IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 14, Issue 3 Ver. 3 (May-June. 2019), PP 54-62
www.iosrjournals.org

Study on Effect of Geometric and Material Parameters on Shear Loaded Notched Composite Panels

Durga charan sahoo[1], Harekrishna Nayak[2]
1(Department of Civil Engineering, Gandhi Engineering College, India)
2(Department of Civil Engineering, Gandhi Institute For Technology, India)

Abstract: *Scores are given in different shapes known as patterns for weight decrease and for giving attached joints. The comprehension of the impacts of cut-out on the heap bearing limit and stress centralization of such plates is significant in planning of structures on account of the subsequent diminished quality of parts and higher measure of harm around this district. Studies were directed already for scored composite plate under strain and pressure. The primary target of this examination is to explore the impact of geometrical parameters and material parameters on shear stacked scored composite board. Numerical examination was broadly done on ASTM D5766 OHT model for various kinds of indents of fluctuating shapes just as for materials-carbon epoxy and fiber strengthened plastic. Contrasted with different sorts of stacking, shear stacking displayed more impact on pressure focus around scores. Additionally, variety of stress focus factor as for geometric parameters was significantly more when contrasted and material parameters. Among geometric variables, various shapes and directions effectsly affected pressure focus factor.*
Key words: *Sheard load, Notched composite panels, Stress concentration, Geometric and material parameters.*

I. Introduction

Notched or holes are provided in various shapes known as cut outs for weight reduction and for providing fastened joints. In addition, Notches in the structure are often used for providing access to areas for damage inspection or installation of electrical and piping systems. The presence of notches in a structure results in a high stress gradient at the vicinity of their edges. The ratio of the maximum stress at the cut-out edge to the nominal stress is called the stress concentration factor (SCF). The understanding of the effects of cut-out on the load bearing capacity and stress concentration of such plates is very important in designing of structures because of the resulting reduced strength of components and higher amount of damage around this region. The point near maximum stress concentration is often the location of initialization of damage in the structure. Currently, the study of SCF around circular notches for isotropic material has reached a high level. The strength prediction of isotropic material with a notch can be accurately predicted since the stress gradient around the notch is not dependent of the material. However, unlike isotropic material, the stress gradient around a notch in laminated composites can be affected by various parameters like material constants, fibre orientation, laminate stacking sequence etc. [1-6]. This complex stress gradient results in a complicated failure mechanism near the notch.

Tension and compression loadings are the common types of loading which are applied to the material for the investigation. But in many cases, notched composites may undergo shear loading as seen widely used in aerospace structures. When the composite materials are subjected to these type of shear loads the chances of failure are very high. It is also seen that geometry of the notch plays a significant role in the stress concentration. Extensive studies are done for composite panels in tension and compression. In this study, an investigation is conducted to determine the effect of shear loading in composite panels with different geometric parameters and material parameters for effective design of composite structures with notches.

II. Material

One of the material used for this study is Fibre reinforced plastic (FRP) In this fibre glass acts as fibre and matrix material used is Polyester Resin GP 002. Fiberglass is a lightweight, extremely strong, and robust material. Its bulk strength and weight properties are also very favorable when compared to metals. Other material used is the Carbon fibre reinforced is an extremely strong and light fiber-reinforced plastic which contains carbon fibers. The binding polymer is often a thermoset resin such as epoxy, but other thermoset or thermoplastic polymers, such as polyester, vinyl ester or nylon, are sometimes used. Material properties are shown in Table 1

Table 1 Material properties

Material	**Density, (kg/mm^3)**	**E_{11}, (N/mm^2)**	**E_{22}, (N/mm^2)**	**ν12**	**ν13, ν23**	**G12, G23, G13, (N/mm^2)**
Fibre reinforced plastic	$1.8x10^{-06}$	18576	9976	0.29	0.25	4800
Carbon fibre reinforced polymer	$1.99x10^{-06}$	138000	9500	0.40	0.28	5200

III. Numerical Model

ASTM D5766 OHT model is a widely accepted model for studies related to composite materials. Numerical model of the OHT specimen is prepared using ABAQUS software. Three dimensional study is conducted. A typical OHT specimen is shown in Fig 1 below.

