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Research Article

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Analysis of Epoxy composite rectangular plate with a circular hole: A Finite Element Approach

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ABSTRACT

The composite is a structural material that consists of two or more combined constituents that are combined at a microscopic level and are not soluble in each other to increase the strength of the material. Epoxy resins are widely used for most advanced composites. Composite epoxy materials are a group of composite materials typically made from woven glass fabric surfaces and non-woven glass core combined with epoxy synthetic resin. They are typically used in printed circuit board. In the present work, an attempt is made to design the graphite / epoxy composite plate. A rectangular plate is designed with concentric circular hole and four loads are applied to determine stresses induced. Further, analytical results are validated with FEA results.

Keywords: Graphite / Epoxy composite, Finite Element Analysis, Rectangular plate, Circular hole

INTRODUCTION

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that when combined produce a material with characteristics different from the individual components. The desired properties of composite materials are toughness, corrosion resistance, thermal/electrical insulation and conductivity. Mustafa Akbulut et al. [1] describes optimization procedure to minimize thickness or weight of laminated composite plates subjected to in-plane loading and results of optimization for different combinations of in-plane loadings. G NarayanaNaik et al. [2] presented minimization of weight of composite plates subjected to in plane loads using failure mechanism based (FMB).

M. Walker & R.E. Smith [3] developed a methodology for using genetic algorithms with the finite element method to minimize the mass and deflection of fiber reinforced structures with several design variables is described. Further reduction is also possible by optimizing the material system itself such as fiber orientations, ply thickness, stacking sequence, etc. Rafael F. Silvaa et al. [4] proposed methodology for minimum weight design of laminated composite tubes. Chung Hae Park et al. [5] proposed an integrated optimization methodology to taking into account the weight saving, the improvement of structural performance and the cost reduction of composite structures. SukruKarakaya et al. [6] proposed genetic algorithm and generalized pattern search algorithm are used for optimal Stacking sequence of a composite panel, which is simply supported on four sides and is subject to biaxial in-plane compressive loads. T.Rangaswamy et al. [7] presented the design and analyze of a composite drive shaft for power transmission applications. Genetic Algorithm (GA) has been successfully applied to minimize the weight of shaft which is subjected to the constraints such as torque transmission, torsion buckling capacities and fundamental natural frequency. Wenbin Yu et al. [8] developed a Reissner–Mindlin theory for composite laminates without invoking adhoc kinematic assumptions by using the variation-asymptotic method. Instead of assuming a priori the distribution of three dimensional displacements in terms of two-dimensional plate displacements as what was usually done in typical plate theories, an exact intrinsic formulation had been achieved by introducing unknown three-dimensional warping functions. Cardenas Diego et al. [9] developed a reduced-order finite-element model suitable for Progressive Failure Analysis (PFA) of composite structures under dynamic aero elastic conditions based on a Thin-Walled Beam (TWB) formulation is presented.

Junaid Kameran Ahmed et al. [10] presented the behavior of laminated composite plates under transverse loading using an eight-node diso-parametric quadratic element based on first order shear deformation theory, the element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes.

EXPERIMENTAL SECTION

Analytical method for Rectangle Plate with Circular Hole:
Geometry considered for analytical calculations and Finite Element Modeling is depicted in Fig.1 and Geometric factors defined for various, diameters to width of plate, ratios are shown in Table 1.

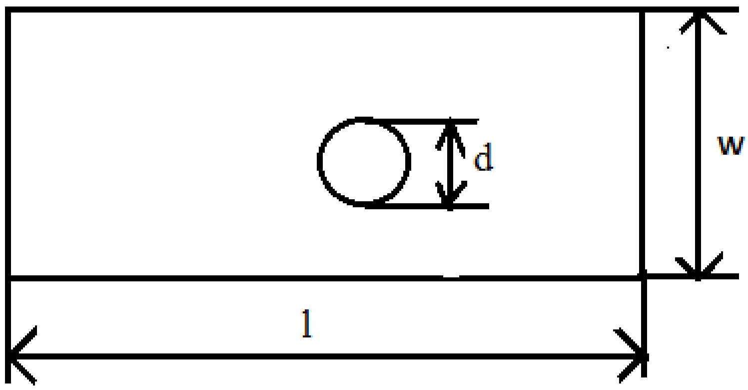

Fig .1 Rectangular plate with circular hole

Table 1 Stress concentration factor values

$\frac{d}{w}$	0.05	0.1	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55
K_t	2.83	2.69	2.59	2.50	2.43	2.37	2.32	2.26	2.22	2.17	2.13

