Composites are somewhat more difficult to model than an isotropic material such as iron or steel. It requires taking special care in defining the properties and orientations of the various layers since each layer may have different orthotropic material properties. The FEA programs allow to model composite materials by using specialized elements called layered elements. Once model is build using these elements, we can do any structural analysis (including nonlinear ties such as large deflection and stress stiffening).
The sandwich composite is modeled using SOLID185 element. The ply stack up used has been shown in Figure 2. Table 1 describes about the Young's modulus, Shear modulus and Poisson's ratio in various directions and Equivalent values.

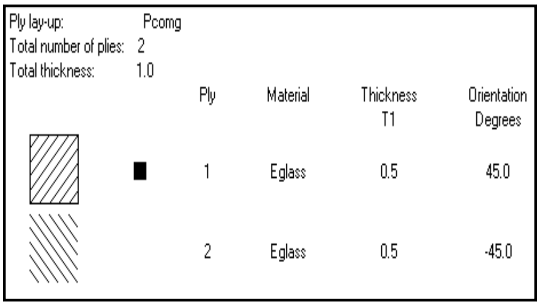

Fig.2. Ply stack up for E-glass fiber sandwich

Table 1.Material Properties used for modeling

S. No.	Material property	Glass Fiber	Carbon Fiber
1	Longitudinal young's modulus in direction-1(E_1)	42500	63777
2	Transverse young's modulus in direction-2(E_2)	42500	63777
3	Poisson's ratio in direction-12□□□□□	0.24	0.27
4	Poisson's ratio in direction-23□□□□□	0.24	0.27
5	Shear modulus in direction-12(G_{12})	4800	5380
6	Shear modulus in direction-23(G_{23})	4800	5380
7	Shear modulus in direction-13(G_{13})	4800	5380
8	Equivalent young's Modulus (E) in N/mm^2	16386	19153
9	Poisson's ratio□□□	0.33	0.35

2.2. Load Cases and Boundary Conditions

Two types of boundary conditions are specified, one for validation of three point bending and another for flat wise compression test. Node to node connection is maintained between fiber and core material. 100 mm span is maintained between the ends and load is applied at mid span of the beam for bending as shown in Figure 3.

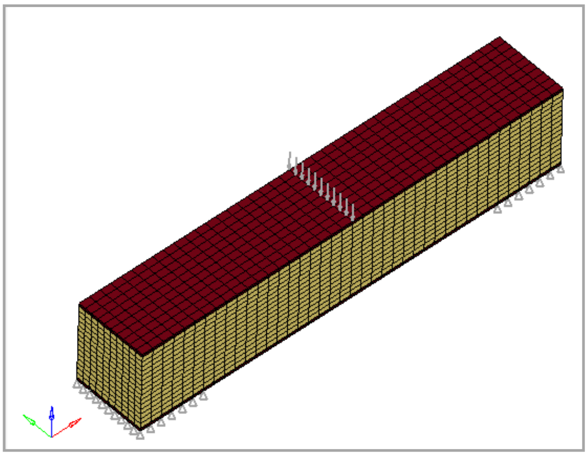

Fig.3. Sandwich beam with bending load and applied boundary condition

For compression test entire base face is fixed in all DOF and load is applied at the top face as shown in Figure 4.