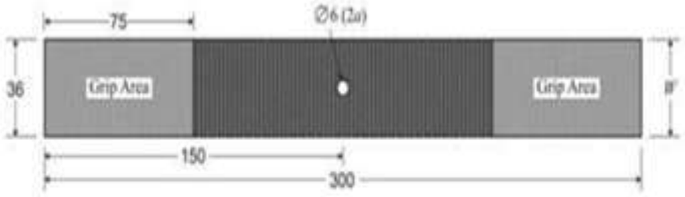

Figure 1 ASTM D5766 OHT model

Suitable size for the notches are being taken in account, based on constant area. The different notch shapes considered for the study and their dimensions are given in Table 2

Table 2 Notch dimensions

Shape of notch	Dimensions
Circle	Radius, r = 4 mm
Ellipse	Half major axis, x = 6 mm, Half minor axis, y = 2.7 mm
Square	Side, a = 7 mm
Triangle (Equilateral)	Side, a = 11 mm

IV. Mesh Convergence Study

Accuracy of the solution of a FE problem depends on the discretization of the domain or the order of the finite element being used. A numerical analysis on composite panel with selected material and selected notch shape is conducted in different global mesh size (4mm, 3mm, 2mm, 1mm) for the mesh convergence study. FEM analysis on both tensile and compressive loading are done on the notched composite panel as per the ASTM D5766 standard.

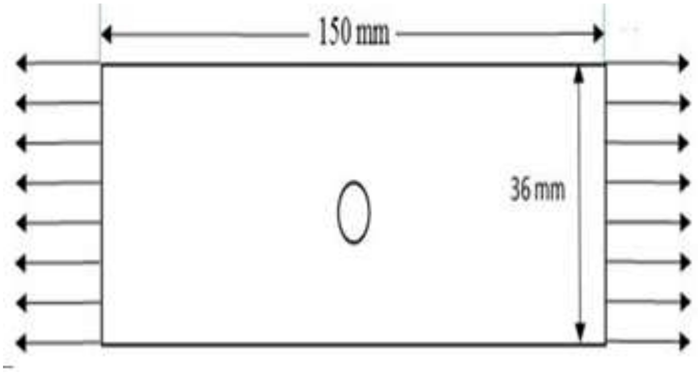

Figure 3 Schematic diagram of plate with central hole uniaxial tension loading

The dimensions of the ASTM model is 150 mm x 36 mm x 2 mm. The material selected for mesh convergence study is Fibre Reinforced Plastic, whose properties are given in Table 1. The load applied is 50 N/mm^2.

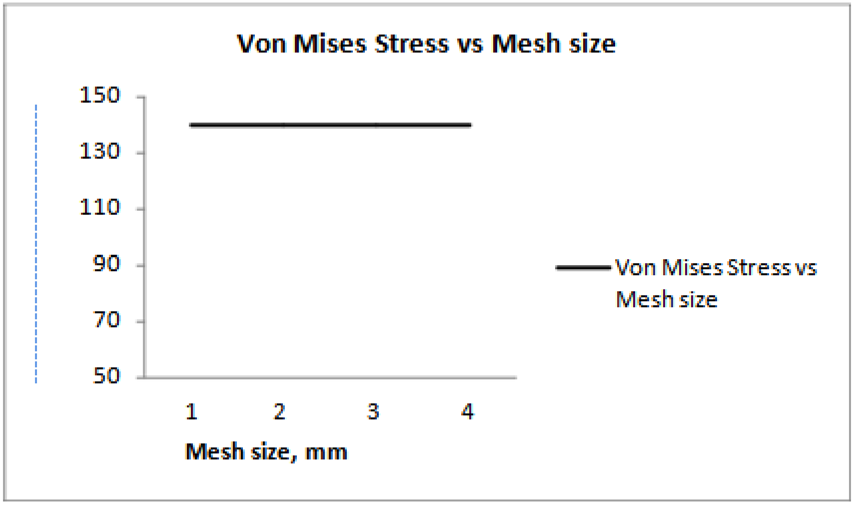

Figure 4 Mesh convergence study

Mesh convergence study with uniaxial tensile loading on selected composite panel with different notches are done. Result obtained from the FEM analysis is shown in the Table 3. Convergence graph for the Circular notch under tensile load is shown in Fig 4. Element mesh size (Global mesh size) selected is '2 mm' from the study.

