Structural Analysis of Thin Isotropic and Orthotropic Plates using Finite Element Analysis

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Abstract

The strength and stability of a structural member is affected by the discontinuity and its features, namely geometry, position, and dimensions determined during the design process. It results in localization of stresses resulting in excessive plastic deformation leading to distortion. The failure mode may get transformed to distortion; or tearing; or buckling, depending on the boundary as well as loading conditions. In this work the structural response of a thin plate with a circular hole subject to various boundary conditions is studied. The response of the plate is studied by performing stress, modal and buckling analysis. The effect of parameters like d/w (hole diameter to plate width) ratio, location of the hole & support conditions on the stress concentration factor, natural frequency, mode shape and buckling load is presented for isotropic and orthotropic materials. The d/w ratio is varied over a span of 0.1 - 0.5 with an incremental step of 0.1. The study concludes that increase in d/w ratio results in increase of frequency ratio & deflection ratio which is because of decrease in the stiffness of the material. In addition that it has been observed that the stress concentration factor and buckling load factor decreased with increase of d/w ratio.

Keywords — *Finite element analysis Structural response, stress concentration factor, buckling factor, frequency ratio*

I. INTRODUCTION

During the design process, discontinuities generated for weight reduction or assembly of components, will greatly affect the stiffness as well as strength of the material. This results in increased rate of energy release thereby accelerating the permanent failure. Lot of research has been carried out to study the response of plates with cutouts subject to various boundary conditions. Nitin Kumar Jain [1] analyzed the effect of D/A ratio on the stress concentration and distribution of stress and deflections in a rectangular plate with a central circular cutout made of isotropic and orthotropic materials using finite element analysis. Sasi Kumar et. al [2] performed the modal analysis to study the response of a rectangular plate with central circular cutout and studied the effect of aspect ratio, ratio of diameter of the hole to plate width, thickness of the ply and orientation of the fibres on the natural frequencies and mode shapes. Nagpal et. al [3] presented a critical review and compared the various methods like analytical, numerical and experimental methods proposed to study the response of rectangular plates with central circular and elliptical cutouts available in the literature. Hwai-Chung Wu et. al [4] proposed computational model to estimate the stress concentration factors in isotropic as well as orthotropic rectangular plate as well as cylinder with circular cutout under uniaxial and biaxial tension. P. Srikanth et. al [5] performed the finite element analysis to study the deformations and stresses induced in beams and plates made of carbon fiber and Eglass/epoxy subject to different boundary conditions. Banerjee et. al [6] conducted a detailed analysis of rectangular plate with central circular cutout with all edges fixed using finite element analysis to study the effect of various parameters like thickness to plate width ratio, diameter to width ratio and material properties on the stress concentration calculated using stresses in different directions. Vanam et. al. [7] studied the static response of an isotropic rectangular plate subject to uniformly distributed transverse load using numerical solution (finite element analysis), classical solution and simulation in ANSYS for different loadings and boundary conditions. Devidas R. Patil el. al [8] performed the modal analysis of a rectangular plate to study the effect of boundary conditions, plate width to length ratio, and thickness ratio on the vibrational characteristics of the plate. Okafor et. al [9] proposed the analytical solution for the static analysis of an isotropic rectangular plate subject to various boundary conditions by employing the Direct variational Ritz method. Ming-Hung Hsu [10] presented a numerical solution for studying the vibration response of isotropic and orthotropic plates using differential quadrature method (DQM).

II. FINITE ELEMENT ANALYSIS

In this work the natural frequencies & corresponding ratio's , principal stresses, stress concentration factor's , maximum shear stress are determined numerically using finite element analysis software ANSYS.

A. *Modeling*

Two thin composite plates of size 1m x 1m and 1m x 0.5m of each 1mm thickness are considered in this analysis the plate is assumed to contain a hole of diameter 'd' such that it is related to the plate width 'w'.

d/w ratio is varied as between 0.1 to 0.5 with an interval of 0.1. The position of the hole is assumed to be

a. Centre of the plate.
b. Nearer to the shortest end.
c. Nearer to the longest end.
d. Nearer to the corner.

