FINITE ELEMENT ANALYSIS OF SANDWICH STRUCTURES WITH A FUNCTIONALLY GRADED CORE

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Abstract: Sandwich structures, broadly utilized in aviation and maritime applications, will in general be restricted to a little scope of material mixes. Practically evaluated materials (FGMs) have properties that shift slowly with area inside the material. For instance, a rocket engine packaging can be made with a material framework to such an extent that within is made of an unmanageable material, the outside is made of a solid metal, and the change from the hard-headed material to the metal is progressive through the thickness. In this proposal, limited component investigation is performed on a sandwich structure with a practically evaluated center for dissecting its solidarity. Numerical connections are done to decide the material properties of practically reviewed material with metal Steel utilizing Ceramic as interface zone for each layer up to 10 layers. FGM's are considered for volume parts of K=2. The sandwich structure material is steel. 3D demonstrating is done in Creo 5.0. Static, Modal and Random Vibration examination are done the ordinary sandwich design and sandwich structure with a practically reviewed center utilizing limited component investigation programming ANSYS 19. The outcomes are looked at for both the models.

1. INTRODUCTION

A sandwich structure comprises of two flimsy, solid, and solid face sheets associated by a thick, light and low-modulus center utilizing glue joints to acquire productive lightweight construction (Zenkert, 1997; Vinson, 2001). In the vast majority of the cases the faces convey the stacking, both in-plane and bowing, while the center opposes cross over shear loads. A sandwich works similarly as an I-shaft with the distinction that the center of a sandwich is of an alternate material and is loosened up as a consistent help for the face sheets. The fundamental favorable position of a sandwich structure is its incredibly high flexural solidness to-weight proportion contrasted with different designs. As an outcome, sandwich development brings about lower horizontal distortions, higher clasping obstruction, and higher characteristic frequencies than do different designs. Accordingly, for a given arrangement of mechanical and natural burdens, sandwich development frequently brings about a lower underlying load than do different setups. Not many of the downsides of sandwich structures are: producing techniques, quality control and joining challenges.

1.1 Sandwich Theory

Sandwich hypothesis depicts the conduct of a bar, plate, or shell which comprises of three layers – two face sheets and one center. The most normally utilized Sandwich structures, generally utilized in aviation and maritime applications; will in general be restricted to a little reach

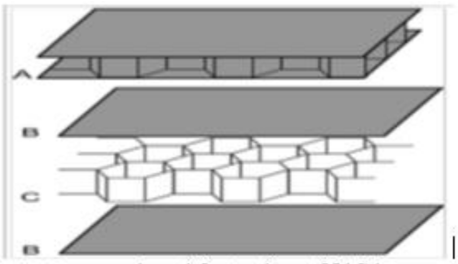


Fig 1.5 – Composite sandwich structure panel used for testing at NASA

Fig 1.6 – Diagram of an assembled composite sandwich (A), and its constituent sheets or skins (B) and honeycomb core (C) (alternately: foam core)

Sandwich hypothesis is straight and is an augmentation of first request shaft hypothesis. Straight sandwich hypothesis is of significance for the plan and investigation of sandwich boards, which are useful in building development, vehicle development, plane development and refrigeration designing.

2. LITERATURE REVIEW

The accompanying works are finished by certain creators on practically evaluated center. Neeraj Kumar Sharma [1], a versatility arrangement is gotten for a sandwich pillar with a practically evaluated center exposed to cross over burdens. Nicoleta Alina Apetre [2], introduced diverse scientific and limited component models for sandwich structures with practically evaluated center. Victor Birman [3], the audit traces current patterns in hypothetical turns of events, novel plans and present day uses of sandwich structures. The latest work distributed at the hour of composing of this survey is thought of, more seasoned sources are recorded uniquely on depending on the situation premise. B. Woodward [4], introduced the consequences of an examination concerning the conduct of sandwich boards, with solidness of the center evaluated in the thickness bearing, based on the as of late created 3D flexibility arrangement. The utilization of reviewed center to improve execution of sandwich structures, particularly under confined stacking, is inspected and talked about. Shiqiang Li [5], introduced subtleties and brief aftereffects of an exploratory examination on the reaction of metallic sandwich boards with stepwise evaluated aluminum honeycomb centers under impact stacking. In view of the tests, comparing finite component reproductions have been attempted utilizing the LS-DYNA delicate product. Ehsan Etemadi [6], Three-dimensional limited component reproductions were led for examining low speed sway conduct of sandwich radiates with a practically reviewed (FG) center. Jamal Zamani [7], the effect conduct of sandwich radiates with lopsided and balanced Functionally Graded (FG) centers are researched utilizing limited component technique. As far as possible and leftover speed of a few sandwich radiates with a FG center are examined.

