Behaviour of Composite Structures with Different Cutouts: A Comparitive Study

Jinju James Olickal
PG Student ,
Civil Engineering Department,
Christ Knowledge City,
Muvattupuzha, Kerala.

Er. Lakshmipriya A R
Asst.Professor,
Civil Engineering Department,
Christ Knowledge City,
Muvattupuzha, Kerala.

Abstract- **Use of composite materials for the construction of structural component can result in significant benefits on high strength and better performance. Cut-outs are passages, used for electrical wires, control rods, hydraulic lines in aircraft structural design. Different cut-out shapes in structural elements are needed to reduce the self weight of the elements and also provide access to other parts of the structure. In this paper we study about the parameters for the finite element analysis of structure with cut-out and their influence on the results. Study was conducted by comparing the journal papers.**

Keywords—Finite element analysis, Composite materials, ANSYS

I. Introduction

Use of composite materials for the construction of structural component can result in significant benefits on high strength and performance. Application of such materials will leads to formation of light weight structure with a considerable cost reduction. And they have high design flexibility and corrosion resistance. They are generally used for the construction of Boat hull, swimming pool panel, bath tub, storage tank etc.. .

In recent years, the increasing need for lightweight structures has led to optimization of structural shape. Different cut-out shapes in structural elements are needed to reduce the self weight of the elements and also provide access to other parts of the structure. The presence of a cut-out in a stressed member creates highly localized stresses at the vicinity of the cut-out. The ratio of the maximum stress at the cut-out edge to the nominal stress is called the stress concentration factor (SCF). It is very necessary to understand the effects of cut-out on the load bearing capacity and stress concentration of structure is very important in designing of structures.

In this paper a comparative study of behavior of different structure with different cutout is done. Through this study we can understand the effect of cutout in a composite structure under different loading. We can also determine the important parameters considered in this study and their effect on the analysis results. Like cut-out size, cut-out shape, orientation etc

II. LITERATURE REVIEW

A. Relative Comparison of Geometrical Shapes for Cut-outs

In this paper, a study was conducted about the various geometrical shapes and analyzing modal analysis. From the study result information about the analyses is obtained**.** Here Finite element analysis for the frequency and stress concentration of perforated steel plates was conducted. The steel plate dimensions are 200 m (x-direction), 200 m (y-direction), and 10 m (z-direction). Material properties of plates are Young's modulus of 1100MPa, poissons ratio of 0.3 and density of 0.000728kg/m^3. The cut-out is provided at the centre of the plates. In order to observe the stress concentration more clearly, the plate size is modelled as large for the cut-out size. ANSYS is used for analysis. The plate is constrained at one edge. All the geometric shapes have same area ie. 2826m^2.

Modal analysis is done for the following cut-out shapes.

- Circle
- Triangle
- Square
- Pentagon
- Hexagon
- Heptagon
- Octagon
- Nonagon
- Decagon
- Plus

From the analysis result we can make a table to indicate the values of frequency and deflection. it is observed that the heptagon has less frequency and plus shape also has least frequency compared to the other shapes. The value of deflection is almost same for the different shapes; i.e the deflection is not much affected in the modal analysis.

TABLE 1: MODAL ANALYSIS OF GEOMETRICAL SHAPES

SHAPE	FREQUENCY	DEFLECTION
Plate without hole	113.944	.117020
CIRCULAR	104.628	.122230
TRIANGULAR	107.337	.121957
SQUARE	110.554	.122974
PENTAGONAL	111.259	.122686
HEXAGONAL	111.052	122068
HEPTAGONAL	102.684	.123206
OCTAGONAL	107.141	.122743
PLUS	103.589	.123116

B. Study On The Effect Of Stress Concentration On Cut-out Orientation Of Plates With Various Cut-outs And Bluntness

This study mainly focuses on concentration of stress analyses of perforated aluminium plates with various cut outs (circle, triangle, and square) , bluntness (it is a counter measure of radius ratio, *r/R*) and also for different cut-out orientation (θ = 15, 30, 45). For the analyses, initially, we select three different cut-outs: circle, triangle, and square; then we identify a number of degrees of bluntness to describe the radius ratio; and finally, we consider the rotation of cut-outs. The ratio of the maximum stress at the cut-out edge to the nominal stress is called the stress concentration factor (SCF).