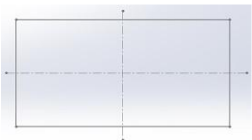

Fig. a Plate without hole

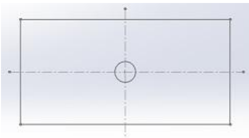

Fig. b Plate with central circular hole

Fig. c Plate with hole at shortest edge

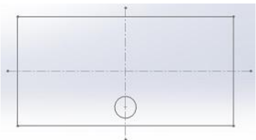

Fig. d plate with hole at longest edge

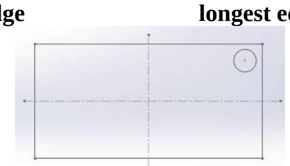

Fig .e Plate with hole at corner

B. *Material properties*

In this work two materials are considered.

1) ***Carbon/epoxy***.

TABLE: I
MATERIAL PROPERTIES OF CARBON/EPOXY

Young's modulus (E)	Shear Modulus (G)	Poisson's ratio
E_x=130 Gpa	G_{XY}=4.8 Gpa	XY=0.28
E_y=9 Gpa	YZ=4.8 Gpa	YZ=0.28
E_z=9 Gpa	ZX=4.8 Gpa	ZX=0.28

Density=1656 kg/m^3

2) ***Aluminum 6061***

Young's modulus(E) = 71.2 Gpa
Poisson's ratio = 0.3
Density = 2700 kg/m^3

C. *Meshing*

The rectangular plate has been meshed with shell 3D 4node 181. It is a 3-D element having 3 DOF at each node (translation in 3 directions-u_x, u_y, u_z). Number of elements generated in stress analysis, modal analysis and buckling analysis are 1006, 40254 and 2452 respectively.

D. *Boundary conditions*

Two edge conditions are considered in the analysis.

i. All edges are fixed.
ii. Alternate edges are fixed & hinged.

Considering the self weight of the plate, stress and vibration analysis are performed to determine the parameters like principal stresses, maximum stresses, stress concentration factor, mode shapes, natural frequencies and von mises stresses.

E. *Analysis performed*

In this work the following analysis are performed to study the structural response of a thin rectangular composite plate

1. ***Stress analysis -*** In this analysis, parameters like stress concentration factor's, principal stresses & von-mises stresses, deflection ratio's are determined in a thin composite lamina subjected to its self weight. The analysis is carried out on the plate with & without hole and the results are compared with those obtained for an isotropic plate under the same conditions.
   Deflection ratio: It is defined as the ratio of deflection of the plate with hole to without hole
   Stress concentration factor: It is defined as the ratio of stress concentration of the plate with hole to without hole
2. ***Modal analysis -*** The natural frequencies and the corresponding mode shapes are determined for the rectangular plate as well as Square plate made of isotropic & orthotropic materials,
   The frequency ratio's and the normalized mode shapes are calculated for the various aspect ratio's & d/w ratio's.
   Frequency ratio: It is defined as the ratio of natural frequency of the plate with hole to without hole.
3. ***Buckling analysis -*** In general thin components will fail in buckling because of excessive lateral deflections. Hence there is a need to determine the critical load at which the buckling will initiate. Sheet metals fail by buckling because of lesser strength and resistive area.
   In this work buckling load is calculated in the thin lamina made of isotropic & orthotropic materials and the buckling load factor is calculated for various conditions.

Buckling load factor: It is the ratio of buckling loads to the applied loads.

III. RESULTS

Graphs are plotted to present the variation of stress concentration factor's, frequency ratio's, mode shapes, maximum stresses& von mises stresses.