3. Modeling Of Sandwich Structure

The reference for displaying is taken from diary paper "Sandwich boards with practically reviewed center by NICOLETA ALINA APETRE" indicated in References

Table.3.1 – Dimensions of Plates and Core

Identity	Plate	Core
Length (mm)	300	300
Width (mm)	300	300
Thickness (mm)	0.3	5

3d Model Of Sandwich Structure


Fig.3.1 – 3D Model of Top and Bottom Plat

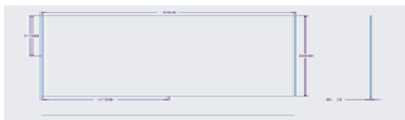


Fig.3.2 – 2D Drawing of Top and Bottom Plates

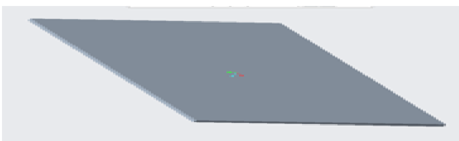


Fig.3.3 – 3D model of Core

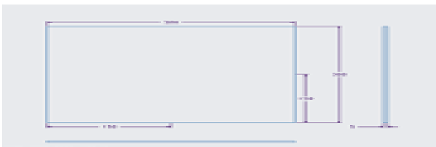


Fig.3.4 – 2D Drawing of Core

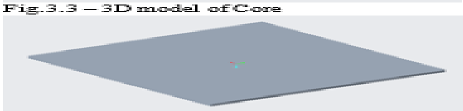


Fig.3.5 – Assembly of Plates and Core

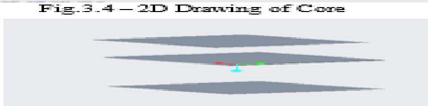


Fig.3.6 – Exploded view of Assembly of Plates and Core

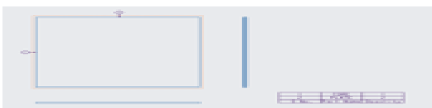


Fig.3.7 – 2D Drawing of Assembly of Plates and Core

3.1 3d model of sandwich structure with core as surface

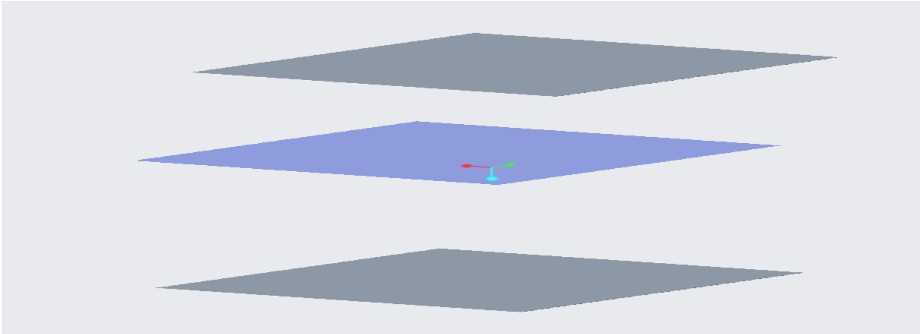


Fig.3.8 – Assembly with core as surface

3.2 Analysis of sandwich structure

Theoretical calculations to determine material properties of fgm

The properties for practically evaluated material with metal Steel utilizing Ceramic as interface zone for each layer up to 10 layers. FGM's are considered for volume portions

of K=2.

Material Properties

Young's Modulus Calculations

Top material: Ceramic (E_t = 380000MPa)

Bottom material: Steel (E_b = 200000 MPa)

1) k = 2; z = 1

$E(Z_1) = (Et-Eb)(z/h+1/2)^K+Eb$

$= (380000-200000)\ (1/5+1/2)^2+200000$

$= (180000)\ (0.49)\ +200000$

$= 88200+200000$

$E(Z_1) = 2882000$ MPa

2) k = 2; z = 2

$E(Z_2) = (Et-Eb)(z/h+1/2)^K+Eb$

$= (380000-200000)\ (2/5+1/2)^2+ 200000$

$= (180000)\ (0.81)\ +200000$

$= 145800+200000$

$E(Z_2) = 345800$ MPa

3) k = 2; z = 3

$E(Z_3) = (Et-Eb)(z/h+1/2)^K+Eb$

= (380000-200000) $(3/5+1/2)^2$+ 200000

= (180000) (1.21) + 200000

= 217800+200000

$E(Z_3)$ = 417800 MPa

4) k = 2; z = 4

$E(Z_4)$ = (Et-Eb)$(z/h+1/2)^K$+Eb

= (380000-200000) $(4/5+1/2)^2$+ 200000

= (180000) (1.69) +200000

= 304200+200000

$E(Z_4)$ = 504200 MPa

5) k = 2; z = 5

$E(Z_3)$ = (Et-Eb)$(z/h+1/2)^K$+Eb

= (380000-200000)$(5/5+1/2)^2$+ 200000

= (180000) (2.25) + 200000

= 405000+200000

$E(Z_4)$ = 605000 MPa

4.1.2 Density Calculations

Ceramic (ρt=0.00000396Kg/mm^3)

Steel (ρb=0.00000785 Kg/mm^3)

1. k = 2; z = 1

ρ(Z) = (ρt-ρb)$(z/h+1/2)^K$+ρb

= (0.00000396-0.00000785)$(1/5+1/2)^2$+0.00000785

= -0.00000389(0.49)+0.00000785

=-0.0000019061+0.00000785

= 0.0000059439Kg/mm^3

2. k = 2; z = 2

ρ(Z) =(ρt-ρb)$(z/h+1/2)^K$+ρb

= (0.00000396-0.00000785)$(2/5+1/2)^2$+0.00000785

= -0.00000389 (0.81)+0.00000785

= 0.0000046991 Kg/mm^3

3. k = 2; z = 3

ρ(Z) $= (\rho t-\rho b)(z/h+1/2)^K+\rho b$

$= (0.00000396-0.00000785)(3/5+1/2)^2+0.00000785$

$= -0.00000389\ (1.21)+0.00000785$

$= 0.0000031431\ Kg/mm^3$

4. k = 2; z = 4

ρ(Z) $= (\rho t-\rho b)(z/h+1/2)^K+\rho b$

$= (0.00000396-0.00000785)\ (4/5+1/2)^2+0.00000785$

$= -0.00000389\ (1.69) +0.00000785$

$= 0.0000012759\ Kg/mm^3$

5. K = 2; z = 5

ρ(Z) $= (\rho t-\rho b)(z/h+1/2)^K+\rho b$

$= (0.00000396-0.00000785)\ (5/5+1/2)^2+0.00000785$

$= -0.00000389\ (2.25)+0.00000785$

4. ANALYSIS

4.1 Boundary Conditions

The reference for limit conditions is taken from diary paper "sandwich boards with practically evaluated center by nicoleta alina apetre" determined in references [2]. The material properties are determined in the underneath table which are taken from site.