Formulae used for calculations are depicted in eq. (1) – (5)

$$\text{Geometric factor} = \frac{\text{Dia.of Hole}}{\text{Width of plate}} = \frac{d}{w} \quad (1)$$

Where d = diameter of hole, W= width of the plate, K_t = stress concentration factor

$$K_t = \frac{\textbf{Maxi.stress}}{\textbf{Nominalstress}} \quad (2)$$

Tensile force = pressure *cross-sectional area (3)

$$\text{Nominal stress} = \frac{Tensileforce}{(w-d)t} \quad (4)$$

Maximum stress = K_t × Nominal stress (5)

Rectangle plate with circular hole at 14MPa:
Considered data as given below
Diameter of hole = 40mm
Width of the plate = 100mm
Thickness = 25mm
Pressure = 14MPa

Formulae:

$$\text{Geometric factor} = \frac{\text{Dia.of Hole}}{\text{Width of plate}} = \frac{d}{w}$$

$$\text{SCF} = \frac{\textbf{Maxi.stress}}{\textbf{Nominalstress}}$$

Tensile force = pressure *cross-sectional area

Nominal stress $=\frac{Tensileforce}{(w-d)t}$

Maximum stress = SCF×Nominal stress

Procedure:
Geometric factor $= \frac{\text{Dia.of Hole}}{\text{Width of plate}} = \frac{\text{d}}{\text{w}}$
$= \frac{40}{100}$
$= 0.4$
The $\frac{d}{w}$ ratio for stress concentration factor is taken from Table 1

Hence,
SCF = 2.26

We know that

SCF $=\frac{\boldsymbol{Maxi.stress}}{\boldsymbol{Nominalstress}}$

Hence,
Tensile force = pressure *cross-sectional area
= 14×100×25
= 35000N

Nominal stress $= \frac{Tensileforce}{(w-d)t}$
$= \frac{35000}{(100-40)\times 25}$
= 23.33MPa

Maximum stress = SCF×Nominal stress
= 2.26×23.33
= 52.7MPa

Rectangle plate with circular hole at 16MPa:
Considered data as given below
Diameter of hole = 40mm
Width of the plate = 100mm
Thickness = 25mm
Pressure = 16MPa

Procedure:
Geometric factor $= \frac{\text{Dia.of Hole}}{\text{Width of plate}} = \frac{\text{d}}{\text{w}}$
$= \frac{40}{100}$
$= 0.4$

The $\frac{d}{w}$ ratio for stress concentration factor is taken from Table 1
Hence,
SCF = 2.26

We know that
SCF $= \frac{\boldsymbol{Maxi.stress}}{\boldsymbol{Nominalstress}}$

Hence,
Tensile force = pressure *cross-sectional area
= 16×100×25

=40000N

Nominal stress = $\frac{Tensile force}{(w-d)t}$

$= \frac{40000}{(100-40)\times 25}$

= 26.6MPa

Maximum stress = SCF×Nominal stress

= 2.26×26.6

= 60MPa

Rectangle plate with circular hole at 18MPa:

Considered data as given below

Diameter of hole = 40mm

Width of the plate = 100mm

Thickness = 25mm

Pressure = 18MPa

Procedure:

Geometric factor $= \frac{\text{Dia.of Hole}}{\text{Width of plate}} = \frac{d}{w}$

$= \frac{40}{100}$

= 0.4

The $\frac{d}{w}$ ratio for stress concentration factor is taken from Table 1

Hence,

SCF = 2.26

We know that

SCF $= \frac{\boldsymbol{Maxi.stress}}{\boldsymbol{Nominalstress}}$

Hence,

Tensile force = pressure *cross-sectional area

= 18×100×25

= 45000N

Nominal stress = $\frac{Tensile force}{(w-d)t}$

$= \frac{45000}{(100-40)\times 25}$

= 30MPa

Maximum stress = SCF×Nominal stress

= 2.26×30

= 68MPa

Rectangle plate with circular hole at 20MPa:

Considered data as given below

Diameter of hole = 40mm

Width of the plate = 100mm

Thickness = 25mm

Pressure = 20MPa

Procedure:

Geometric factor $= \frac{\text{Dia.of Hole}}{\text{Width of plate}} = \frac{d}{w}$