Table 3 Mesh convergence study-Tension test

Notch Type	**Orientation with x-axis**	**Von Mises stress (N/mm^2) v/s Global mesh size**				**Selected global element size**
		4	**3**	**2**	**1**	
Circular	0^0	139.9	139.9	139.9	140	2
Double Circle	0^0	126.3	126.3	126.3	126.4	2
	45^0	191.9	191.9	191.6	191.5	2
	90^0	238.7	238.8	238.6	239.9	2
Square	0^0	116.4	116.4	116.4	116.2	2
	45^0	194.4	194.4	194.4	191.1	2
Ellipse	0^0	108.3	108	108	107.9	2
	45^0	170.4	169.8	169.9	170.3	3
	90^0	210.6	210.6	210.6	211.5	2
Triangle	$_00$	193.7	193.7	193.7	187	2

45^0	190.6	190.6	190.6	188.7	2

V. Notched Composite Panels Under Shear Loading

A large number of applications are available, where shear loading is applied on notched composite panels. The present study concentrates on how shear load on the composite panel affects the stress concentration factor of the notches. The influence of geometric parameters (notch shapes) and material parameters (materials considered are FRP and Carbon Epoxy). The study is conducted on quasi-isotropic layup also.

5.1. Numerical Analysis-Geometrical Parameters

Test No. 1
Material used: Fibre Reinforced Plastic (FRP)
Dimensions: 150 mm x 36 mm x 2 mm
Type of element: 3D Shell element
Selected Notch: Ellipse (0º orientation, 0º fibre orientation)
Boundary condition: One end fixed
Applied shear stress (τ): 50 N/mm^2

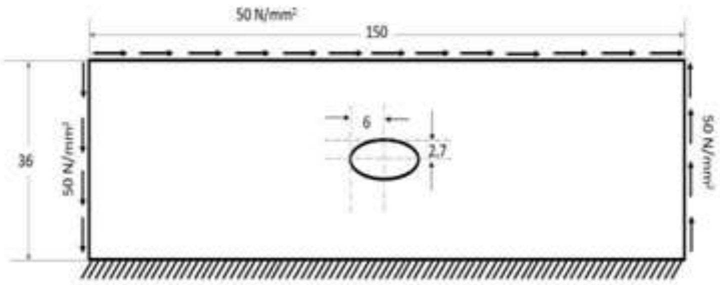

Figure 5 Shear loaded composite panel with 0º Elliptical notch

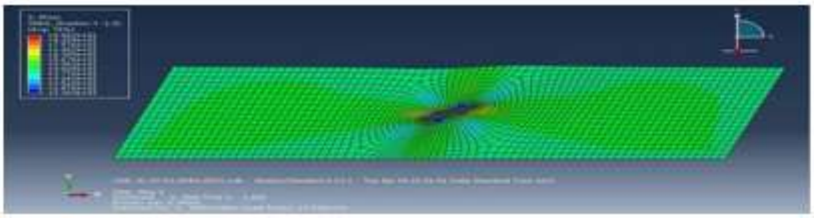

Figure 6 Shear loaded composite panel with 0º Elliptical notch (FRP) - FEM result

Usually elliptical notches have less Stress Concentration Factor (SCF) in tensile and compressive loads. The maximum stress produced due to the shear loading is 88.42 N/mm^2.

$$\text{Therefore SCF} = \frac{\quad}{\quad} = \frac{\quad}{\quad} = 1.76$$

Similarly shear loading is applied for all the selected types of notches with selected material (FRP). Von Mises value obtained and the corresponding SCF of each tests are shown in the Table.4

Table 4 Numerical Analysis-Geometrical parameters- Fibre Reinforced Plastic

Notch Type	Orientation with X-axis	Fibre Orientation	Von Mises stress (σ_{max}) (N/mm^2)	Applied shear stress (τ) (N/mm^2)	SCF ( )
Circular	0º	0º	85.62	50	1.71
		45º	101.5	50	2.03
		90º	84.39	50	1.68
	0º	0º	112.9	50	2.25
		45º	124.4	50	2.48
		90º	136.6	50	2.73

Two circular holes	45º	0º	141.5	50	2.83
		45º	126.1	50	2.52
		90º	142.8	50	2.85
	90º	0º	147.7	50	2.95
		45º	130.7	50	2.61
		90º	106.6	50	2.13
Square	0º	0º	101.7	50	2.03
		45º	105.7	50	2.11
		90º	99.91	50	1.99
	45º	0º	74.07	50	1.48
		45º	77.72	50	1.55
		90º	72.18	50	1.44
Ellipse	0º	0º	88.42	50	1.76
		45º	102.6	50	2.05
		90º	88.58	50	1.77
	45º	0º	102.7	50	2.05
		45º	88.47	50	1.76
		90º	102.2	50	2.04
	90º	0º	90.05	50	1.80
		45º	108.8	50	2.17
		90º	89.78	50	1.79
Triangle	0º	0º	119.6	50	2.39
		45º	124.7	50	2.49
		90º	103.6	50	2.07
	90º	0º	98.39	50	1.96
		45º	111.9	50	2.23
		90º	114.2	50	2.28

