STRENGTH EVALUATION IN J-NOSE PANEL OF AN AIRCRAFT WING UNDER STATIC LOAD

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Abstract- The sandwich construction has been recognized as a promising concept for structural design of light weight systems such as wings of aircraft. The strength evaluation J-nose sandwich panel of an aircraft wing under various types of loading. The sandwich composites are multilayered materials made by bonding stiff, high strength skin 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. A sandwich construction, which consists of two thin facing layers separated by a thick core, offers various advantages for design of weight critical structure. These structures can carry in-plane and out-of-plane loads and exhibit good stability under compression, keeping excellent strength to weight and stiffness to weight characteristics. Depending on the specific mission requirements of the structures, glass fiber reinforced polymer composites are used as the material of facings skins. The core shape and material may be utilized in the construction of sandwich among them; it has been known that the glass fiber reinforced polymer with honeycomb core has excellent properties with regard to weight savings and fabrication costs. In order to use these materials in different applications, the knowledge of their static behavior is required and detailed design procedures are presented for determining deflections of sandwich beams or panels and buckling of sandwich columns and simply supported panels under edge load.The modes of failure of sandwich under various loadings are illustrated and a better understanding of the various failure mechanisms under static loading condition is necessary and highly desirable.

The objective of this study is to develop a modeling approach to predict response of composite sandwich panels under static bending conditions . The different models including Mono-core and Multi-core were modeled in advanced finite element software. Comparison of mono core and multi core model predictions with experimental data on sandwich panel bending properties helped in establishing appropriate modeling approach. Analytical solutions were also used to verify the some of the mechanical properties such as bending stress and shear stress with the MSC NASTRAN/PATRAN results.

The sandwich panel consists of 2 layers of face sheets (Glass fiber reinforced polymer composites), with ply 1 has 0.3 mm thickness & ply 2 has 0.1 mm thickness and core (Mono and Multi core) is present between top and bottom face sheets which has 19.2 mm (Mono-core) and 9.4 mm (Multi-core) thickness.

Key words-Aircraft ,wing, Multilayer sandwich composite, sandwich panel, FEM, analytical solution, MSC NASTRAN/PATRAN, glass fiber, Nomax flex core.

1. AIR CRAFT

Aircraft heavier than air flying machine, supported by aero foils, designed to obtain,when driven through the air at an angle inclined to the direction of motion,are action from the air approximately at right angles to their surface, the major parts of an aircraft with different composite materials such as CFRP,GFRP,Hybrid,Glare and majorly honeycomb is used in aircraft to reduce the weight as shown in Fig.1.

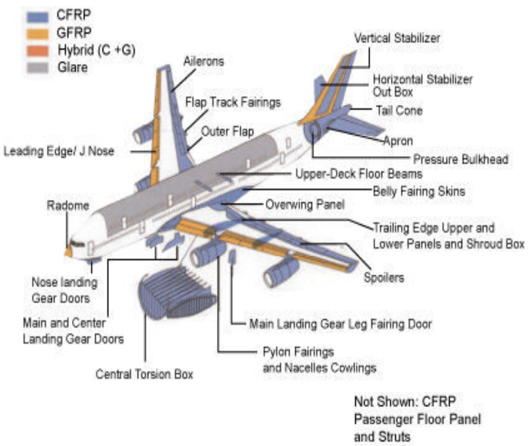


Fig.1 The major parts of an aircraft with different composite materials

II .WINGS

Providing lift is the main function of the wings of an aircraft. The wings consist of two essential parts. The internal wing structure as shown in Fig.2, consisting of spare ribs, stringers, and the external wing, which is the skin. Ribs give the shape to the wing section, support the skin (prevent buckling), Aerodynamic forces not only bend the wing, they also twist it.

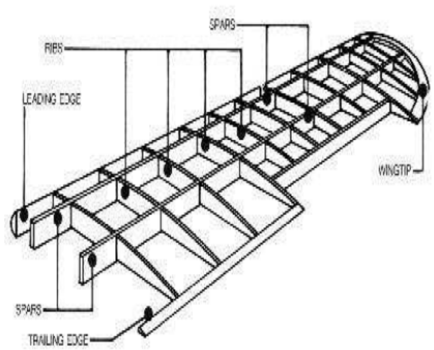


Fig.2 Internal structure of the wing.