Table.4.2 Material Properties

Material	**Density (g/cc)**	**Young's modulus (GPa)**	**Poisson's ratio**
Structural steel	7.85	200	0.3
Ceramic	3.96	380	0.36

4.2 Sandwich Structure

The material for plate is Steel and Core is Ceramic.

4.3 Static Structural Analysis

Open Workbench 19 – Double Click Static Structural

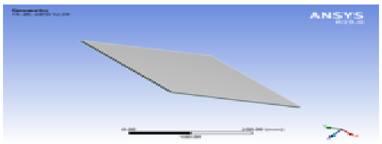
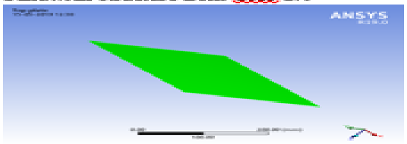


Fig 4.1 – Static Structural window in Ansys Workbench Fig 4.2- Imported model of Sandwich structure from Creo 2.0



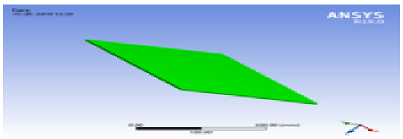


Fig 4.3 - Imported model of top plate of Sandwich structure from Creo 2.0

Fig 4.4 - Imported model of core of Sandwich structure from Creo 2.0

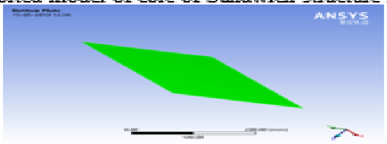


Fig 4.5 - Imported model of bottom plate of Sandwich structure from Creo 2.0

The above figures show the bit by bit strategy to import the top plate, base plate and center into Creo 2.0.

Select Part – Create or select materials

Primary Steel is chosen for top and base plates and Ceramic is chosen for center.

Properties of Outline Row 3: Ceramic

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	3960	kg m^-3		
4	Isotropic Elasticity				
5	Derive from	Young's Mo...			
6	Young's Modulus	3.8E+05	MPa		
7	Poisson's Ratio	0.36			
8	Bulk Modulus	4.5238E+11	Pa		
9	Shear Modulus	1.3971E+11	Pa		

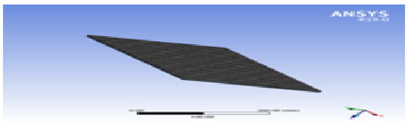
Fig 4.6 – Properties of Ceramic

Properties of Outline Row 4: Structural Steel

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7850	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's M...			
8	Young's Modulus	2E+11	Pa		
9	Poisson's Ratio	0.3			

Fig 4.7 – Properties of Structural Steel

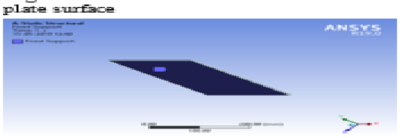
Select Mesh, Select Fine in significant focus and select update. This will fine work the sandwich structure



Statistics	
Nodes	51900
Elements	7203

Fig 4.8 – Meshed Model of sandwich structure Fig 4.9 – Number of nodes and elements

Right click on static structural – select fixed support in Insert – select bottom of bottom plate surface



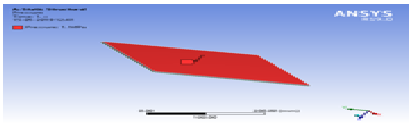


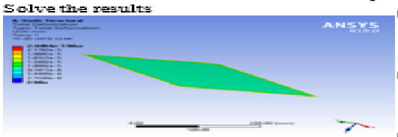
Fig 4.10 – Fixed support is selected on bottom surface of bottom plate

Right click on static structural – select pressure in Insert – select top of top plate surface

Fig 4.11 – Pressure is applied on the top of top plate

Right click on Solution – Select Total Deformation, Equivalent Strain and Equivalent Stress as results of Static Structural analysis

Solve the results



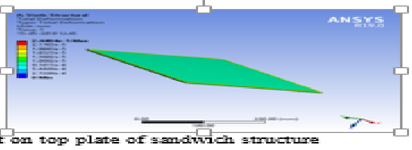


Fig 4.12 – Total Deformation of on top plate of sandwich structure

Fig 4.13 – Total Deformation of on core of sandwich structure

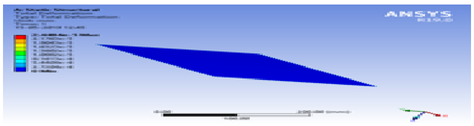
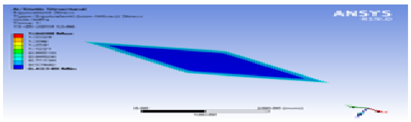