The structural aluminium plates have dimensions 200 mm (x-direction), 200 mm (y-direction), and 5 mm (z-direction). Material properties are

Young's Modulus, (GPa)	73.1
Poisson ratio, µ	0.33
Tensile yield strength (MPa)	345
Tensile Ultimate strength (MPa)	483

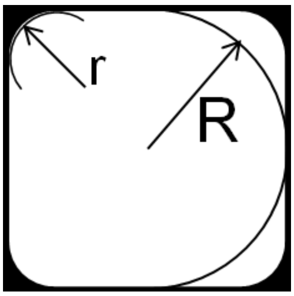

Fig 1: Radius ratio (r/R) defined by edge radius (r) and Inscribing circle radius (R)

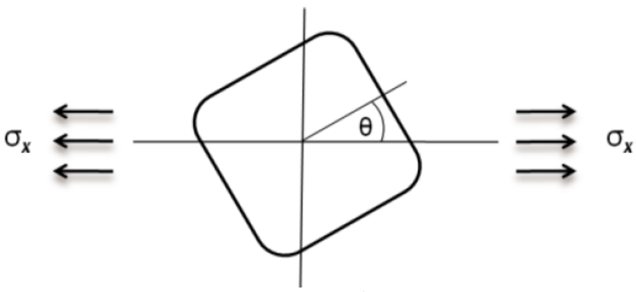

Fig 2: Rotation of cut-out

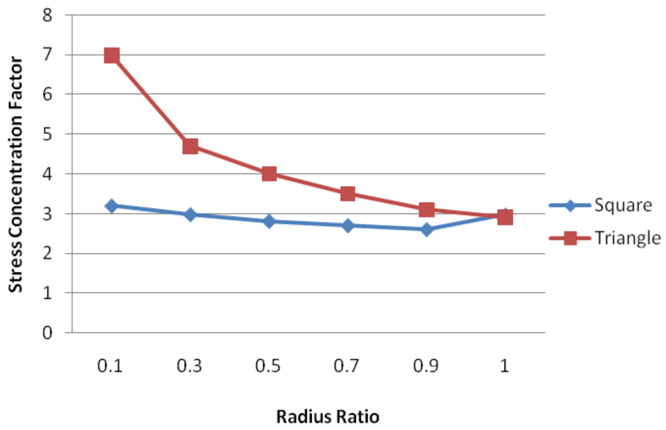

Fig 3: SCF with respect to radius ratio for square and triangle cutout

Here the zero bluntness (r/R = 1) actually means that the cut-out shape is a circle;,from the Graph, we can see how the shapes and the degrees of bluntness vary the stress concentration factor. Fig.3 shows how the stress concentration factor (SCF) changes with respect to cut-out shapes and the radius ratio (a counter measure of degree of bluntness)

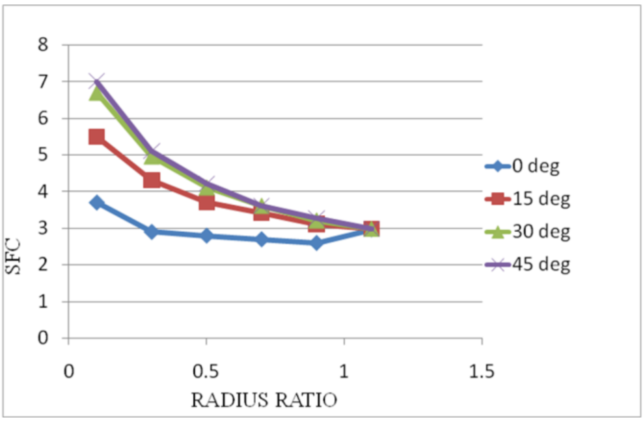

Fig 4: SCF with respect to rotation for square cut-outs

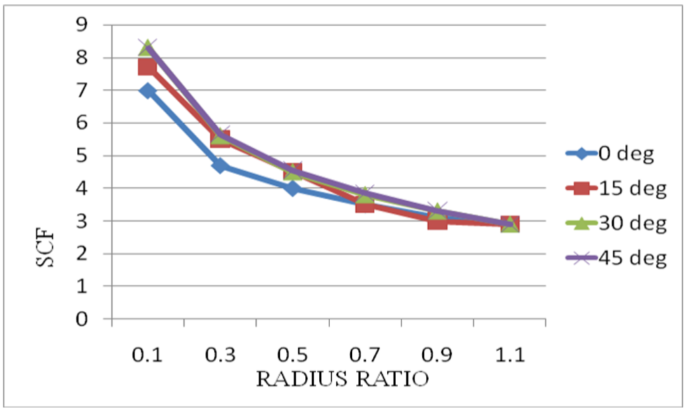

Fig 5: SCF with respect to rotation for triangle cut-outs

From this study, it is clear that orientation of two sides of square cutout perpendicular to the applied tensile force leads to reduction of maximum stress. Similarly in triangle cut-out, orient one side of the triangle cut-out should be perpendicular to the applied tensile forces to the stress reduction. Accordingly, determining the direction of a major tensile force is necessary at the design stage. Then trough the alignment of these polygon cutouts, we can reduce the stress concentration. In addition to rotation, similarly to the previous section, for all the degrees of orientation, it is also clear that the stress concentration decreases as the bluntness of the cut-outs decreases. In summary, the smooth edges of cutout and proper rotation are necessary to minimize the stress concentration of the aluminium plates with polygon cut-outs. In other words, the stress concentration of the perforated aluminium plates can be reduced by controlling the smoothness (or bluntness) and rotation. Among bluntness and rotation, controlling bluntness is analytically preferable to minimize the stress concentration