The sand wich panels are most commonly used in air craft's to increase the strength. Most of the critical areas in J nose panel of an aircraft wing are lot of skin imperfections and core failure modes, therefore to increase stiffness and core strength in j-nose panel of an aircraft wing, a wing leading edge formed from honeycomb material and glass fiber reinforced polymer composite as shown in Fig.3.

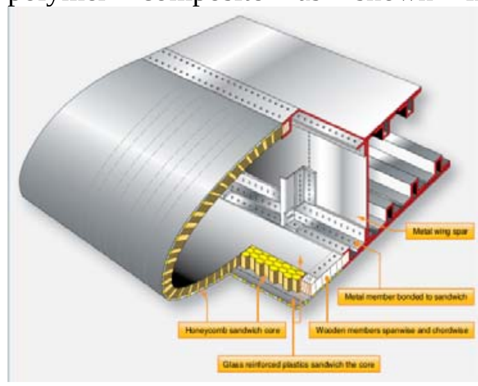


Fig.3 A wing leading edge formed from honeycomb material and glass fiber reinforced polymer composite.

III. INTRODUCTION

Composite sandwich panel have been increasingly used in aerospace industry for various applications such as floor panels, comportment partitions, bulkheads, and even the skin and wings. It is important to design light weight structure for aircraft operations, sandwich panel serves this requirement. The sandwich composites are multilayered materials made by bonding stiff, high strength skin facings to low density core material. The main benefits of using the sandwich concept in structural components are the high stiffness and low characteristics. In order to use these materials in different applications, the knowledge of their static behavior is required and a better weight ratios. These structures can carry in-plane and out-of-plane loads and exhibit good stability under compression, keeping excellent stiffness and strength to weight understanding of the various failure mechanisms under static loading condition is necessary and highly desirable.

M.M. Venugopal and S K Maharana [1]In this paper sandwich composites are multilayered materials made by bonding stiff, high strength skin facings to low density core material. These structures can carry in-plane and out-of-plane loads and exhibit good stability under compression, keeping excellent strength to weight and stiffness to weight characteristics. In order to use these materials in different applications, the knowledge of their static behavior is required and a better understanding of the various failure mechanisms under static loading condition is necessary and highly desirable.Belouettar and Abbadi [2] presented experimental investigation of static behavior of composite honeycomb material made up of aramide fibers and aluminium cores are investigated through four point bending test. The local and global parameters considered to evaluating behavior of sandwich composite, but results are not accurate due to the only experimental study is shown there is no comparison made with any other analytical method. Meyer-Piening [3] suggested that local failures in sandwich structures often occurred because of a lack of awareness of designers of important aspects such as the distribution of displacements through the thickness, axial forces in the face sheets, and the difference between the vertical deflections of upper and lower face sheets. Kemmochi and Uemura [4] investigated the stress distribution in sandwich beams made of three kinds of photo elastic materials under four-point bending. Juli F Davalos and Pizhong qiao [5] studied design modeling and experimental characterization of a FRP honeycomb panel with sinusoidal core geometry in the panel and extending vertically between face laminates. The finite element modeling of test sample is conducted. The result correlates with analytical prediction and experimental values excellent matching is achieved between results.

A.Bezazi and A El Mahi [6] studied analysis of stiffness during static test of sandwich panels and their components. Sandwich panel made of glass fiber and epoxy resin, are subjected to three point bending tests, poly vinyl chloride cores of different densities were investigated in this study, the effect of core densities and its thickness on the behavior is highlighted this paper proves that sandwich structure has better mechanical characteristics compared to its components. Engin M, Reis and Sami.H.Rize kalla [7] presented material characteristics of 3D FRP sandwich panel this paper investigated, flexural, shear, tensile and compressive behavior of sandwich panel face sheet made of FRP and GFRP with foam core the top and bottom face sheets connecter with thick fibers, this paper summarized extensive experimental program discussed many parameters to evaluate sandwich panel behaviors. Jamal Arbaoui, Yves Schmitt and Franc¸ois-Xavier Royer [8] in this paper, an experimental investigation, an analytical analysis and a numerical model of a typical four-point bending test on a polypropylene honeycomb multi-layer sandwich panel are proposed. The polypropylene honeycomb core is modelled as a single solid and multi-layer of equivalent material properties. Analytical and numerical (finite element) homogenization approaches are used to compute the effective properties of the single honeycomb core and analytical homogenization of the multi-layer one. The results obtained by numerical simulation (finite element) of four-point bending are compared with the experimental results of a polypropylene honeycomb core/composite facing multi-layer sandwich structures

IV. DESCRIPTION OF PROBLEM

The four point bending test composite (nomax flex core) sandwich panel of size 700 mm x 75 mm x 20 mm, under uniform static four point bend loading was considered. The sandwich panel consists of 2 layers of face sheets (Glass fiber reinforced polymer composites), with ply 1 has 0.3 mm thickness & ply 2 has 0.1 mm thickness and core (Mono and Multi core) is present between top and bottom face sheets which has 19.2 mm (Mono-core) and 9.4 mm (Multi-core) thickness. The face plate laid stacking sequence is [0/90]. A sandwich panel that consists of GFRP face sheets and Nomax Flex core has been considered for the analysis.