$= \frac{40}{100}$

=0.4

The $\frac{d}{w}$ ratio for stress concentration factor is taken from Table 1

Hence,
SCF = 2.26

We know that

$$SCF = \frac{Maxi.stress}{Nominalstress}$$

Hence,

Tensile force = pressure *cross-sectional area
= 20×100×25
= 50000N

$$\text{Nominal stress} = \frac{Tensileforce}{(w-d)t}$$
$$= \frac{50000}{(100-40)\times 25}$$
$$= 33.33\text{MPa}$$

Maximum stress = SCF×Nominal stress
= 2.26×33.33
= 75MPa

Finite Element Analysis of Rectangle Plate with Circular Hole

ANSYS12.0 is used to perform finite element analysis of Rectangle Plate with Circular Hole. Maximum and minimum stress obtained after analyzing are depicted in Fig.2 to Fig.5 for applied load of 14MPa, 16MPa, 18MPa and 20MPa respectively.

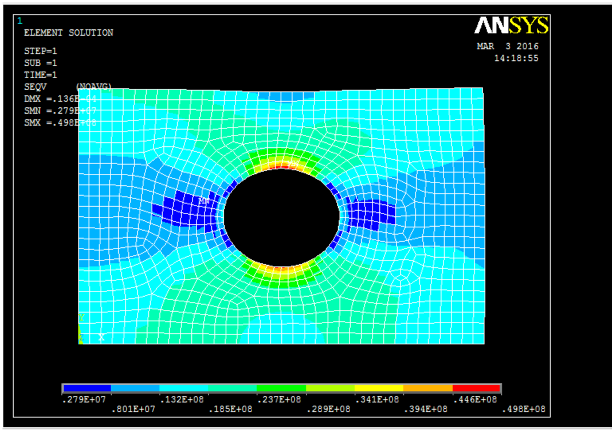

Fig.2 Maximum and minimum stress at 14MPa

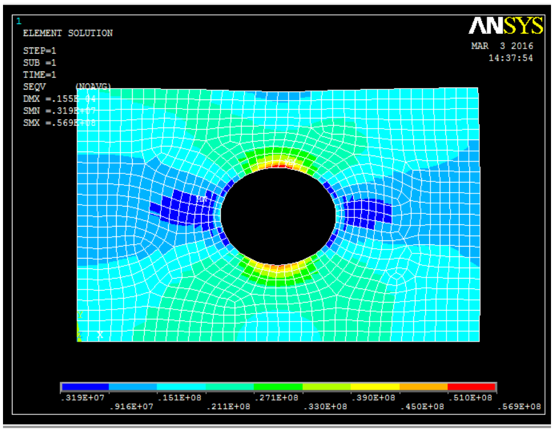

Fig.3 Maximum and minimum stress at 16MPa

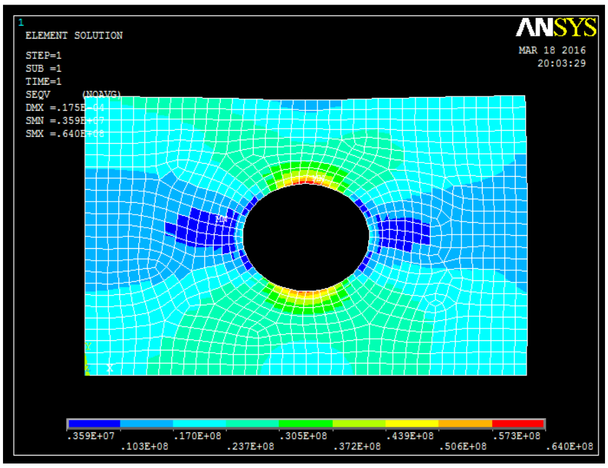

Fig.4 Maximum and minimum stress at 18MPa

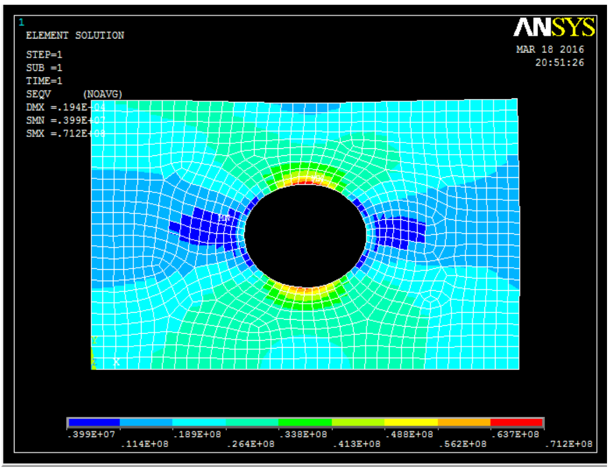

Fig.5 Maximum and minimum stress at 20MPa

RESULTS AND DISCUSSION

A rectangular plate modeled with a concentric circular hole is subjected to four various loads. Table 2 and Table 3 represent results of FEM analysis and analytical results respectively. Graphical comparison of both results is depicted in Fig.6

