Volume 5, Issue 1 (2017) 96-99 ISSN 2347 - 3258
International Journal of Advance Research and Innovation

Effect of Skin-Core Delamination on theInterlaminar Stress Distribution in Sandwich Composites

Avnish Kumar Shukla*, Ashutosh Kumar, Hukam Singh, Rakesh Kumar Shukla, Pawan Mishra
Department of Mechanical Engineering, Krishna Engineering College, Ghaziabad (UP), India-201007

Article Info
Article history:
Received 25 January 2017
Received in revised form
20 February 2017
Accepted 28 February 2017
Available online 15 March 2017

Keywords:-
Interlaminar stress, Sandwich Composites, Face sheet, core, Laminate, FEM, Flexural stiffness, Fiber Orientation Angle

Abstract
Sandwich honeycomb panels are used in wing-fuselage fairings, rudder and elevator surfaces, and the leading and trailing edge of wing panels etc.It consists of thin facesheetswith high stiffness and a thick corewith high shear strength, between them. It is advantageous due to high strength to weight ratio.Interlaminar stresses are developed due to mismatch of elastic moduli and fibre orientation angle between the layers, which causes delamination. The possibility of delamination growth is more when even a small delamination is present in the sandwich panel. In this study, the effect of delamination between core and facesheet on interlaminar stresses is analysed. Ansys 14.0 software is used to perform the finite element analysis.A uniformtransverse load is applied on the top facesheet. The interlaminar stresses along the circumference of selected concentric rings, around the delamination are observed. The variation in interlaminar stresses, along three concentric rings, due to the presence of delamination of different sizes are presented.

1. Introduction

A sandwich structure is a type of composite which consists of two thin and stiff facesheets and a thick but low weight core between them. Skins and coreare attached with the help of adhesives. Facesheets are rigid and core is relatively weak and flexible, but overall sandwich panel is stiff, strong and lightweight.

The basic concept of a sandwich structure is that the facesheets carry the bending loads while the core carries the shear loads. The facesheets are strong and stiff in tension and compression. The core maintains a high section modulus and seperates the facesheets. The core material has relatively low density (e.g., honeycomb or foam), which results in high specific mechanical properties, likewise, high flexural strength and stiffness properties relative to the overall panel density. Therefore, sandwich panels are efficient in carrying bending loads.

Sandwich panels result in lower lateral deformations and higher buckling resistance. Sandwich panels behave like an I-beam, having twoflanges connected with the web. The connecting web makes it possible for the flanges to act together and resist shear stresses. The difference between an I-beam and sandwich panel is that, in sandwich panels, laminates are of different materials and the core provides the continuous support to the laminates while it is concentrated as narrow web in I-beam.

Sandwich structures are used for transportation applications, including cars, subway cars and trains with an aim of reducing weight, emissions, and to integrate details for reduced manufacturing costs, acoustical and thermal insulation. Sandwich design is also included in flooring, interior and exterior panels.GRP terrain vehicles use sandwich in parts of the structure to obtain higher stiffness and strength and integrated thermal insulation. Low structural weight is a feature of the vehicle in order to be able to operate in deep snow conditions. By reducing the structural structure, the pay-load can be increased. A similar application to the truck structure is the sandwich container which possess low weight with high thermal insulation for the transportation of cold goods, e.g. fruit or other types of food.

2. Methodology

To analyze the sandwich composite laminate Ansys 14.0 software is used. 10-noded Solid187 element is used.

2.1 Element type description: In this study, 10-noded Solid 187 element is used for modelling purpose whose description is given as:
10-noded Solid187elementis a higher order 3-D element. SOLID187 has a quadratic displacement behavior. It is well suited to model irregular meshes.The element is defined by 10 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, hyperelasticity, creep, stress stiffening, large deflection, and large strain capabilities[4].