A. Effect on frequency ratio

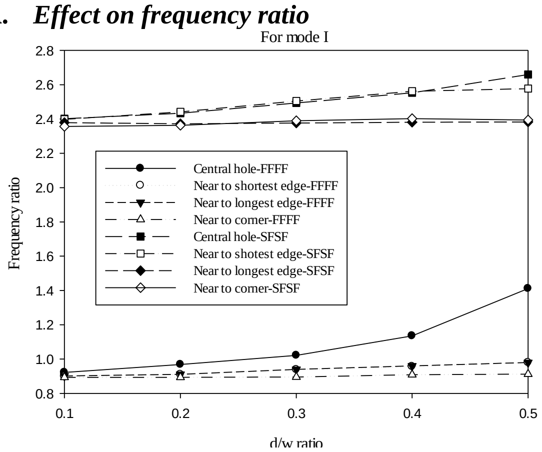

Fig 1a: Square plate for mode I- Carbon/Epoxy

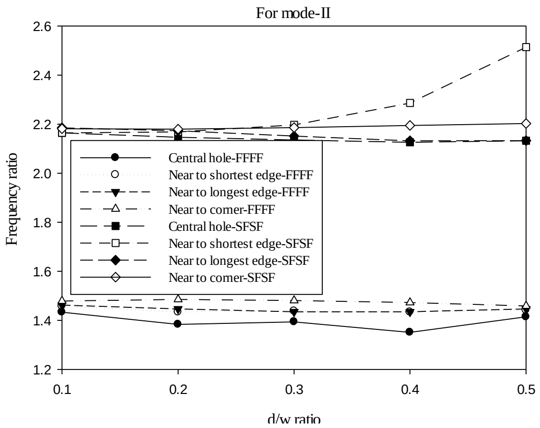

Fig 1b: Square plate for mode II- Carbon/Epoxy

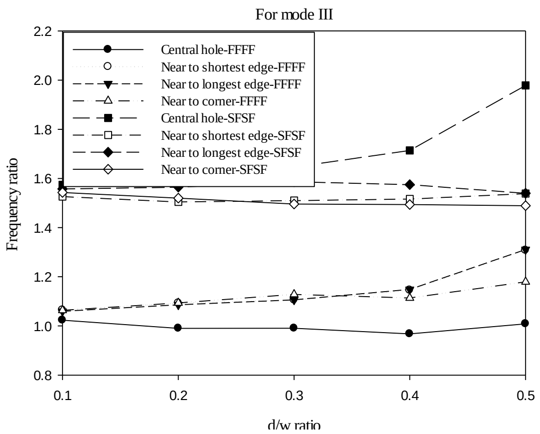

Fig 1c: Square plate for mode III- Carbon/Epoxy

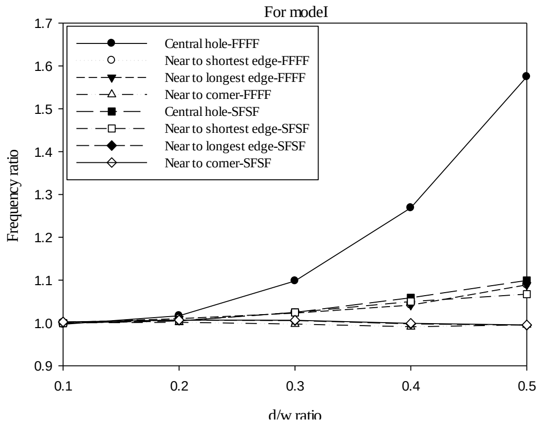

Fig 2a: Square plate for mode I-Al-6061

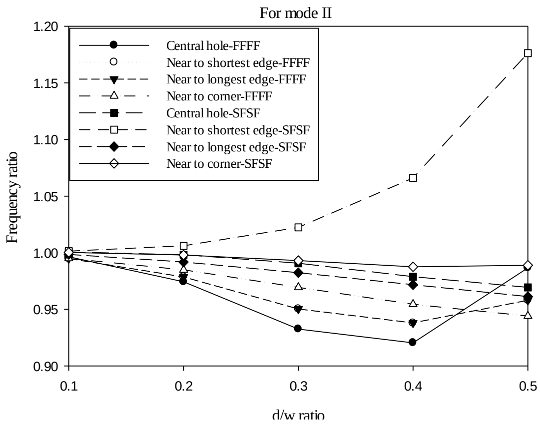

Fig 2b: Square plate for mode II-Al-6061

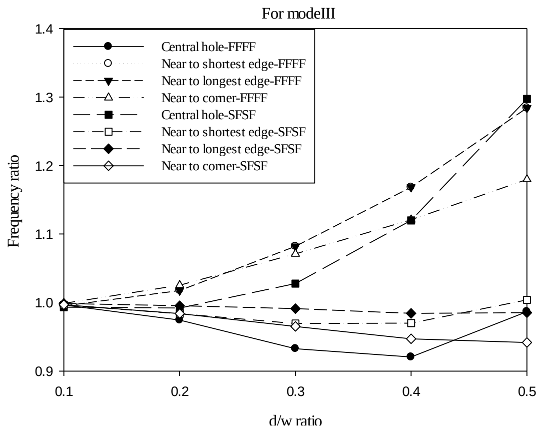

Fig 2c: Square plate for mode III-Al-6061

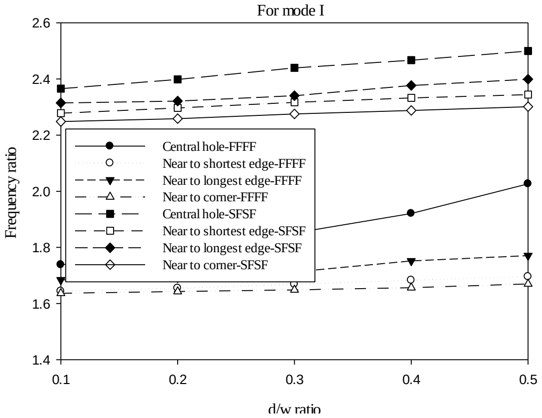

Fig 3a: Rectangle plate for mode I -Carbon/Epoxy

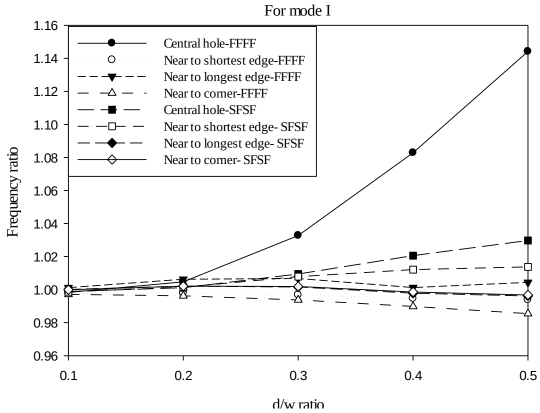

Fig 4a: Rectangle plate for mode I-Al-6061