V.FINITE ELEMENT MODELING

The finite element software was used to model the sandwich panel, in this analysis both mono core and multi core models are created by using following element type based on convergence test and it is used throughout the study 2D-non linear layered shell element called shell 91 is used for modeling of thick sandwich structures this has ability to take up to 100 layers. 3D 8 nodded multi layered solid element called as solid46, is used to model for 3D sandwich panel this element takes orthotropic material properties, layered material direction angles and layered thicknesses. The geometry, nodal locations and coordinate system of the elements are shown on the Fig.4, and also the core uses 3D anisotropic structural solid element called solid64. This element has eight nodes having three degree of freedom at each node;

translation in x, y, and z directions. The element has stress stiffening and large deflection capabilities and the element has various applications, such as for crystals and composites.

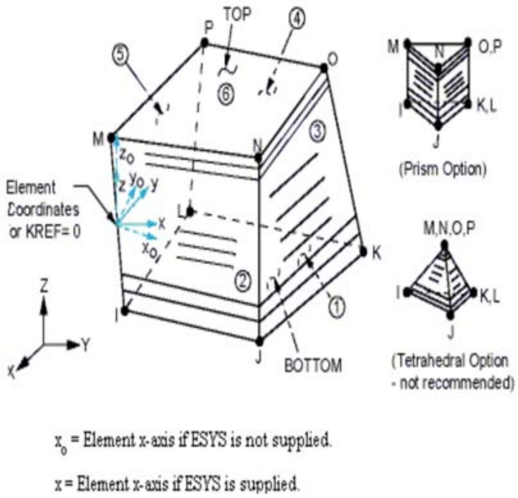


Fig.4 Element geometry of 3D layered solid element.

Fig.5 Finite Element modeling of composite sandwich panel – 3D Mono Core.

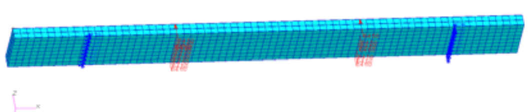


Fig.6 Finite Element modelling of composite sandwich panel – 3D MultiCore.

The solid model accounts for a three dimensional nature uses solid layered element to model the two face sheets and anisotropic solid element used for model core. This 3D sandwich panel model was able to accommodate both orthotropic and anisotropic material properties. Finite Element modeling of composite sandwich panel – 3D Mono Core as shown in Fig.5 & Finite Element modelling of composite sandwich panel – 3D MultiCore as shown in Fig.6.

VI.MATERIAL PROPERTIES OF SANDWICH PANEL

The four point bending test composite sandwich panel of size 700 mm x 75 mm x 20 mm, under uniform static four point bend loading was considered. The sandwich panel consists of 2 layers of face sheets, with ply 1 has 0.3 mm thickness & ply 2 has 0.1 mm thickness and core (Mono and Multi core) is present between top and bottom face sheets which has 19.2 mm (Mono-core) and 9.4 mm (Multi-core) thickness. The material properties of composite sandwich panel are given by Table.1. Material Properties of composite sandwich panel – Mono core as shown in Fig.7 & Material Properties of composite sandwich panel – Multicore as shown in Fig.8.

Material	Ply	Core
E_{11}, Mpa	28800	1
E_{22}, Mpa	28800	1
E_{33}, Mpa	28800	240
G_{12}, Mpa	3000	1
G_{23}, Mpa	337	30
G_{13}, Mpa	3000	48
v_{12}	0.13	0.5
v_{23}	0.01	0.0
v_{13}	0.13	0.0

Table.1 Material properties of composite sandwich panel.