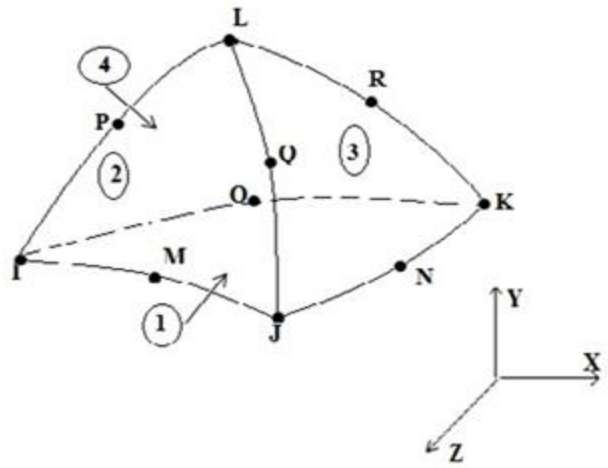

Fig.1 10 noded Solid187 element

2.2 Parameters: Three parameters are considered for analysis. They are given as:

- Size of delamination
- Thickness of facesheet layers
- Types of loading

2.2.1 Size of delamination*:*Delaminations of three different radius (0.05m,0.1m and 0.15m on the interface between bottom facesheet and core), having centre at the geometric centre of sandwich composite laminate in XY-plane, are considered. In Z-direction, thickness is provided. The other case is considered for analysis, with no delamination.

2.2.2 Thickness of the facesheet layers*:*Two different thicknesses (3mm and 4mm) which are same for both facesheets are taken into consideration for each case.

2.2.3 Type of loading*:*To study the effect of magnitude of uniform transverse loading on delamination,two different uniform transverse loads, are considered. One load is uniform pressure of 1KPa and other is a uniform pressure of 9 MPa , applied on the top facesheet.

2.3 Problem specification: For analysis purpose, two sandwich plateshaving dimensions 1m *1m with an overall thickness of 0.056m and 0.058m respectively are considered. The construction of the sandwich plate consists of top and bottom facesheetsseparated by a honeycomb core of 50 mm thickness.The materials for facesheet layer and honeycomb core are bi-directional CFRP laminae and aluminium, respectively. The relevant material properties of the facesheet and honeycomb core are given in Table 1.

Table 1 Material Properties [12]

Elastic	Facesheet (CFRP	honeycomb core

***Corresponding Author,**
E-mail address: jajivarghese@gmail.com; Phone:+91- 09968009210

Properties	laminae)	(aluminium)
E_{xx}(GPa)	132	0.709
E_{yy}(GPa)	10.8	0.447
Ezz (GPa)	10.8	1.34
G_{xz}(GPa)	5.65	0.345
G_{yz} (GPa)	3.38	0.207
G_{xy}(GPa)	5.65	0.162
ν_{xz}	0.24	0.31
ν_{yz}	0.49	0.082
ν_{xy}	0.24	0.198

The purpose of present work is, to evaluate the interlaminar stresses around the circumference of these rings, at different angles from X-axis for following cases:

- No delamination
- Circular delamination of radius=0.05m
- Circular delamination of radius=0.1m
- Circular delamination of radius=0.15m

3.Validation of Results

3.1.For validation of results, normal and shear stresses are plotted along thickness direction using Ansys14.0 and are compared with the results of [6], which isplotted using MSC Nastran software. A sandwich plate has dimensions 1m *1m with an overall thickness of 0.051 m is considered. The construction of the sandwich plate consists of top and bottom facesheets each of 0.5 mm thickness, separated by a honeycomb core of 50 mm thickness. The material properties for facesheet layer and honeycomb core are bi-directional CFRP laminae and aluminium,respectively.The relevant material properties of the facesheet and honeycomb core are given in Table 2.

Table 2. Material Properties for validation[12]

Elastic Properties	Facesheet	Honeycomb core
E_{xx}(GPa)	147	0.709
E_{yy}(GPa)	147	0.447
E_{zz}(GPa)	6.6	1.34
G_{xz}(GPa)	1.5	0.345
G_{yz}(GPa)	1.5	0.207
G_{xy}(GPa)	4	0.162
ν_{xz}	0.38	0.31
ν_{yz}	0.38	0.082
ν_{xy}	0.03	0.198

3.2 The stress analysis of the composite sandwich plate is carried out for a uniform normal traction pressure of 1000 N/m^2 acting on the top surface of the top facesheet with all edges of the plate fixed .Distributions of six components of 3-D stresses along the thickness direction are evaluated using Ansys APDL at a location (0.25m, 0.25m, z) and compare with paper results (Rao et al.).