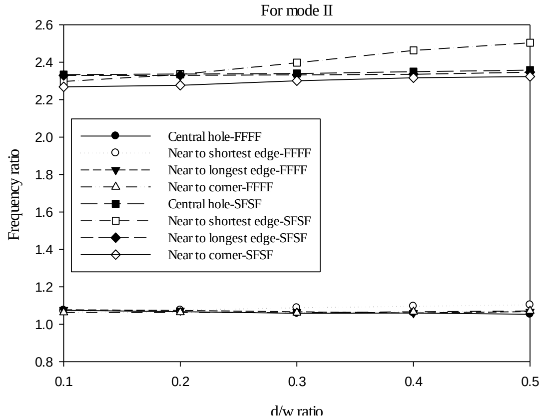

Fig 3b: Rectangle plate for mode II -Carbon/Epoxy

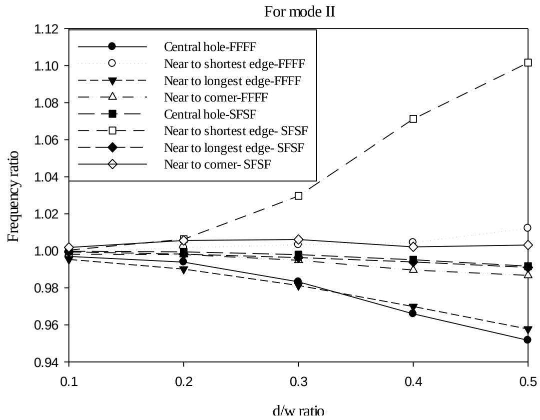

Fig 4b: Rectangle plate for mode II-Al-6061

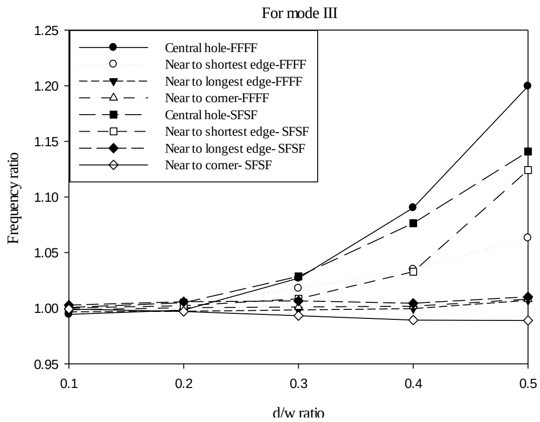

Fig 4c: Rectangle plate for mode III-Al-6061

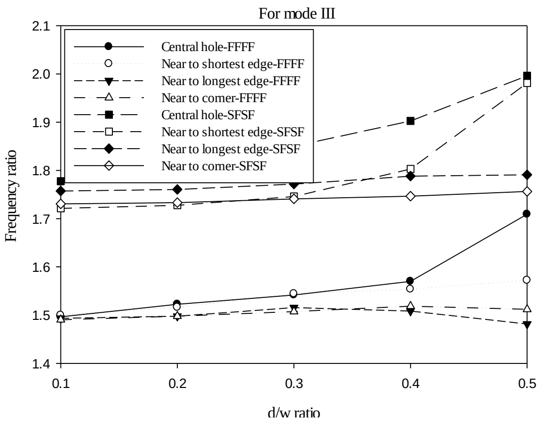

Fig 3c: Rectangle plate for mode III -Carbon/Epoxy

The natural frequencies determined for plates with holes are normalized taking the corresponding frequencies of plate without hole for all the modes. The obtained frequency ratio's are plotted against d/w ratio's for various conditions as shown in fig 1a to 4c. With increase in d/w ratio the frequency ratio is observed to be increasing for both rectangle as well as square plates.