Fig 4.14 – Total Deformation of on bottom plate of sandwich structure

Fig 4.15 – Von – mises stress of on top plate of sandwich structure

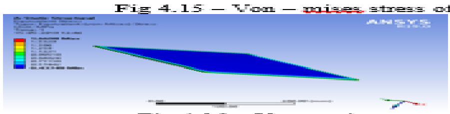
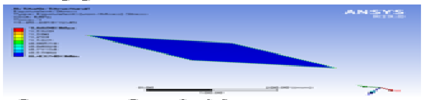



Fig 4.16 – Von – mises stress of on core of sandwich structure

Fig 4.17 – Von – mises stress of on bottom plate of sandwich structure

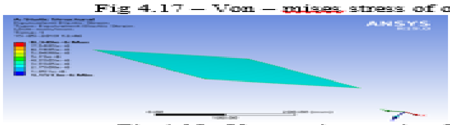
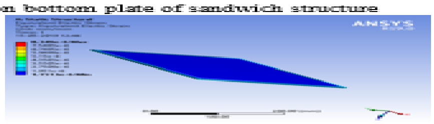



Fig 4.18– Von – mises strain of on top plate of sandwich structure

Fig 4.19 – Von – mises strain of on core of sandwich structure

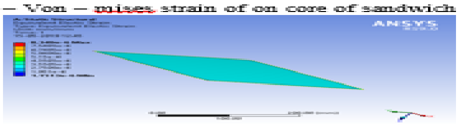
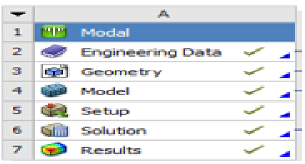


Fig 4.20– Von – mises strain of on bottom plate of sandwich structure

4.4 Modal Analysis

Open Workbench 19 – Double Click Modal



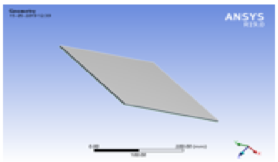


Fig 4.21 – Modal analysis window in Ansys Workbench

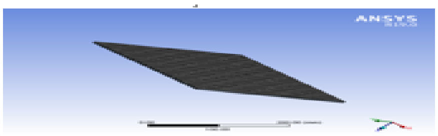
Right click on geometry – Select the Creo model in .iges format

Fig 4.22 - Imported model of Sandwich structure from Creo 2.0

Select Part – Create or select materials

Primary Steel is chosen for top and base plates and Ceramic is chosen for center.

Select Mesh, Select Fine in relevant center and select update.



Statistics	
Nodes	51900
Elements	7203

Fig 4.23 – Meshed Model of sandwich structure

Fig 4.24 – Number of nodes and elements

Right click on static structural – select Fixed support in Insert – select bottom of bottom plate surface

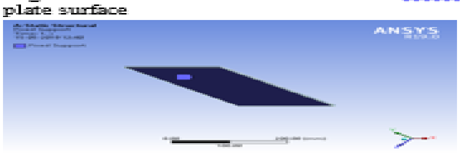
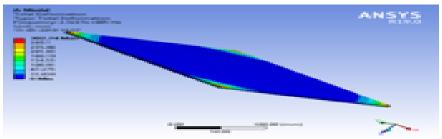



Fig 4.25 – Fixed support is selected on bottom surface of bottom plate

Right click on Solution – Select Total Deformation for mode 1, mode 2, mode 3, mode 4, and mode 5

Solve the results

Fig 4.26 – Total Deformation at mode 1 of sandwich structure

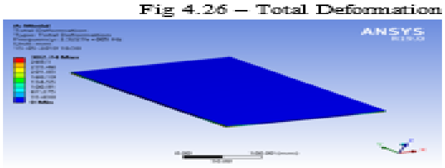
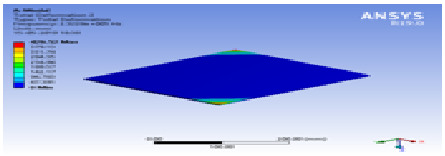
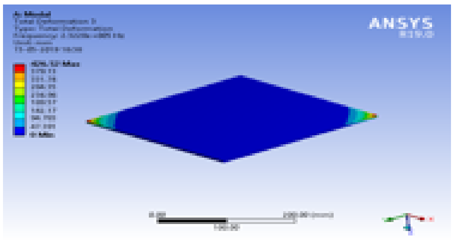



Fig 4.27 – Total Deformation at mode 1 on bottom plate of sandwich structure

Fig 4.28 – Total Deformation at mode 2 of sandwich structure



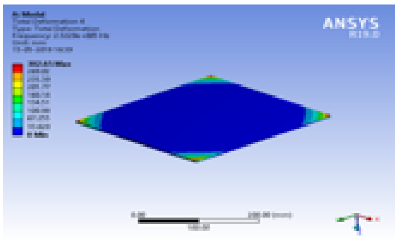


Fig 4.29 – Total Deformation at mode 3 of sandwich structure

Fig 4.30 – Total Deformation at mode 4 of sandwich structure

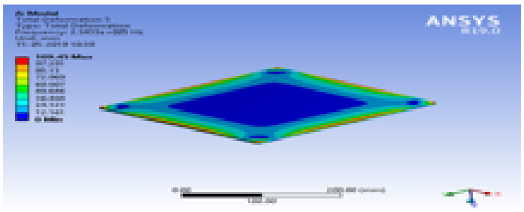


Fig 4.31 – Total Deformation at mode 5 of sandwich structure

4.5 Random Vibration Analysis

In Ansys primary window – Right snap on arrangement of Modal, select Transfer Data to New – select Random vibration