4. Results and discussions

4.1 Effect of size of delamination

The distribution of interlaminar stresses i.e. Sz, Syz and Sxz are plotted along ring 1, ring 2 and ring 3. Figs. 5.13-5.15 represent the distribution of interlaminar stresses along the ring 1, ring 2 and ring 3 respectively. Sub-figures (a), (b) and (c) corresponds to the stresses S_z, S_{yz} and S_{xz} respectively. All the values are at the interface between bottom facesheet and honeycomb core for following four different sizes delaminations:

- No delamination i.e. delamination radius, d=0
- Circular delamination of radius, d=0.05m
- Circular delamination of radius, d=0.10m
- Circular delamination of radius, d=0.15m

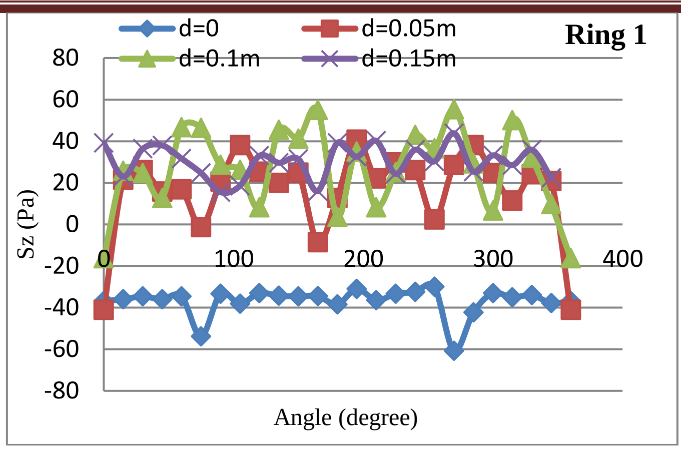

Fig 2(a)

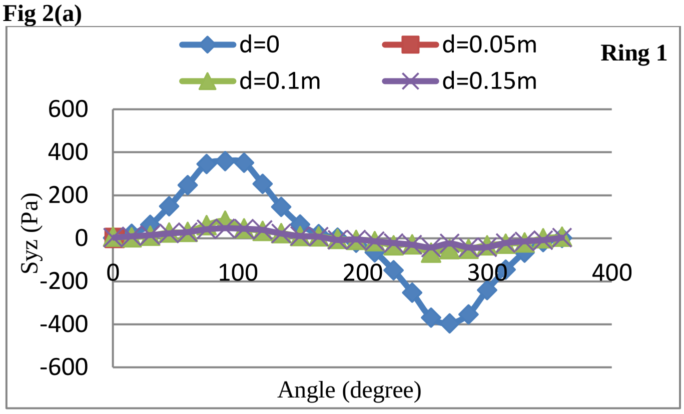

Fig 2(b)

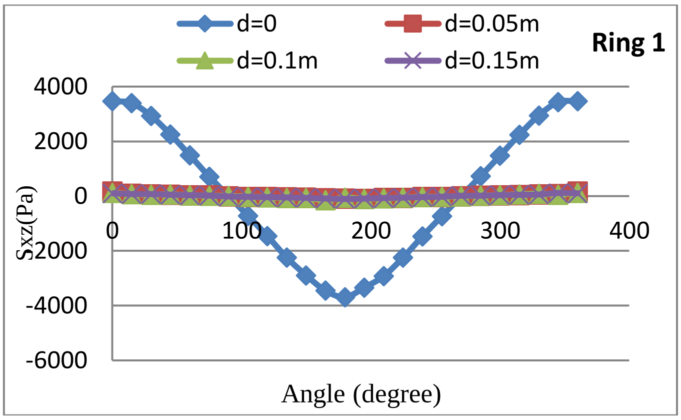

Fig.2 (b)

Fig.2 Distribution of S_z, S_{yz} and S_{xz} respectively, along the ring of radius=0.2m for various sizes of delamination