5.2. Numerical Analysis-Material Parameters

Test No. 2
Material used: Carbon Epoxy
Dimensions: 150 mm x 36 mm x 2 mm
Type of element : 3D Shell element
Selected Notch: Ellipse (0º orientation, 0º fibre orientation)
Boundary condition: One end fixed
Applied shear stress (τ) : 50 N/mm^2

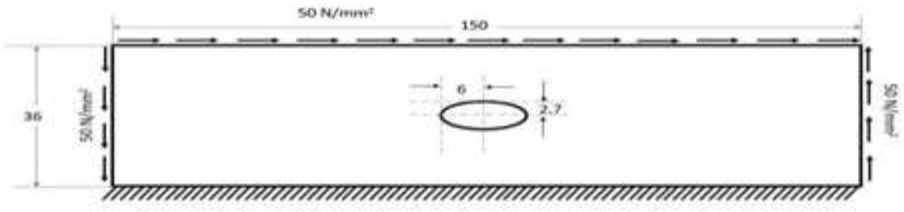

Figure 7 Shear loaded composite panel with 0º Elliptical notch

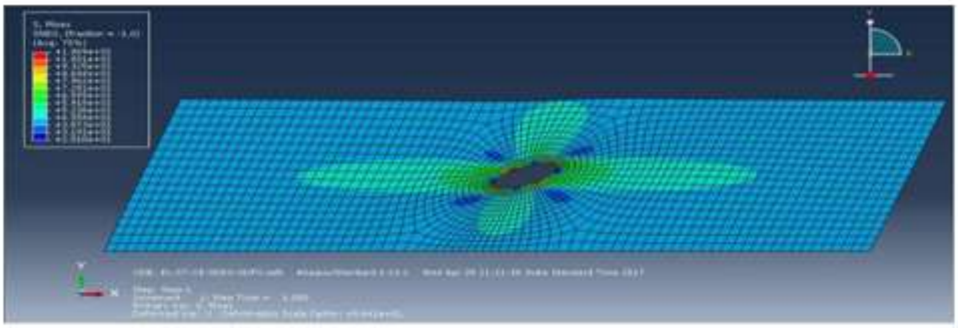

Figure 8 Shear loaded composite panel with 0º Elliptical notch (Carbon Epoxy) – FEM result

The maximum stress produced due to the shear loading is 106.9 N/mm^2.

Therefore SCF = ——— = ——— = 2.138

Similarly shear loading is applied for all the selected types of notches with selected material (Carbon Epoxy). Von Mises value obtained and the corresponding SCF of each tests are shown in the Table.5

Table 5 Numerical Analysis-Material parameters- Carbon Epoxy

Notch Type	**Orientation with X-axis**	**Fibre Orientation**	**Von Mises stress (σ_{max}) (N/mm^2)**	**Applied shear stress (τ) (N/mm^2)**	**SCF (——)**
Circular	0º	0º	103.2	50	2.06
		45º	162.9	50	3.25
		90º	110.2	50	2.20
Two circular holes	0º	0º	182.7	50	3.65
		45º	231.5	50	4.63
		90º	221.9	50	4.43
	45º	0º	142.2	50	2.84
		45º	184.4	50	3.68
		90º	144.5	50	2.89
	90º	0º	254.5	50	5.09
		45º	240.1	50	4.80
		90º	214.0	50	4.28
Square	0º	0º	177.9	50	3.55
		45º	166	50	3.32
		90º	190.3	50	3.80
	45º	0º	88.96	50	1.77
		45º	138	50	2.76
		90º	88.30	50	1.76
Ellipse	0º	0º	106.9	50	2.13
		45º	151	50	3.02
		90º	111	50	2.22
	45º	0º	117.6	50	2.35
		45º	136.8	50	2.73
		90º	133.3	50	2.66
	90º	0º	99.39	50	1.98
		45º	174	50	3.48
		90º	109.5	50	2.19
Triangle	0º	0º	207.3	50	4.14
		45º	227.36	50	4.54
		90º	97.29	50	1.94