In the case of fundamental frequency (mode-I), the frequency ratio is observed to be increasing with d/w ratio. In the case of Carbon/Epoxy, the maximum is observed at d/w=0.5 with hole located at centre of the plate subject to S-F-S-F in both rectangular as well as square plates whereas for the same location and with same dimension the maximum is observed with F-F-F-F boundary condition in the case of Al-6061 square plate. Also in the case of rectangular plate the maximum is observed at d/w=0.5 with hole nearer to longest edge subject to S-F-S-F. *In addition, it has been observed that fundamental frequency ratio is remaining same for all boundary conditions and hole positions at d/w=0.1 in both rectangular as well as square plates in Al-6061*. Also, the frequency ratio decreased in the case of rectangular plate with hole nearer to corner subject to S-F-S-F in Al-6061.

In the case of square plates, the mode-II frequency ratio remained same for some conditions and increased for the hole positions nearer to shorter edge subject to S-F-S-F and central circular hole subject to F-F-F-F in Carbon/Epoxy. In Al-6061plates, the frequency ratio decreased gradually for all conditions except in the plate with hole nearer to shorter edge subject to S-F-S-F. The maximum is observed at d/w=0.5 in the plate with hole nearer to shorter edge subject to S-F-S-F in Carbon/Epoxy as well as Al-6061exponentially and minimum at d/w=0.4 in the plate with central circular hole subject to F-F-F-F. In rectangular plates, frequency ratio almost remained same for all boundary conditions except for plate with hole nearer to shorter edge subject to F-F-F-F where the frequency ratio increased gradually in Carbon/Epoxy. In Al-6061 the frequency ratio decreased gradually for all conditions except for hole nearer to shorter edge subject to S-F-S-F where the frequency ratio increased. The maximum is observed at d/w=0.5 with hole location nearer to shorter edge subject to S-F-S-F in both Carbon/Epoxy and Al-6061. The minimum is observed at d/w=0.5 with hole located at the centre of the plate subject to F-F-F-F. At lower d/w ratios (<0.1), all the conditions are having same frequency ratio.

In the case of square plates, the mode-III frequency ratio increased gradually in both Carbon/Epoxy and Al-6061 except in plate with central circular hole subject to F-F-F-F in Al-6061 where the ratio decreased gradually. The maximum has been observed at d/w=0.5 with hole located at the centre of the plate subject to S-F-S-F in both Carbon/Epoxy and Al-6061. The minimum is observed at d/w=0.4 in plate with central circular hole subject to F-F-F-F condition. In case of rectangular plates, the frequency ratio increased gradually in both Carbon/Epoxy and Al-6061 except in plate with hole nearer to the corner subject to S-F-S-F where it decreased gradually. The maximum is observed at d/w=0.5 in plate with central circular hole subject to S-F-S-F in Carbon/Epoxy and F-F-F-F in Al-6061 and the minimum is observed at d/w=0.5 in the plate with hole nearer to longest edge subject to F-F-F-F in Carbon/Epoxy whereas in plate with hole nearer to the corner subject to S-F-S-F in Al-6061.