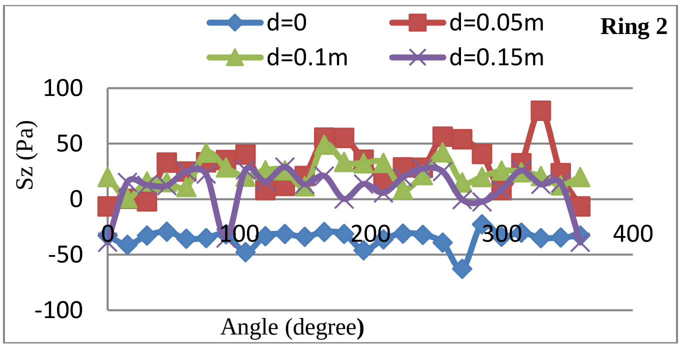

Fig 3(a)

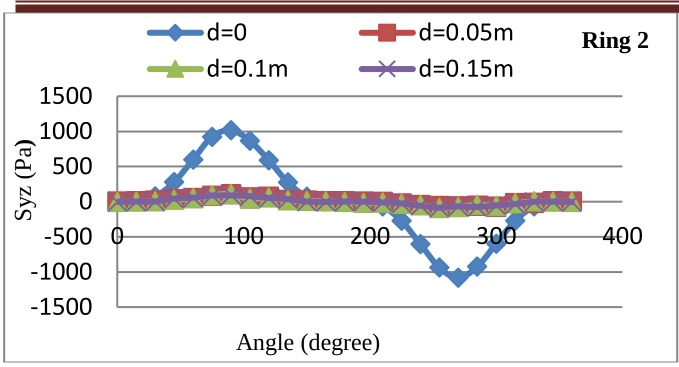

Fig 3(b)

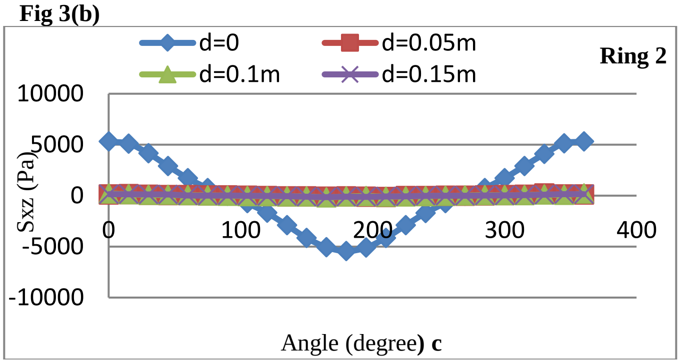

Fig 3(c)

Fig.3 (a-c): Distribution of S_z, S_{yz} and S_{xz} respectively, along the ring of radius=0.3m for various sizes of delamination

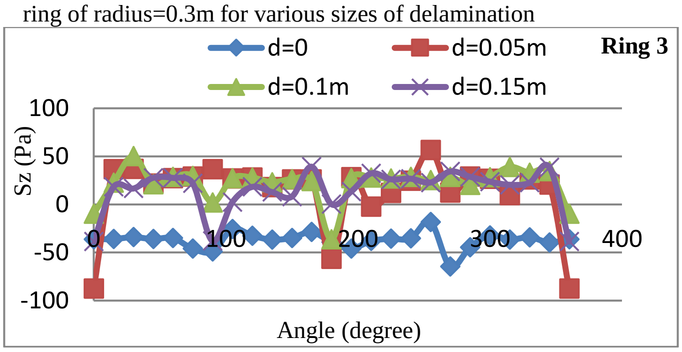

Fig 4(a)

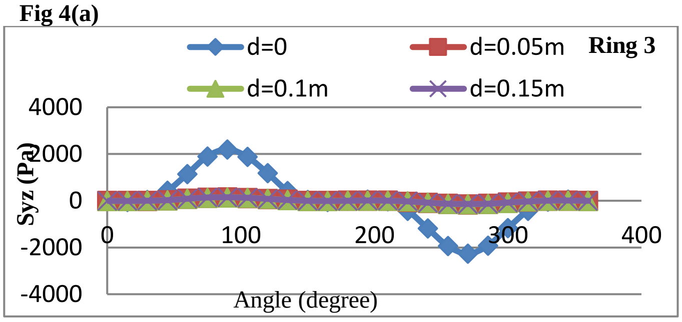

Fig 4(b)