	0º	95.72	50	1.91
90º	45º	164.9	50	3.29
	90º	215.5	50	4.31

5.3. Numerical analysis- Quasi-Isotropic layup 1

Test. No.3
Material used: Fibre Reinforced Plastic (FRP)
Dimensions: 150 mm x 36 mm x 2 mm
Type of element: 3D Shell element
Applied shear stress (τ) = 50 N/mm^2
Selected Notch: Elliptical (0º orientation, 0º fibre orientation)
Boundary Condition: One end fixed
Stacking order: 0º/90º/+45º/-45º/-45º/+45º/90º/0º (N=4, Δθ=45º)
Number of Plies: 8 (Thickness = 0.25 mm; 0.25x8 = 2 mm)

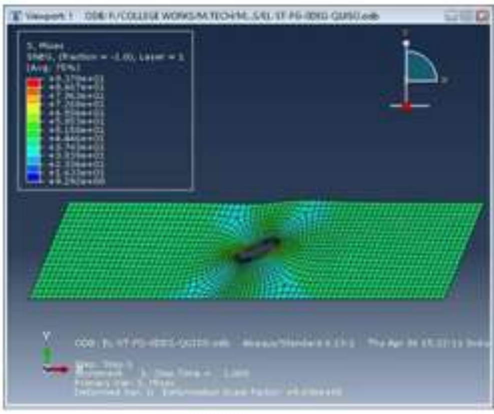

Figure 9a. Quasi-Isotropic layup with 0º Elliptical notch (FRP) – FEM result

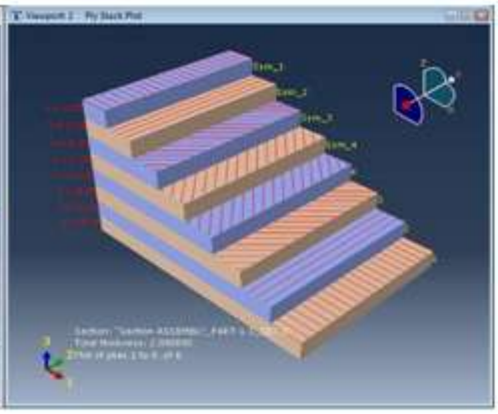

Figure 9b. Quasi-Isotropic layup stack plot

Table 6 Numerical Analysis – Quasi-Isotropic – Fibre Reinforced Plastic

Notch Type	Orientation with X-axis	Von Mises stress (σmax) (N/mm^2)	Applied shear stress (τ) (N/mm^2)	SCF=( )
Circular	0º	84.7	50	1.69
Two circular holes	0º	117.4	50	2.34
	45º	135.6	50	2.71
	90º	151.7	50	3.03
Square	0º	102.1	50	2.04
	45º	60.88	50	1.21
Ellipse	0º	93.7	50	1.87
	45º	104.2	50	2.08
	90º	82.16	50	1.64
Triangle	0º	110.7	50	2.21
	90º	110.8	50	2.21

The maximum stress produced due to the shear loading is 93.7 N/mm^2.

Therefore SCF = ——— = —— = 1.87

Similarly shear loading is applied for all the selected types of notches with selected material (FRP) in Quasi-Isotropic Layup. Von Mises value obtained and the corresponding SCF of each tests are shown in the Table.6

5.4. Numerical analysis- Quasi-Isotropic layup 2
Test. No.4
Material used: Carbon Epoxy
Dimensions: 150 mm x 36 mm x 2 mm
Type of element: 3D Shell element
Applied shear stress (τ) = 50 N/mm^2
Selected Notch: Elliptical (0º orientation, 0º fibre orientation)
Boundary Condition: One end fixed
Stacking order: 0º/90º/+45º/-45º/-45º/+45º/90º/0º (N=4, Δθ=45º)
Number of Plies: 8 (Thickness = 0.25 mm; 0.25x8 = 2 mm)