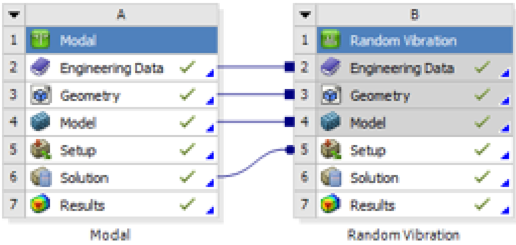


Fig 4.32 – Random vibration analysis window in Ansys Workbench

Right click on Random vibration and select PSD displacement in Insert. Enter frequencies and deformation values from modal analysis

Tabular Data

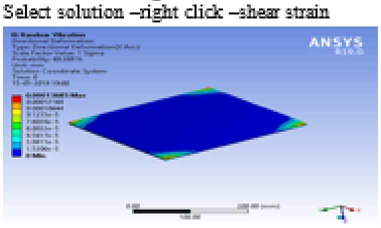
	Frequency [Hz]	Displacement [(mm²)/Hz]
1	2.3227e+005	91651
2	2.3228e+005	1.8192e+005
3	2.3229e+005	91597
4	2.3433e+005	11979
*		

Fig 4.33 – Frequencies and deformation values from modal analysis results

Solution –right click-solve-select solution –right click –directional deformation

Select solution –right click –shear stress

Select solution –right click –shear strain



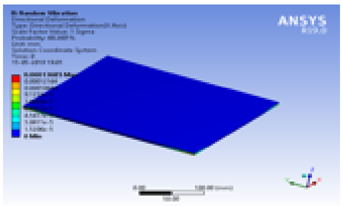


Fig 4.34 – Directional deformation of sandwich structure

Fig 4.35 – Directional deformation on bottom plate of sandwich structure

Fig 4.35 – Directional misshapening on base plate of sandwich structure

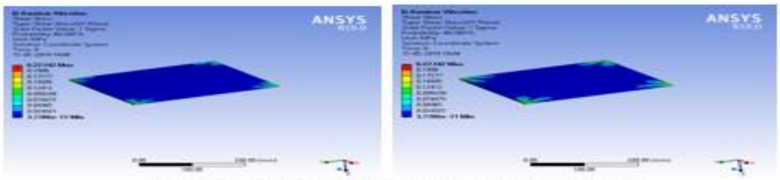


Fig 4.36 – Shear stress on top plate of sandwich structure

Fig 4.37 – Shear stress on core of sandwich structure

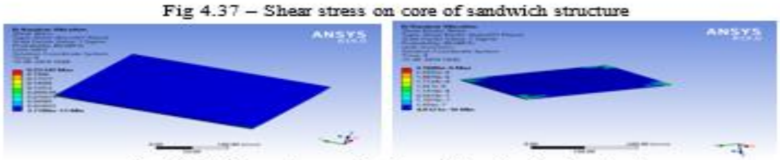


Fig 4.38 – Shear stress on bottom plate of sandwich structure

Fig 4.39 – Shear strain on top plate of sandwich structure

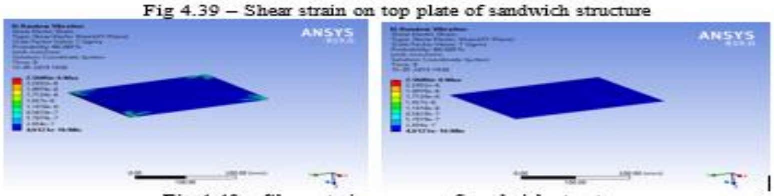


Fig 4.40 – Shear strain on core of sandwich structure

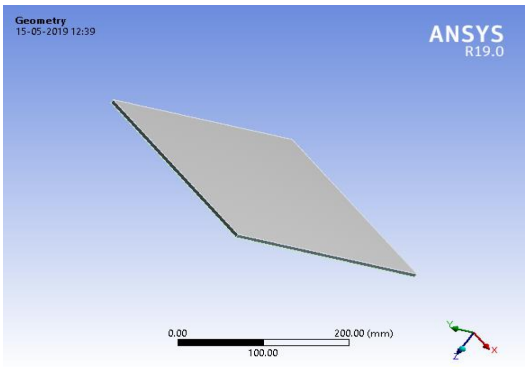
Fig 4.41 – Shear strain on bottom plate of sandwich structure

4.6 Sandwich Structure With Functionally Graded Core

The material for plates is Steel and Core is taken as surface. Layered segment with 10 layers with various material properties for each layer is thought of. The material properties for each layer are determined in the "Hypothetical figurings" section 4.

4.7 STATIC STRUCTURAL ANALYSIS

Open Workbench 19 – Double Click Static Structural



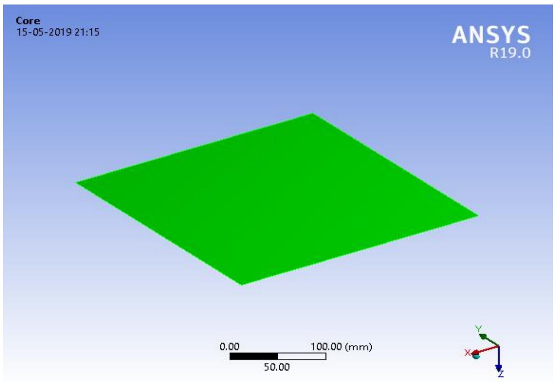


Fig 4.42 - Imported model of Sandwich structure with core as surface
Fig 4.43 – Core geometry.