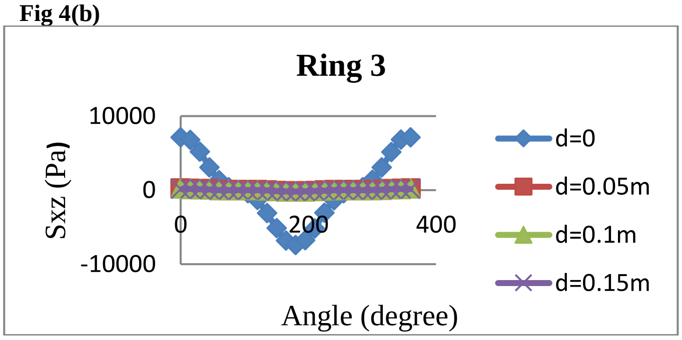

Fig 4(c)

Fig.-4 (a-c): Distribution of S_z, S_{yz} and S_{xz} respectively, along the ring of radius=0.4m for various sizes of delamination.

4.2 Effect of magnitude of uniform transverse load

It is obvious from the graphs shown in figs. (2- 4), under the article effect of thickness on interlaminar stresses that the trend of variation of interlaminar stresses is same, irrespective of magnitude of uniform transverse loading.

4.3 Effect of radial distance from the centre of delamination

The analysis to study the Effect of radial distance from the centre of delamination is done for facesheet thickness of 4mm and uniform transverse load of 1kPa.In figs. 5 - 6, the values of interlaminar stresses S_z, S_{yz} and S_{xz} are shown on the ordinate and angles along the circumference of various rings on abscissa. Sub-fig. (a) shows the distribution of interlaminar normal stress (S_z) along the circumference of various rings of radius 0.2m & 0.3m and 0.4m, for different size of delaminations. Interlaminar normal stress S_z is compressive along the circumference of all rings and maximum at 270 degree in compression for all rings. The effect of radial distance from the centre of delamination is that ,the value of interlaminar normal stress (S_z) increases as radial distance increases along the whole circumference of rings. Sub-fig. (b) shows the distribution of interlaminar shear stress S_{yz} along the circumference of various rings of radius 0.2m, 0.3m and 0.4m, for different size of delaminations. It is anti-symmetric about 180 degree angle. It is obvious from the curves that, as the radial distance increases the magnitude of interlaminar shear stress S_{yz} increases. From 0 to 90degree, it increases from zero to maximum at 90degree and from maximum at 90 degree to zero at 180degree. From 180 to 270degree it increases in magnitude in negative direction and from 270 to 360 degree, it again goes to zero magnitude. Sub-fig. (c) shows the distribution of interlaminar shear stress S_{xz} along the circumference of selected rings of radius 0.2m, 0.3m and 0.4m, for different size of delaminations. It is symmetric about 180 degree angle. It is obvious from the curves for the rings of different radii that, as the radial distance increases the magnitude of interlaminar shear stress S_{xz} increases. From 0 to 90degree, it decreases from maximum at 0 degree to zero at 90degree and from zero at 90 degree to maximum negative at 180 degree.

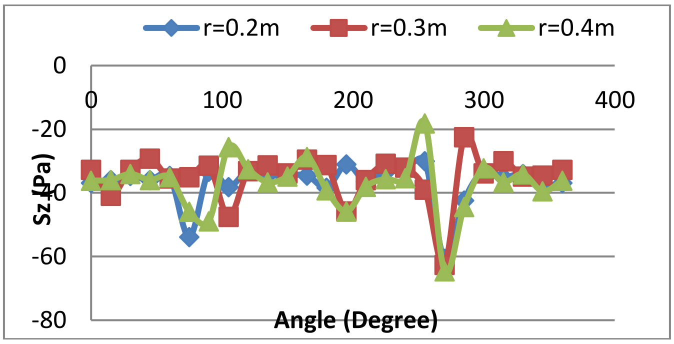

Fig 5(a)