C. Model Analysis Of Fuselage With and Without Cut-Out By changing the material property

In analysis of Fuselage we are considering the model analysis for aluminium alloy and for composite materials. In case of Composite materials we consider two types of composites at first we consider Glass Fabric Epoxy and for this composite we consider different orientations such as 0, 60,120,180,240,300,360. It is consider ten modes of frequencies. Out of ten here now we are considering deformation and displacement vector sum for mode 1 and mode 10.

In second case we consider Carbon Epoxy and for this composite we consider different orientations such as 0, 60,120,180,240,300,360. It is consider ten modes of frequencies. Out of ten here now we are considering deformation and displacement vector sum for mode 1 and mode10.

In this study, the finite element analysis package, ANSYS is used to analyze the structure. dimensions of structure are given below
Length of the shell =500mm

Radius of the shell =100mm
Thickness of shell =4mm

TABLE 2: SHOWS THE MODES OF CYLINDER WITHOUT CUT-OUT FREQUENCIES OF ALUMINUM ALLOY, GLASS FABRIC, CARBON EPOXY WITHOUT CUT-OUTS

No of modes	Aluminum	Glass Fabric	Carbon Epoxy
1	1.52E-02	2.55E-02	4.53E-02
2	1.52E-02	2.55E-02	4.53E-02
3	1.52E-02	2.62E-02	5.03E-02
4	1.52E-02	2.62E-02	5.03E-02
5	1.62E-02	3.06E-02	5.05E-02
6	1.62E-02	3.06E-02	5.05E-02
7	1.67E-02	3.08E-02	6.18E-02
8	1.67E-02	3.08E-02	6.18E-02
9	1.86E-02	3.76E-02	7.07E-02
10	1.86E-02	3.76E-02	7.07E-02

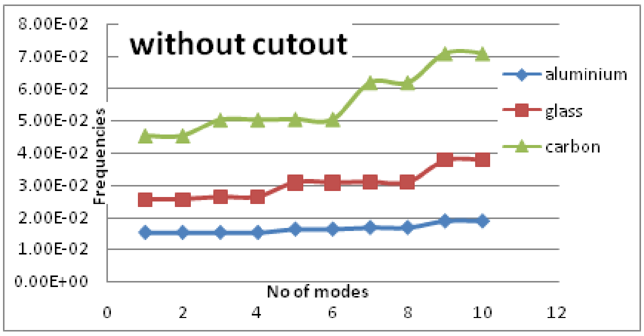

Fig 6: Frequencies of aluminum alloy, glass fabric, carbon epoxy without cut-outs

Again the same structures is analysed by providing cutouts of different shape. Here the adopted shapes are circle rectangular, square, and curved square Results are given below