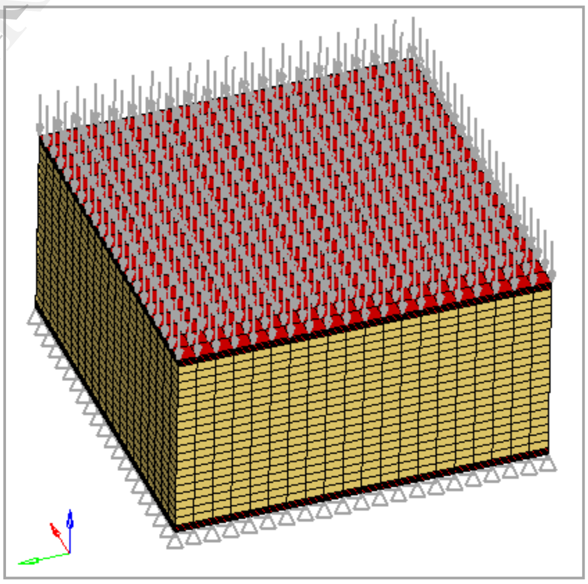

Fig.4. Sandwich beam with compression load and applied boundary condition

3. EXPERIMENTAL ANALYSIS OF SANDWICH STRUCTURE

E-glass non-crimp, Carbon fabrics, epoxy thermosetting resin and polycarbonate based honeycomb core materials were used to fabricate composite sandwich panels. The reinforcement constituent of the composite facesheets is E-glass +45°/-45° biaxial non-crimp fabric. Epoxy resin with Resoltec 1048 amine hardener was used as the matrix material. PC based core material was used that has circular cell configuration with an average cell size of 5.0 mm

3.1. Fabrication process

The sandwich structures were impregnated and laminated by hand lay-up technique. In this technique, four layers of non-crimp glass fabrics were cut in 150 x 100 mm dimensions. Two layers of fabric were wetted by epoxy resin in order to form lower facesheet and then core material was placed on the lower facesheet, the upper facesheet was laminated with two layers of fabric on the core. Manufacturing process was made in a mold, coated with a mold release agent. After the lamination procedure was completed, composites were cured at room temperature under the pressure of 5 Kpa. Figure 5 shows flow chart of composite sandwich fabrication.

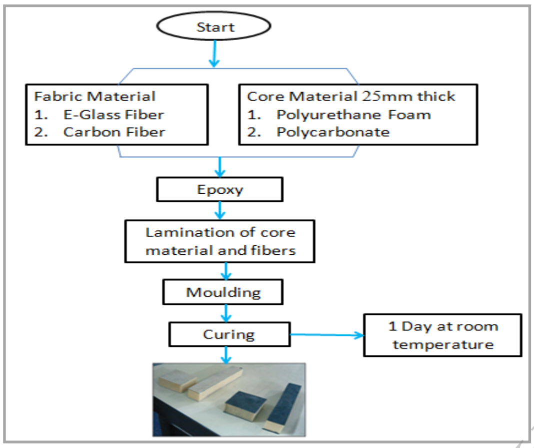

Fig.5. Flowchart of fabrication process of sandwich structure

3.2. Testing

Flatwise compression test and bending test are performed on the respective specimens.

Flatwise compression test method according to ASTM C 365-00 was used to determine the compressive strength, modulus of the composite sandwich panels. For this purpose, compression test specimens were sectioned from larger composite sandwich panels and tests were performed using the mechanical test machine at a crosshead speed of 1 mm/min as shown in Figure 6.

The universal test machine is coupled to a computer this computer is installed with Trapezium software which on giving the input speed gives the compressive strength and modulus, maximum displacement and maximum strength of the specimen

Three point bending test method according to ASTM C 393-00 was used to measure the core shear stress, facing bending stress and panel bending stiffness of the composite sandwich panels. For this purpose, three point bending tests were performed using the mechanical test machine at a crosshead speed of 1.5 mm/min.

Fig.6. Compressive Tests on UTM

The computer controlled UTM (Servo Hydraulic operated universal testing machine) of capacity 50 KN capacity is used to test the sandwich composites. The test was conducted at room temperature and the displacement controlled at a crosshead speed of 0.5 mm/min. Figure 7 shows the specimen setup on Flexural testing mode.