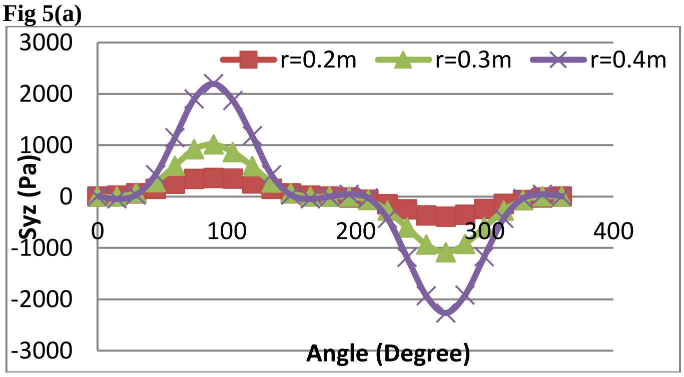

Fig 5(b)

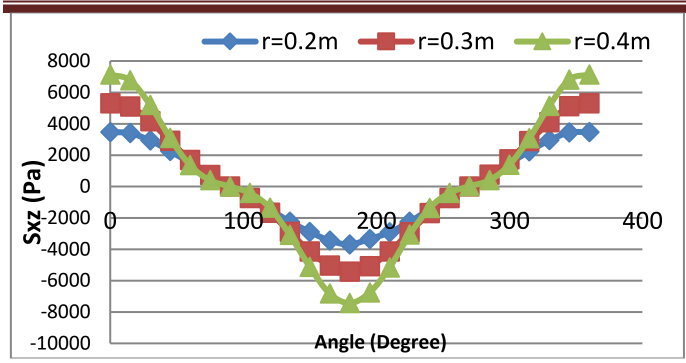

Fig 5(c)

Fig.5. (a-c): Distribution of S_z, S_{yz} and S_{xz} respectively, along the circumference of rings of radius 0.2m,0.3m and 0.4m with no delamination.

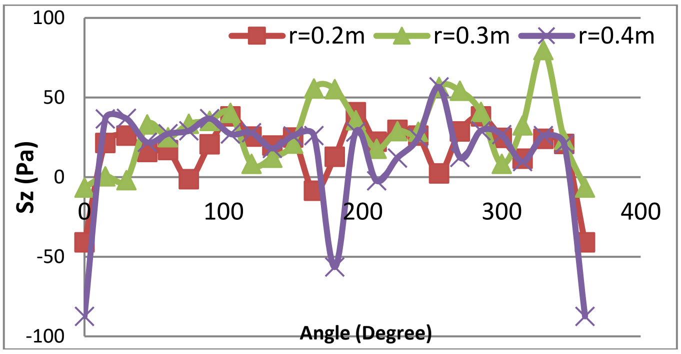

Fig 6(a)

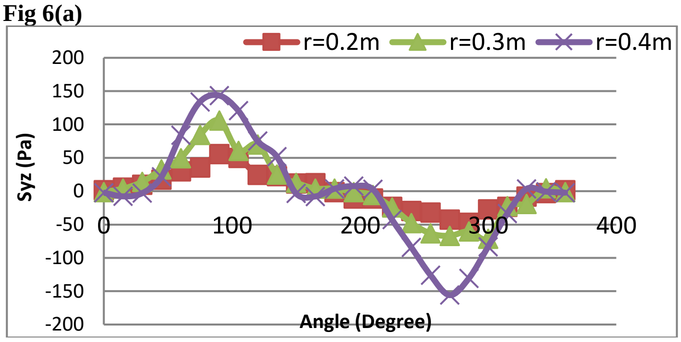

Fig 6(b)

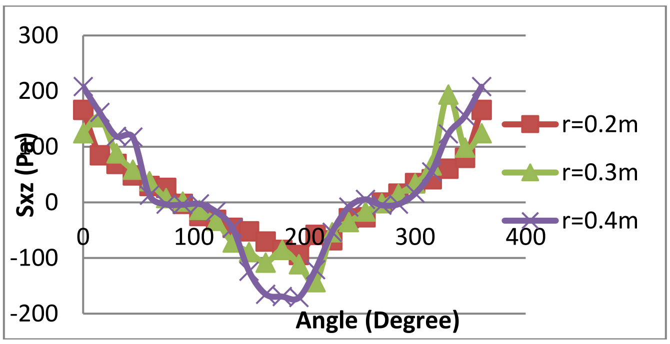

Fig 6(c)

Fig.6 (a-c): Distribution of S_z, S_{yz} and S_{xz} respectively, along the circumference of rings of radius 0.2m,0.3m and 0.4m with delamination of radius 0.05m.