Fig.7 Material Properties of composite sandwich panel –Mono core

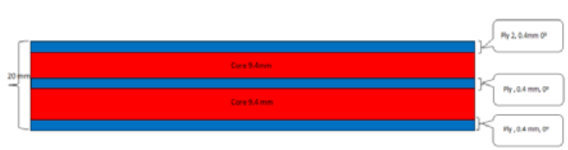


Fig.8 Material Properties of composite sandwich panel – Multi core

VII.BOUNDARY CONDITIONS

The Fig.9 shows the boundary conditions adapted for analyzing sandwich panel. The two supporting points of either end of panel is fixed at translation at Z=0 and static bending load is applied opposite to the supporting point and Below Fig.10 shows four point bending test specimen dimensions. FEA Set-up of Bending Test (Loads and BCs) For Mono-core Sandwich Panel as shown in Fig.11 & FEA Set-up of Bending Test (Loads and BCs) For Multi-core Sandwich Panel as shown Fig.12.

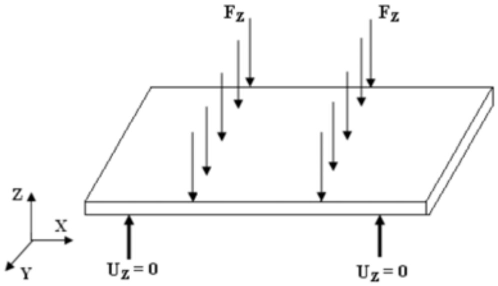


Fig.9 Load applications and boundary condition

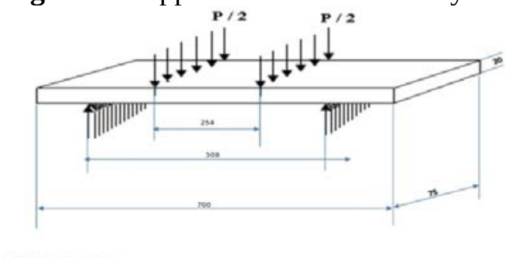


Fig.10 Four Point Bending Test Specimen

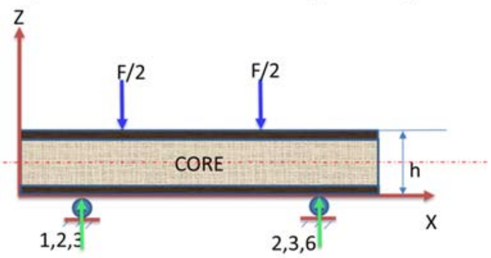


Fig.11 FEA Set-up of Bending Test (Loads and BCs) For Mono-core Sandwich Panel

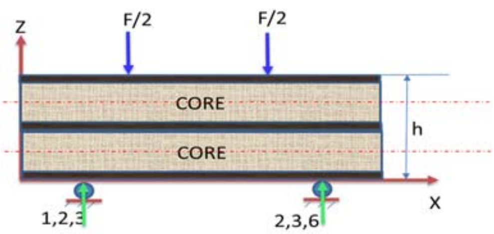
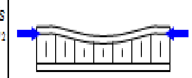
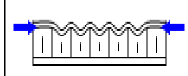
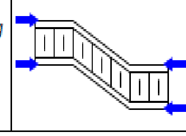


Fig.12 FEA Set-up of Bending Test (Loads and BCs) For Multi-core Sandwich Panel.

VIII.FAILURE MODES

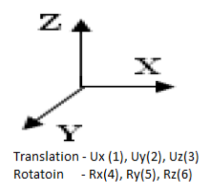
Designers of sandwich panels must ensure that all potential failure modes are considered in their analysis. A summary of the key failure modes is shown below:

FAILURE MODE	DESCRIPTION	FAILURE MITIGATION
• Core Wrinkling *Buckling over many cells* $\sigma < \sigma_{Wr} = 0.82 E_f \left[\frac{E_c t_f}{E_f t_c}\right]^{1/2}$		• Choose thin core or thick skin
• Intracell Dimpling *Buckling in single cell* $\sigma < \sigma_{Dimp} = 2\frac{E_f}{\lambda}\left[\frac{t_f}{S}\right]^2$		• Choose small cell size
• Core Crimping *Combined skin buckling* $\sigma < \sigma_{Cr} = \frac{t_c G_c}{2t_f}$		• Choose thick core or stronger core

IX.FEA VALIDATION

FEM validation has been carried-out by considering the composite sandwich panel and the properties that are published in journal paper (Ref. 1).