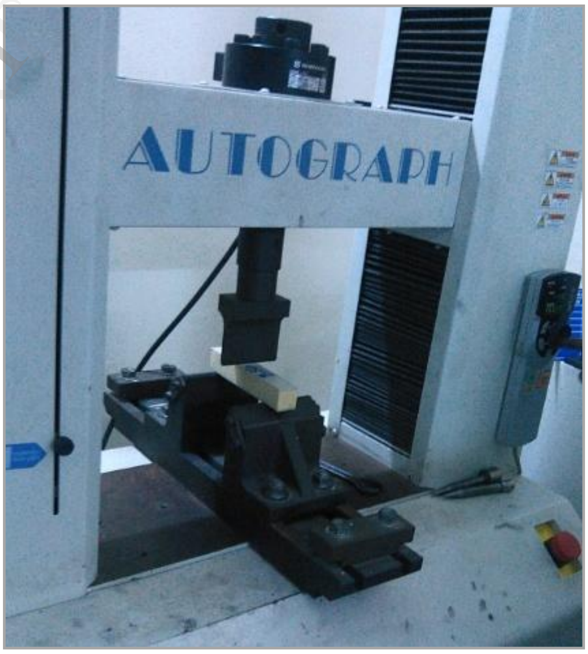

Fig.7. Experimental setup for bending test

4. OPTIMIZATION SETUP FOR COMPOSITES

Any optimization problem has the following constituents

- Design Variable
- Responses
- Constraints
- Objective

Design Variable: The formulation of an optimization problem begins with identifying the underlying design variables, which are primarily varied during the optimization process. A design problem usually involves many design parameters, of which some are highly sensitive to the proper working of the design.

Response: Anything which is measurable in the problem parameters can be termed as response. Various responses are Displacement, Stress, Strain, Failure etc

Constraints: The constraints represent some functional relationships among the design variables and other design parameters satisfying certain physical phenomenon and certain resource limitations. The following two types of constraints emerge from most considerations:
1. Inequality type constraints.
2. Equality type constraints

Objective: The next task in the formulation procedure is to find the objective function in terms of the design variables and other problem parameters. The common engineering objectives involve minimization of overall cost of manufacturing or minimization of overall weight of a component or maximization of total life of a product or others.

There are comprehensive optimization opportunities in Optistruct to achieve improvements on composite models. In general, One have the possibilities to make a free- size optimization, a size- optimization or a ply stacking optimization independent of each other. Optistruct provides a lot of free-sizing constraints:

1. Lower and upper bounds on the total thickness of the laminate.
2. Lower and upper bounds on the thickness of individual orientations.
3. Lower and upper bounds on the thickness percentage of individual orientations.
4. Constant thickness of individual orientations.
5. Thickness balancing between two given orientations.
6.generic manufacturing constraints, pattern grouping or member size control

In addition the solver can implement different constraints in different areas while saving the continuity of plies. In this optimization sequence we want to achieve weight and cost saving with consideration of some manufacturing constraints.

Figure 8 shows the exploded view of laminate stack up modeled in Hypermesh 11.0

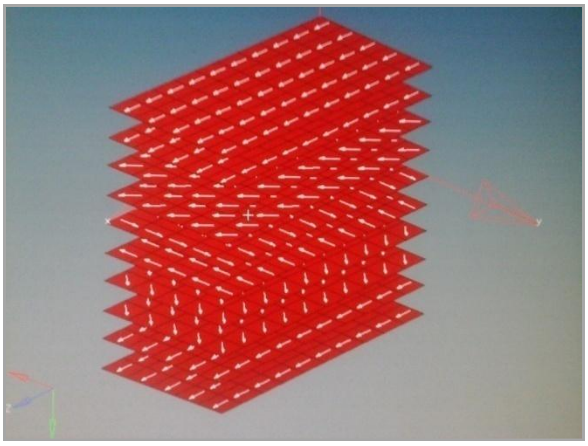

Fig.8. Exploded view of laminate stack up

Figure 9 shows the applied loads and boundary conditions for a composite laminate for free shape optimization.

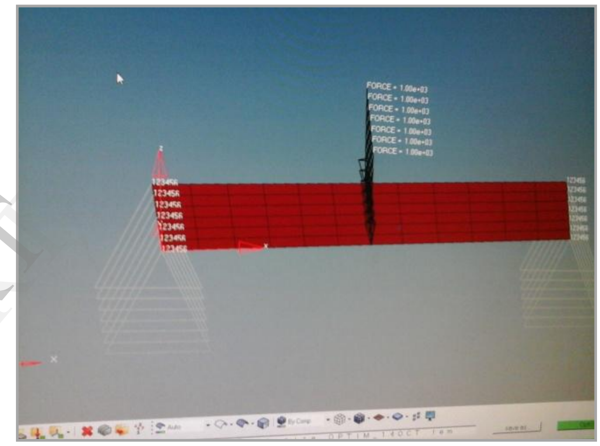

Fig.9.Applied loads and boundary conditions for free size optimization

5. RESULTS AND DISCUSSIONS

In actual practice the laminated sandwich construction exhibits variation in properties. This variation in properties is considered in Finite element Analysis of the structure. The Finite Element Analysis gives the stresses developed in the material, which are compared against the valves obtained from experimental analysis.