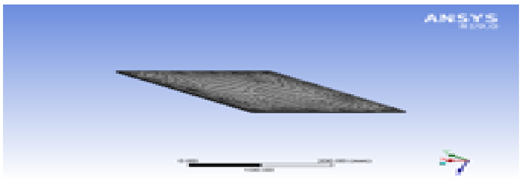
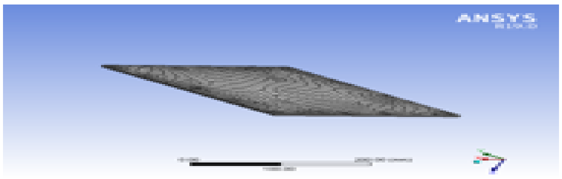



Fig 4.47 – Meshed Model of sandwich structure with functionally graded core

Fig 4.48 – Meshed Model of core

Statistics	
Nodes	35530
Elements	5636

Fig 4.49 – Number of nodes and elements

Right click on static structural – select Fixed support in Insert – select bottom of bottom plate surface

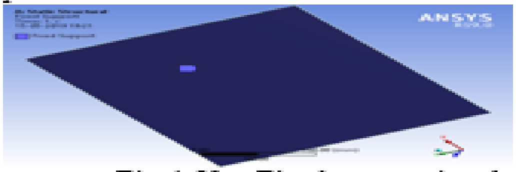
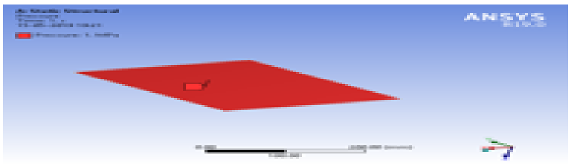



Fig 4.50 – Fixed support is selected on bottom surface of bottom plate

Right click on static structural – select pressure in Insert – select top of top plate surface

Fig 4.51 – Pressure is applied on the top of top plate

Right click on Solution – Select Total Deformation, Equivalent Strain and Equivalent Stress as results of Static Structural analysis

Solve the results

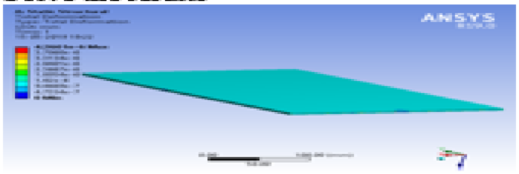
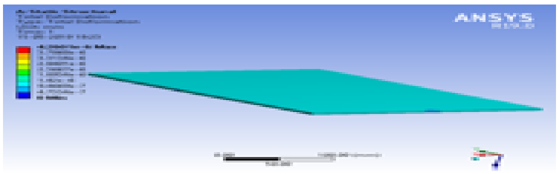



Fig 4.52 – Total Deformation of sandwich structure with functionally graded core

Fig 4.53 – Total Deformation on core of sandwich structure with functionally graded core

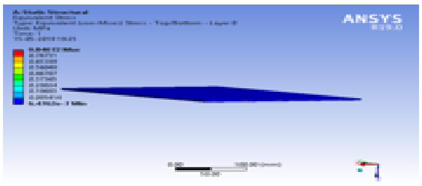
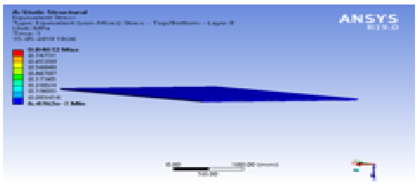



Fig 4.54 – Von – mises stress of sandwich structure with functionally graded core

Fig 4.55 – Von – mises stress on top plate of sandwich structure with functionally graded core

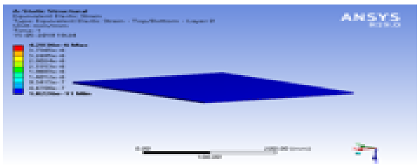
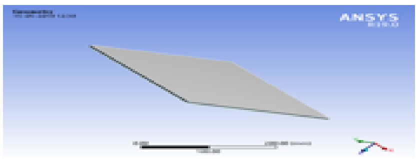



Fig 4.56 – Von – mises strain of sandwich structure with functionally graded core

4.2.3.2 MODAL ANALYSIS

Open Workbench 19 – Double Click Static Structural

Fig 4.57 - Imported model of Sandwich structure with core as surface

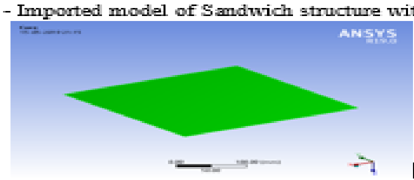


Fig 4.58 – Core geometry

Select Part – Create or select materials

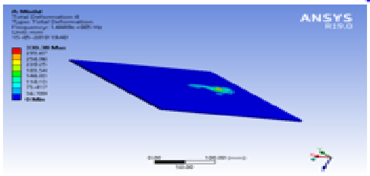
Structural Steel is selected for top and bottom plates

Right snap on calculation – select layered area

Select Core surface as calculation – select Body organize framework – select worksheet

Add layers – select material properties and enter thickness esteem for each layer.

core



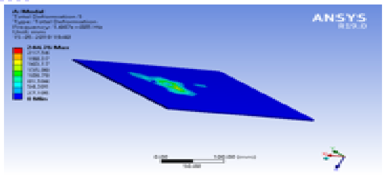


Fig 4.69 – Total Deformation at mode 4 of sandwich structure with functionally graded core