The validation study of composite sandwich panel of size 800 mm x 300 mm x 17.4 mm, under uniform static four point bend loading was considered. The sandwich panel consists of



8 layers of face sheets, each 0.15 mm thickness and core is present between top and bottom face sheets which has 15 mm thickness. The face plate has the stacking sequence [45/-45/0/90]. Below Fig.13 shows four point bending test specimen dimensions of a journal paper (Ref. 1)

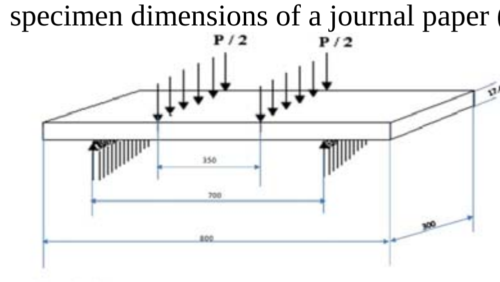


Fig.13 Four Point Bending Test Specimen

X.RESULTS AND DISCUSSION

An application, a full size GFRP honeycomb panel of size 700 mm x 75 mm x 20 mm is tested under static four point bending and also analyzed by FE method. The panel bottom surface is simply supported over a span 700mm and subjected to a pitch load. Four point loading

Load (P) Kg	Load (P) N	Deflection, mm			% Comparison		
		Mono Core (LW-dir)	Mono Core (WL-dir)	Multi Core	Result 1Vs2	Result 1Vs3	Result 2Vs3
100	981	11.83	12.34	12.3	-4.31%	-3.97%	0.32%
200	1962	23.66	24.68	24.6	-4.31%	-3.97%	0.32%
300	2943	35.49	37.02	36.9	-4.31%	-3.97%	0.32%
400	3924	47.32	49.36	49.2	-4.31%	-3.97%	0.32%
500	4905	59.15	61.70	61.5	-4.31%	-3.97%	0.32%

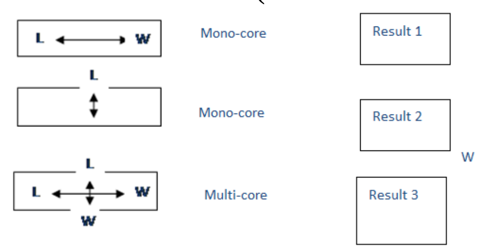
condition are applied at mid span to simulate symmetric condition. FE method is conducted at two modeling condition: (1) Mono core Sandwich panel model, (2) Multi cores Sandwich panel model, for each model condition, the deflections were recorded at mid span with corresponding stresses.

A sandwich panel with equivalent 2 layers (top and bottom faces and core) is modeled. For simplicity and verification purposes, the equivalent properties obtained for face laminates and core are used directly in the model. In case of Mono core Sandwich panel model the face laminates and core are each modeled in single layer using 8-noded shall element called SHELL91. The displacement contours obtained from MSC NASTRAN/PATRAN, Deflection plot of composite sandwich panel – Mono core (LW) for Load case 1 are shown in Fig.14. In case of 3D Sandwich panel model the face sheet and core are modeled in three different layers using 8-noded solid elements called SOLID 46 for two face sheets and SOLID 64 for Core. The displacement contours obtained from MSC NASTRAN/PATRAN. Deflection plot of composite sandwich panel – Mono core (WL) for Load case 1, are shown in Fig.15& Deflection plot of composite sandwich panel – Multi core for Load case 1,as shown in Fig.16
Comparison of 3D deflection for all the load cases (Mono & Multi core) as shown in Table 2, the mono core and multi core Sandwich panel FE predictions based on equivalent material properties compare favorably with experimental data.

The 3D-Results comparison– Multicore (2 layers of core,3 layers of core and 5 layers of core). The height of the sandwich remains same i.e. 20 mm for all the cases as shown in Table 3

and deflection plot for Loadcase 1as shown in Fig.17,for every load case deflection of FEM result can be obtaind, those results comparison of deflection for all the load cases (Experimental Vs FEM) as shown in the Table .4,

Table.2 Comparison of 3D deflection for all the load cases (Mono & Multi core)



Load (P) Kg	Deflection, mm				
	Mono Core (LW-dir)	Mono Core (WL-dir)	Multi core (2 cores)	Multi Core (3 cores)	Multi Core (5 cores)
	Thickness Core = 19.2 Total Face sheet = 0.8	Thickness Core = 19.2 Total Face sheet = 0.8	Thickness Core = 18.8 Total Face sheet = 1.2	Thickness Core = 18.4 Total Face sheet = 1.6	Thickness Core = 18.0 Total Face sheet = 2.0
100	11.83	12.34	12.3	12.02	9.06
200	23.66	24.68	24.6	24.04	18.12
300	35.49	37.02	36.9	36.06	27.18
400	47.32	49.36	49.2	48.08	36.24
500	59.15	61.70	61.5	60.1	45.3

Table 3. 3D-Results comparison– Multicore (2 layers of core,3 layers of core and 5 layers of core). The height of the sandwhich remains same i.e. 20 mm for all the cases.