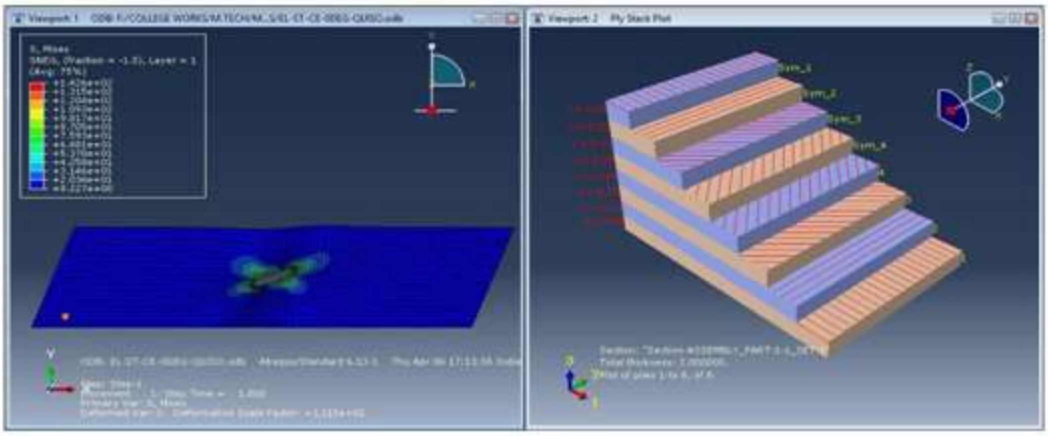

Figure 10 Quasi-Isotropic layup with 0º Elliptical notch (Carbon Epoxy) – FEM result

The maximum stress produced due to the shear loading is 93.7 N/mm^2.

Therefore SCF = ——— = ——— = 2.85

Similarly shear loading is applied for all the selected types of notches with selected material (Carbon Epoxy) in Quasi-Isotropic Layup. Von Mises value obtained and the corresponding SCF of each tests are shown in the Table.7

Table 7 Numerical Analysis – Quasi-Isotropic –Carbon Epoxy

Notch Type	**Orientation with X-axis**	**Von Mises stress (σmax) (N/mm^2)**	**Applied shear stress (τ) (N/mm^2)**	**SCF=( )**
Circular	0º	119.4	50	2.38
Two	0º	193	50	3.86
circular	45º	165.4	50	3.30
holes	90º	272.2	50	5.44
Square	0º	207.3	50	4.14
	45º	62.78	50	1.25
Ellipse	0º	142.6	50	2.85
	45º	149.1	50	2.98
	90º	91.74	50	1.83
Triangle	0º	234.02	50	4.68
	90º	164	50	3.28

VI. Conclusions

The study was conducted to analyze the effect of various geometric and material parameters during shear loading of composite panels. It is primarily established that shear has much more influence on stress concentration around notches when compared to other types of loading - tensile and compressive. However, it is also seen that geometric parameters, with respect of size and shape of notches, have comparably larger effect on stress concentration than material parameters. In this study, the material parameters considered are changes in material of matrix and fiber as well as the layup.

The presence of another hole in the vicinity of a hole is found to be the most contributing geometric factor in raising stress concentration. In particular, when the holes are aligned at 90º to the loading direction, maximum stress concentration is observed. Among different shapes, triangular shaped notch is found to induce more stress intensity when compared to other shapes. Specifically, square shaped notch at 45º orientation shows minimum stress concentration. Carbon epoxy exhibits more stress intensity when compared to fiber reinforced plastic.

References

[1] JWang, P.JCallus, M.KBannister, Experimental and numerical investigation of the tension and compression strength of un-notched and notched quasi-isotropic laminates Composite Structures, Volume 64, Issues 3–4, June 2004, Pages 297-306

[2] Imran Hyder, Tyler M. Froemming, Mitchell Daniels, William C. Beattie, Brian K. Bay, and John P. Parmigiani. "Mode III Loading of Composite Panels", Journal of Aircraft, Vol. 53, No. 2 (2016), pp. 343-350.

[3] Damodar R.Ambur,.NavinJaunky. Mark W.Hilburger, Progressive failure studies of stiffened panels subjected to shear loading, Composite Structures Volume 65, Issue 2, August 2004, Pages 129-142

[4] ShiladityaBasu. Anthony M.Waas Damodar R.Ambur, Prediction of progressive failure in multidirectional composite laminated panels, International Journal of Solids and Structures, Volume 44, Issue 9, 1 May 2007, Pages 2648-2676

[5] B.B. Farande and V. V. Kulkarni, Experimental Investigation of Stress Concentration Factor around Countersunk Hole in Composite Plate, 2016, International Journal of Current Engineering and Technology, E-ISSN 2277 – 4106, P-ISSN 2347 – 5161.

[6] Lotfi Toubal, Moussa Karama , Bernard Lorrain, Stress concentration in a circular hole in composite plate, 2004, Composite Structures 68 (2005) 31–36.