Fig 4.70 – Total Deformation at mode 5 of sandwich structure with functionally graded core

4.2.3.3 RANDOM VIBRATION ALANALYSIS

In Ansys main window – Right click on solution of Modal, select Transfer Data to New – select Random vibration

Fig 4.71 – Random vibration analysis window in Ansys Workbench

Right click on Random vibration and select PSD displacement in Insert. Enter frequencies and deformation values from modal analysis

Tabular Data

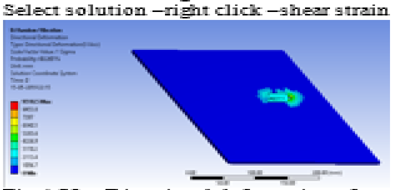
	Frequency [Hz]	Displacement [(mm²)/Hz]
1	1.5268e+005	1.388e+005
2	1.5779e+005	1.4348e+005
3	1.6403e+005	49133
4	1.6449e+005	1.0915e+005
5	1.647e+005	59907

Fig 4.72 – Frequencies and deformation values from modal analysis results

Solution –right click-solve-select solution –right click –directional deformation

Select solution –right click –shear stress

Select solution –right click –shear strain



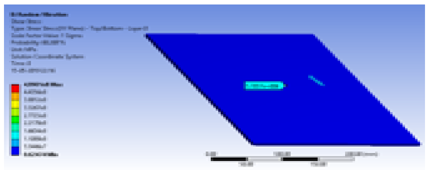


Fig 4.73 – Directional deformation of sandwich structure with functionally graded core

Fig 4.74 – Shear stress of sandwich structure with functionally graded core

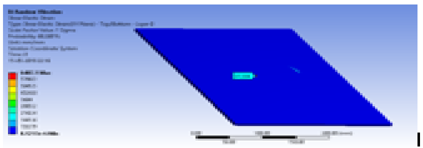


Fig 4.75 – Shear strain of sandwich structure with functionally graded core

5. RESULT & DISCUSSIONS

STATIC STRUCTURAL ANALYSIS

Table 5.1 – Results of Static analysis

Structures	Deformation(mm)	Strain	Stress (MPa)
Sandwich Structure	$2.4484e^{-5}$	$8.349e^{-6}$	1.6698
Sandwich Structure with functionally graded core	$4.2601e^{-6}$	$4.2036e^{-6}$	0.84072

By seeing above outcomes, the pressure, distortion and strain esteems are diminishing for the sandwich structure with practically reviewed center when contrasted and that of customary sandwich structure. The pressure esteem is diminishing by about half, complete misshapening is diminishing by about 82% for the sandwich structure with practically reviewed center when contrasted and that of ordinary sandwich structure.

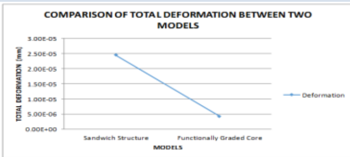


Fig 5.1 – Comparison of Total Deformation between Two Models

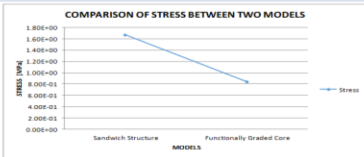


Fig 5.2 – Comparison of Stress between Two Models

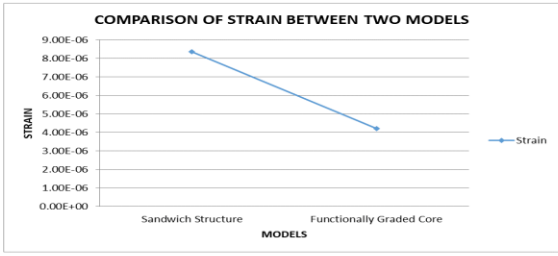


Fig 5.3 – Comparison of Strain between Two Models

5.1 MODAL ANALYSIS

Table 5.2 – Results of Modal analysis

Structures	MODE 1		MODE 2		MODE 3	
	Deformation (mm)	Frequency (Hz)	Deformation (mm)	Frequency (Hz)	Deformation (mm)	Frequency (Hz)
Sandwich Structure	302.74	$2.3227e^5$	302.65	$2.3229e^5$	109.45	$2.3433e^5$
Sandwich Structure with functionally graded core	372.56	$1.5268e^5$	348.79	$1.5779e^5$	244.76	$1.647e^5$

By seeing above outcomes, the recurrence esteems are diminishing for the sandwich structure with practically reviewed center when contrasted and that of traditional sandwich structure however the distortions are expanding. The recurrence esteem is diminishing by about 30%, all out disfigurement is expanding by about 55% for the sandwich structure with practically reviewed center when contrasted and that of customary sandwich structure.