5.Conclusions

The different parameters taken into consideration are:

- Thickness of face sheet layers
- Magnitude of uniform transverse loading
- Size of delamination

1 Thickness of facesheet layers on interlaminar stresses:For the thicknesses considered, no significant change is observed on the distribution of interlaminar stresses.

2. Type of uniform transverse loading: On increasing the value of loading, the value of all interlaminar stresses increase irrespective of various other parameters. The trend of variation remains same for different values of uniform transverse loading.

3. Size of delamination:With delamination,the valuesof $S_{yz}$and $S_{xz}$are very small as compared to that at without delamination. With delamination, as the size of delamination increases,the values of interlaminar shear stressesalong the radial direction decrease .In case of S_z,as the size of delamination increases, the range of values along the selected rings decreases.

References

[1] Adams Donald F. Sandwich panel test methods. High Performance Composites, 5, 2006, 4-6.

[2] AkawutSiriruk, DayakarPenumadu YJack Weitsman. Effect of sea environment on interfacial delamination behavior of polymeric sandwich structures, Composites Science and Technology 69, 2009, 821–828.

[3] AnisGawandi, Leif A Carlsson. Travis A Bogetti, John W Gillespie. Mechanics of discontinuous ceramic tile core sandwich structure: Influence of thermal and interlaminar stresses, Composite Structures 92, 2010, 164–172.

[4] Ansys14.0 Tutorial

[5]Callister William D. Materials Science and Engineering: An Introduction. India: Wiley 2000.

[6] Hiroyuki Matsunaga,Assessment of a global higher-order deformation theory for laminated composite and sandwich plates,Composite Structures 56, 2002, 279–291.

[7] Hitesh Kapoor, Rakesh K Kapania, Som R Soni. Interlaminar stress calculation in composite and sandwich plates in NURBS Isogeometric finite element analysis, Composite Structures 106, 2013, 537–548.

[8] L Lagunegrand, Th Lorriot , R Harry, H Wargnier. Design of an improved four point bending test on a sandwich beam for free edge delamination studies, Composites: Part B 37, 2006, 127–136.

[9] Mamalis AG, Manolakos DE, Ioannidis MB, DP Papapostolou. On the crushing response of composite sandwich panels subjected to edgewise compression: experimental. Composite structures. 71, 2005, 246–257.

[10] MAJBoscoa, K Palanikumarb, BDurgaPrasadc, A Velayudhamd. Influence of machining parameters on delamination in drilling of GFRP-armour steel sandwich composites,Procedia Engineering 51, 2013, 758 – 763.

[11] MiroslavMarjanovic, DjordjeVuksanovic,Layerwise solution of free vibrations and buckling of laminated composite and sandwich plates with embedded delaminations, Composite Structures 108, 2014, 9–20.

[12] MV PeereswaraRao, DineshkumarHarursampath, K Renji. Prediction of inter-laminar stresses in composite honeycomb sandwich panels under mechanical loading using Variational Asymptotic Method, Composite Structures 94, 2012, 2523–2537.

[13] N Mitra, BR Raja. Improving delamination resistance capacity of sandwich composite columns with initial face/core debond, Composites: Part B 43, 2012, 1604–1612.

[14]O. Rahmani ,S.M.R. Khalili ,O.T. Thomsend,A high-order theory for the analysis of circular cylindrical composite sandwich shells with transversely compliant core subjected to external loads, Composite Structures 94, 2012, 2129–2142.

[15] RosalinSahoo, BN Singh. A new inverse hyperbolic zigzag theory for the static analysis of laminated composite and sandwich plates, Composite Structures 105, 2013, 385–397.

[16] SaiSudha Ramesh , C.M. Wang , J.N. Reddy , K.K. Ang, A higher-order plate element for accurate prediction of interlaminar stresses in laminated composite plates, Composite Structures 91, 2009, 337–357.

[17] SanjibGoswami, Wilfried Becker,The effect of facesheet/core delamination in sandwich structures in transverse loading, Composite Structures 54, 2001, 515-521.