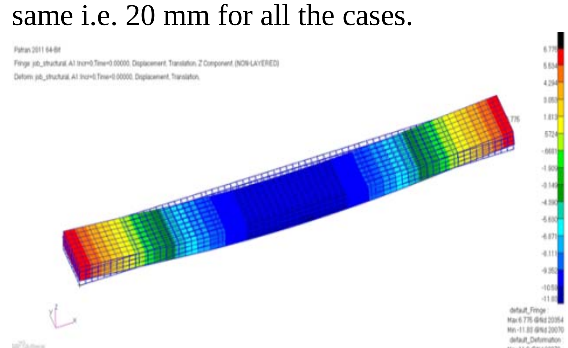


Fig.14 Deflection plot of composite sandwich

panel – Mono core (LW) for Load case 1

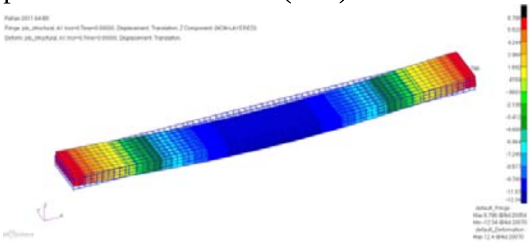


Fig.15 Deflection plot of composite sandwich panel – Mono core (WL) for Load case 1

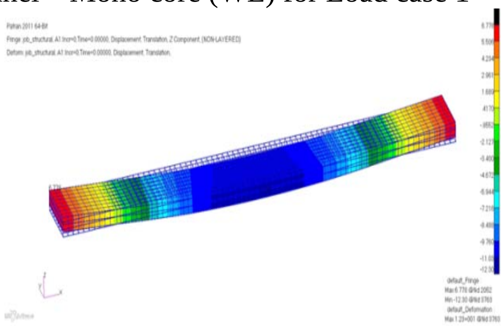


Fig.16 Deflection plot of composite sandwich panel – Multi core for Load case 1

Load Case	Load (P) KN	Experimental, mm	FE Deflection, mm	Deviation
1	2	4.6	4.53	1.52%
2	2.5	5.9	5.85	
3	3	6.9	6.83	
4	3.5	8	7.97	
5	4	9.1	9.05	
6	4.5	10.3	10.26	
7	5	11.5	11.48	
8	5.5	12.7	12.67	
9	6	13.8	13.73	
10	6.5	15.2	15.16	
11	7	16.2	16.18	
12	7.5	17.3	17.26	
13	8	18.4	18.33	0.38%
14	8.5	19.7	19.67	

Table.4 Comparison of deflection for all the load cases (Experimental Vs FEM)

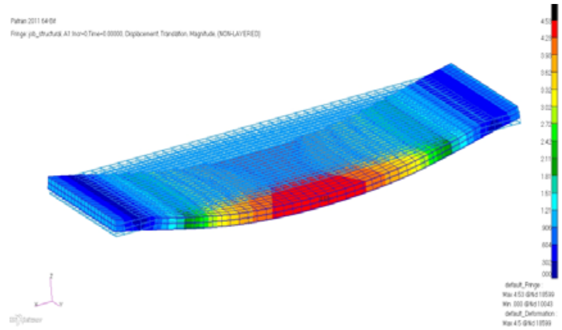


Fig.17 Deflection plot for Loadcase 1

XI.CONCLUSIONS

This paper presents a combined Finite element modeling and experimental analysis of glass fiber composite sandwich panel. The core consists of Nomax honey comb structure presented in between top and bottom face laminate. The emphasis of this study is on evaluation of deflection, under static four point bending condition. The mono core and multi core FE model predictions correlate with experimental results of Sandwich specimen. The predicted deflection in this study is success fully matching the response of glass fiber composite sandwich panels. The multicore FE model under static loading condition is closely matching with experimental deflection. Displacements reduces on increasing the numbers of cores. This may be because increasing the number of ply layers which adds to stiffness.

XII.ACKNOWLEDGEMENT

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