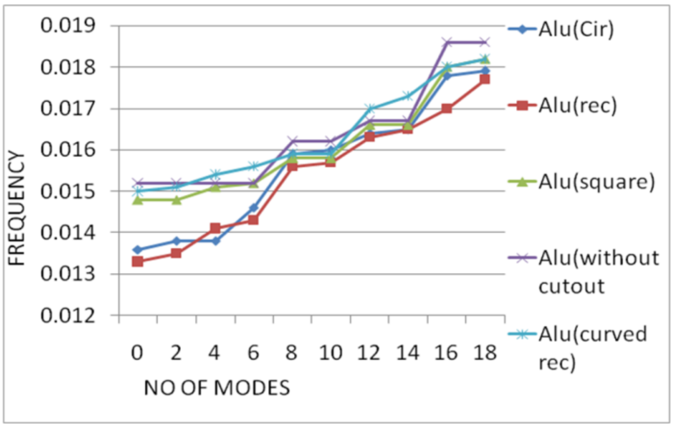

Fig 7: Frequencies of aluminum alloy with cut-outs

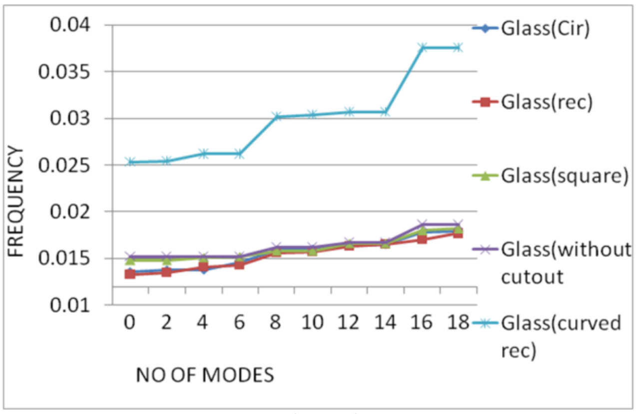

Fig 8: Frequencies of glass fabric with cut-outs

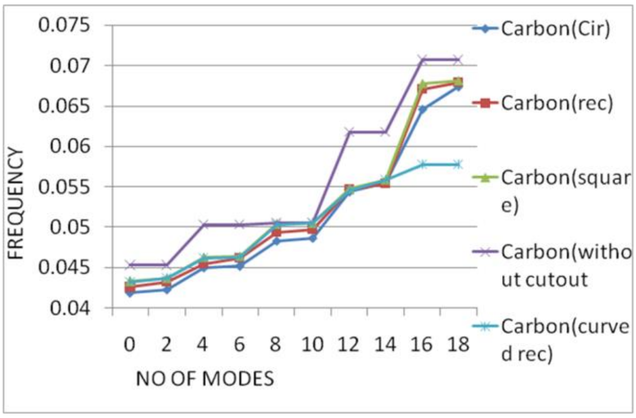

Fig 9: Frequencies of carbon epoxy with cut-outs

The frequency values of carbon Epoxy are higher than Aluminum, Glass Fabric, where as the glass fabric values are in between aluminium and carbon epoxy in case of cylinder without cut-out. The above results are repeated for cylinder with circular cut-out, square cut-out, rectangle cut-out, rectangle with rounded corners cut-out. If we observe each and every graph with same material for different cut-outs the frequencies are high with the cylinder without cut-out but cut-outs are necessary for aircraft fuselage section to accommodate windows, doors, etc. Therefore from above cases the next higher frequencies are observed for the cylinder with rectangle with rounded corners cut-out. If we observe each and every graph of any type of cut-out the frequencies are high for carbon epoxy material. By comparing the results of carbon epoxy material for all cut-outs the results are high in case of the cylind er with rectangle with rounded corners cut-out, indicating that it has a higher structural stiffness. Therefore rectangle with rounded corners cut-out with them Carbon Epoxy material is preferred for aircraft fuselage section.

III. CONCLUSION

The conclusion is obtained from the comparison of above study. All the above studies are based on the finite element analysis. from these studies we get an idea about the parameters that affect the analysis result.

From the first study we can conclude that, for model analysis, change in shapes results in change in frequency and deflection. From the second study, we can conclude that, concentration of stress will vary according to the cut-out shapes, bluntness and rotation effects. In general, as bluntness increases, the stress concentration increases, regardless of the shape and rotation. And also it is clear the stress concentration increases as the cut-outs become more oriented from the baseline.

From the observation of each and every graph of third study, with same material for different cut-outs the frequencies are high with the cylinder without cut-out. Also frequencies vary with composite material. Here the frequency of the carbon epoxy material is higher than other .

From the above study we can conclude that presence of cut-out, shape of cut-out, size of cut-out, and composite material have a great role in the stress concentration, frequency, and deflection of structure. And also the orientation is also a relatively significant design factor to reduce stress concentration

IV ACKNOWLEDGMENT

I Jinju James Olickal , convey my sincere thanks to my guide Er. Laksmipriya A.R, Er. Reshma Theresa (HOD of Civil Department) and my parents for their sincere support and constant guidance. At last but not the least, I thank almighty for his constant blessings, showered on me.

REFERENCES

[1] K. Anusha Reddy, and G. Eason, B Ravi Katukam "Relative Comparison of Geometrical Shapes for Cutouts" Volume 5 Issue 3 June 2015, ISSN: 2319 – 1058

[2] Sudhir Sastry Y B, Sindhura .G, Sarwade A. G R. Model Analysis of Composite Fuselage like Structures with Cutouts "Vol. 2 Issue 11, November - 2013 , ISSN: 2278-0181

[3] M Mohan Kumar, Rajesh S, Yogesh H, " Study on the Effect of Stress Concentration on Cutout Orientation of Plates with Various Cutouts and Bluntness" Vol.3, Issue.3, May-June. 2013 pp-1295-1303 ISSN: 2249-6645.