From results of different combinations of core and fiber it was observed that Combination of E-Glass fiber and polycarbonate as core material gives the low deformation and can sustain high loads in bending and compression test. The following analysis results are the displacement and stress contours of E-glass and Polycarbonate sandwich structure in bending test.

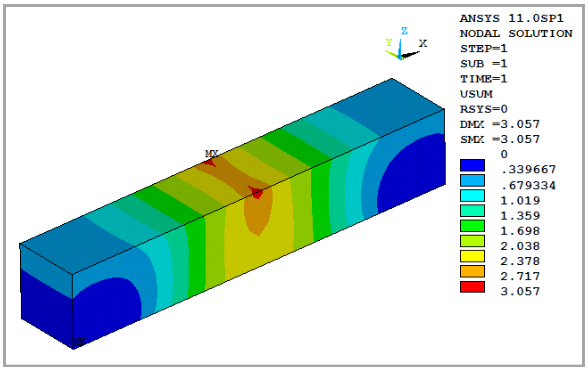

Fig.10. Displacement plot of E-glass + Polycarbonate when subjected to bending

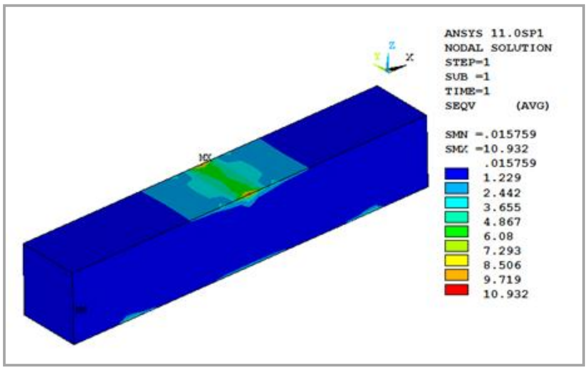

Fig.11 Stress plot of E-glass + Polycarbonate when subjected to bending

Figure 12 and Figure 13 are the displacement and stress contours of E-glass and Polycarbonate sandwich structure in compression test.

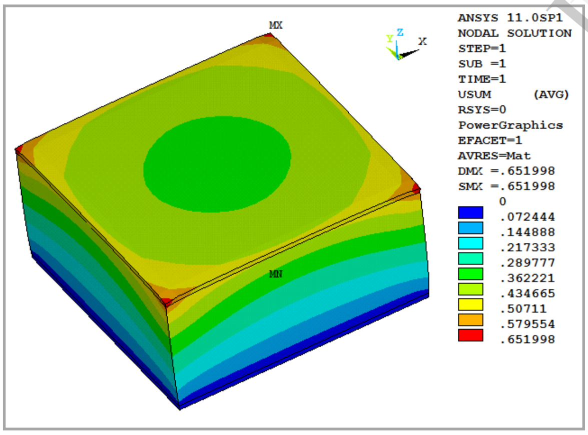

Fig.12. Displacement plot of E-glass + Polycarbonate when subjected to compression

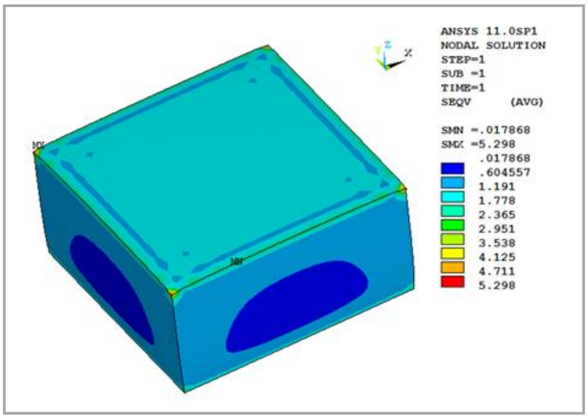

Fig.13. Stress plot of E-glass + Polycarbonate when subjected to compression

Table 2.Comparison of FE and Experimental results

		Max displacement(mm)		Max Stress(Mpa)	
Specimen	Test	FE Results	Test Results	FE Results	Test Results
E-glass+ PC	Bending	3.06	2.92	10.93	10.28
E-glass+ PC	Flat compression	0.65	0.61	5.3	5.19