Table 2 Results of FEM analysis

S.NO	Elements	Stress	Applied pressure			
			14MPa	16Mpa	18MPa	20MPa
1.	Rectangular plate circular hole	Maximum stress	0.484E+08	0.56E+08	0.640E+08	0.712E+08

Table 3 Results of analytical analysis

S.NO.	Elements	Stress	Applied pressure			
			14MPa	16MPa	18MPa	20MPa
1.	Rectangle plate with circular hole	Maximum stress	52.5	60	68	75

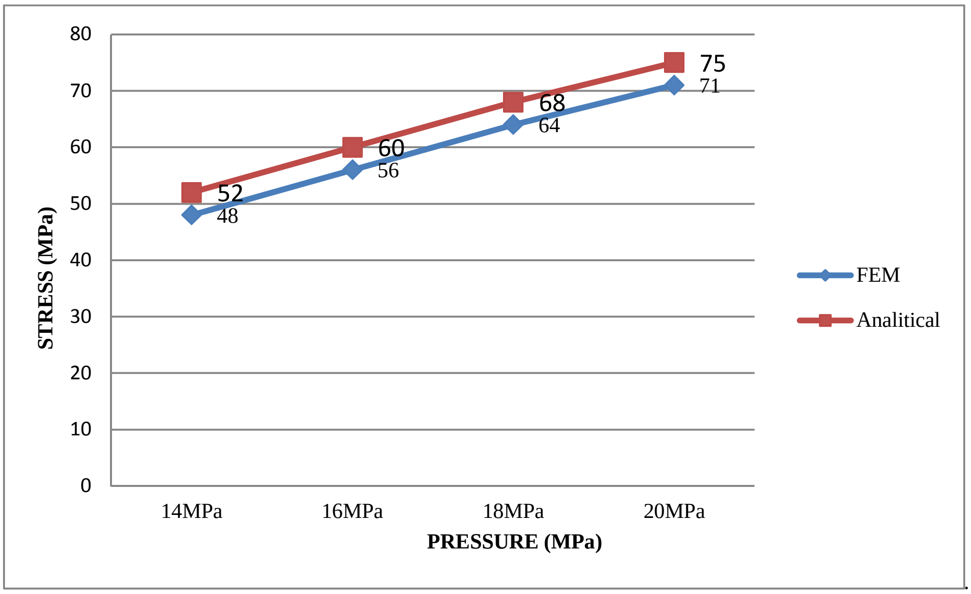

Fig.6 Graphical comparison

CONCLUSION

In this paper a rectangular plate with concentric circular hole is modeled and various loads are applied to determine stresses induced. Finally analytical results obtained are validated with FEA results. So that composite material that consists of two or more combined constituents combined are suitable to increase the strength of the material.

REFERENCES

[1] Akbulut M; Sonmez F. O; *Computers & Structures*, **2008**, 86(21), 1974-1982.
[2] Naik G N; Gopalakrishnan S; Ganguli R; *Composite Structures*, **2008**, 83(4), 354-367.
[3] Walker M; Smith R E; *Composite Structures*, **2003**, 62(1), 123-128.
[4] Silva R F; Rocha I B; Parente Júnior E; Melo A; Holanda Á. S. D; **2010**, *SILVA*.
[5] Park C H; Saouab A; Bréard J; Han W. S; Vautrin A; Lee W I; *Composites Science and Technology*, **2009**, 69(7), 1101-1107.
[6] Soykasap O; Karakaya Ş; **2007**, *Key Engineering Materials*, 348, 725-728.
[7] Rangaswamy T; Vijayarangan S; Chandrashekar R A; Venkatesh T K; Anantharaman K; **2002**, *International Symposium of Research Students on Materials Science and Engineering December*, 4, 1-9.
[8] Yu W; **2005**, *International journal of solids and structures*, *42*(26), 6680-6699.
[9] Cárdenas D; Elizalde H; Marzocca P; Abdi F; Minnetyan L; Probst O; **2013**, *Composite Structures*, 95, 53-62.
[10] Ahmed J K; Agarwal V C; Pal P; Srivastav V; **2013**, *International Journal of Innovative Technology and Exploring Engineering*, 3(6), 56-60.