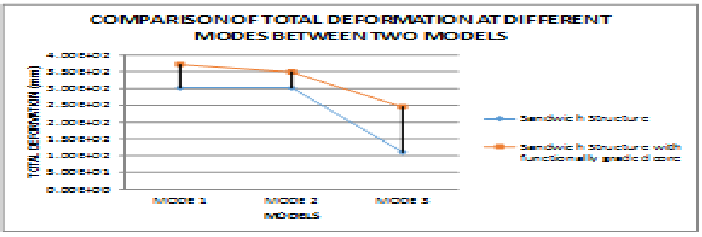


Fig 5.4 – Comparison of Total Deformation at Different Modes between Two Models

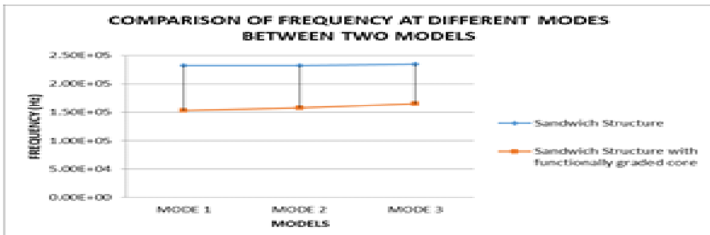


Fig 5.5 – Comparison of Frequency at Different Modes between Two Models

5.2 RANDOM VIBRATION ANALYSIS

Table 5.3 – Results of Random Vibration analysis

Structures	Directional Deformation(mm)	Shear Stress (MPa)	Shear Strain
Sandwich Structure	0.00013685	0.22342	2.5686e^{-6}
Sandwich Structure with functionally graded core	4623.5	5.7037e^{6}	37.339

By seeing above outcomes, the shear pressure, directional twisting and shear strain esteems are expanding for the sandwich structure with practically reviewed center when contrasted and that of ordinary sandwich structure. The qualities are expanding because of increment of misshapening values from Modal examination for sandwich structure with practically reviewed center.

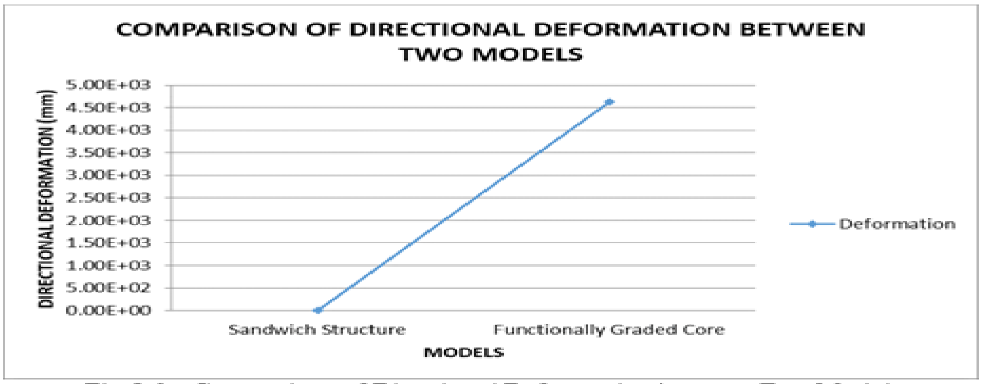


Fig 5.6 – Comparison of Directional Deformation between Two Models

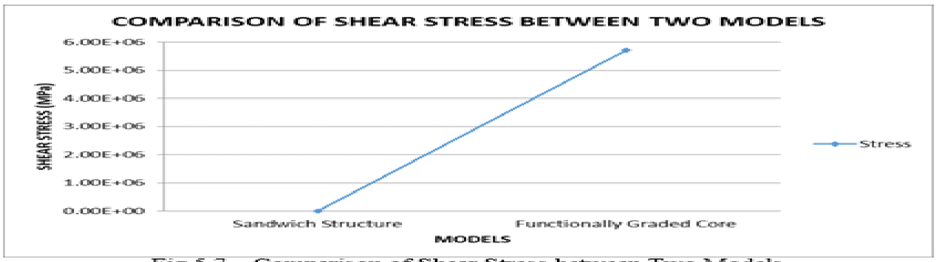


Fig 5.7 – Comparison of Shear Stress between Two Models

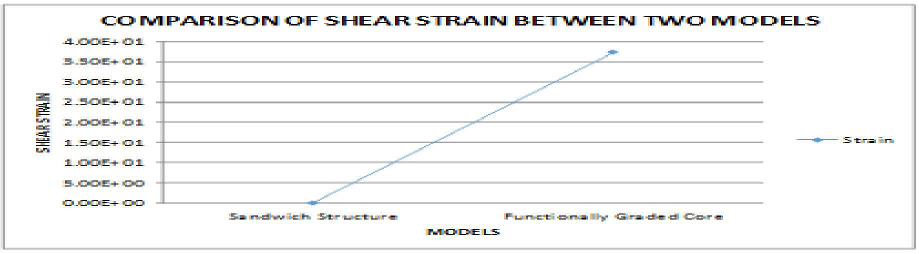


Fig 5.8 – Comparison of Shear Strain between Two Models

6. CONLUSION

Static, Modal and Random Vibration examination are accomplished for the customary sandwich design and sandwich structure with a practically reviewed center utilizing limited component investigation programming ANSYS 19. By noticing Static Structural examination results, the pressure, distortion and strain esteems are diminishing for the sandwich structure with practically evaluated center when contrasted and that of traditional sandwich structure. The pressure esteem is diminishing by about half, absolute disfigurement is diminishing by about 82% for the sandwich structure with practically evaluated center when contrasted and that of customary sandwich structure. By noticing Modal examination results, the recurrence esteems are diminishing for the sandwich structure with practically reviewed center when contrasted and that of ordinary sandwich structure yet the distortions are expanding. The recurrence esteem is diminishing by about 30%, complete disfigurement is expanding by about 55% for the sandwich structure with practically reviewed center when contrasted and that of traditional sandwich structure. By noticing Random Vibration examination results, the shear pressure, directional misshaping and shear strain esteems are expanding for the sandwich structure with practically reviewed center when contrasted and that of ordinary sandwich structure. The qualities are expanding because of increment of misshapening values from Modal examination for sandwich structure with practically evaluated center.

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