Optimization results: The objective of minimizing the weight of the structure and imposing constraints on the thickness of plies yielded the following results.

Figure 14 and 15 are the thickness contours given by optistruct after optimization for the objective of minimizing the mass.

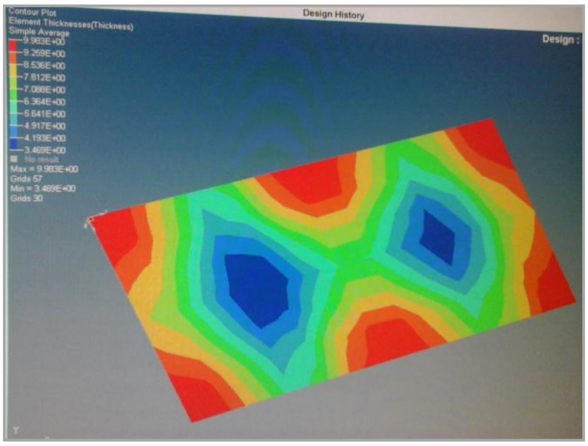

Fig.14. Element thickness contour of Composite laminate after optimization

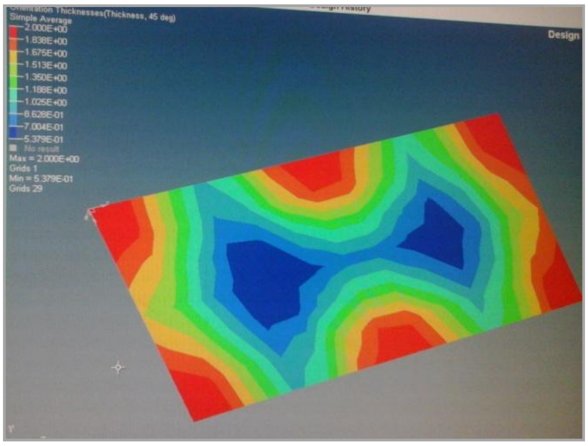

Fig.15. Orientation thickness contour of 45^0 ply in the laminate after optimization

6. CONCLUSIONS

The Experimental calculations and FE analysis results are compared and it is observed that the structure with E-glass fiber and with polycarbonate core can sustain high loads. Also the optimization output shows that better stack can be obtained with imposed constraints and required objective.

From the comparison between FE and experimental results it may be concluded that proper simulation ensures closer results and optimization tool can be used in selection of better combination of plies and orientation before going to the production phase. The Manufacturing difficulties can also be taken into consideration by imposing proper constraints.

Future scope of work includes extension of optimization to Random vibration of composite structures.

REFERENCES

[1]. *Borsellino, C., Calabrese, L. and A. Valenza*. 2004. Experimental and numerical Evaluation of Sandwich Composite Structures. *Composite Science and Technology*, 64:1709-1715.
[2]. *W. Steven Johnson and C. Kyle Berkowitz*- Fracture and Fatigue Tests and Analysis of composite Sandwich Structure, volume 39, No. 16, Pages 1417-1431 [2005].
[3]. *G. Caprino, P. Iaccarino , and A. Lamboglia*- The effect of shear on the rigidity in three point bending of unidirectional CFRP laminates made of T800H/3900-2 Volume 88, Issue 3, May 2009, Pages 360-366 [2008]
[4]. *M. Dawood, E. Taylor and S. Rizkalla*- Two-way bending behavior of 3-D GFRP sandwich panels with through-thickness fibre insertions. (Volume 92, Issue 4, pages950- 963) [2010]
[5]. Altair hyperworks Optistruct theoretical manual.