B. Effect on deflection ratio

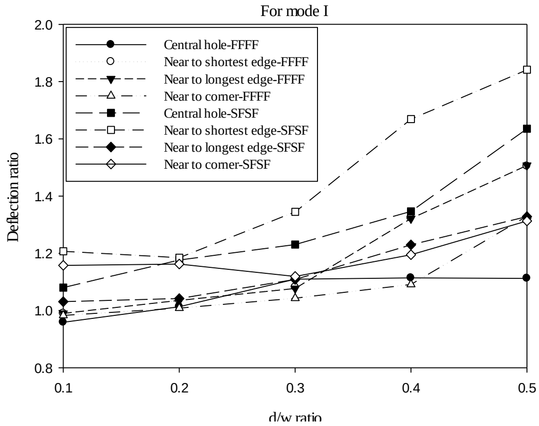

Fig 5a: Square plate for mode I-Carbon/Epoxy

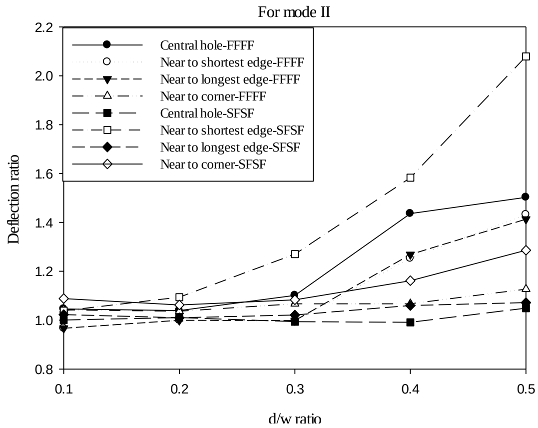

Fig 5b: Square plate for mode II- Carbon/Epoxy

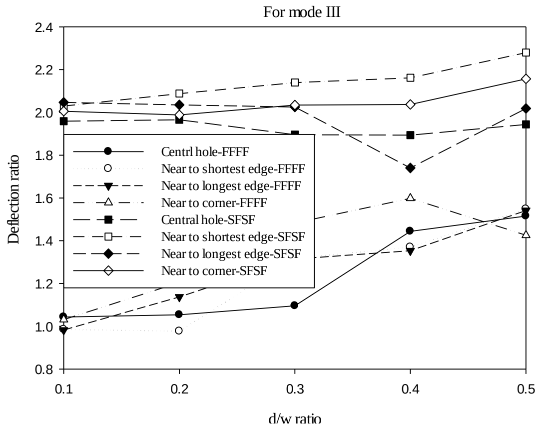

Fig 5c: Square plate for mode III- Carbon/Epoxy

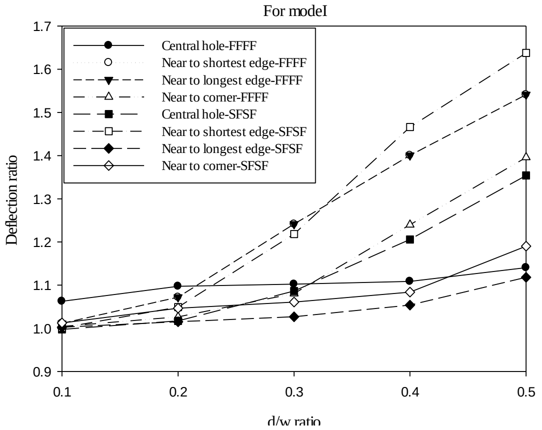

Fig 6a: Square plate for mode I-Al-6061

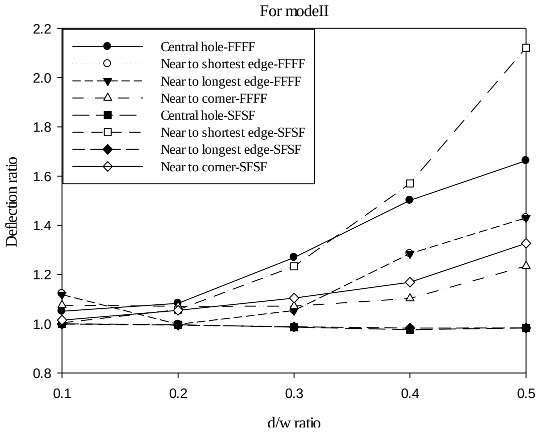

Fig 6b: Square plate for mode II-Al-6061

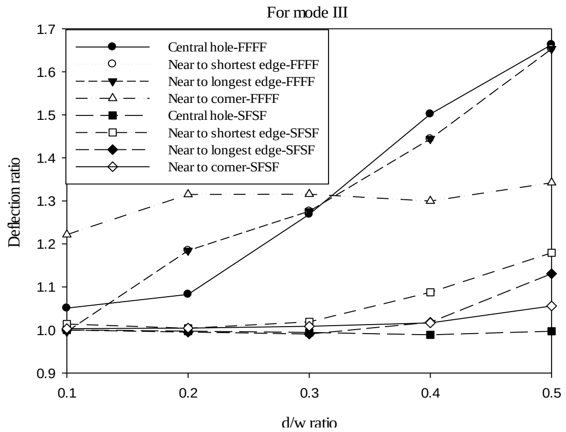

Fig 6c: Square plate for mode III-Al-6061

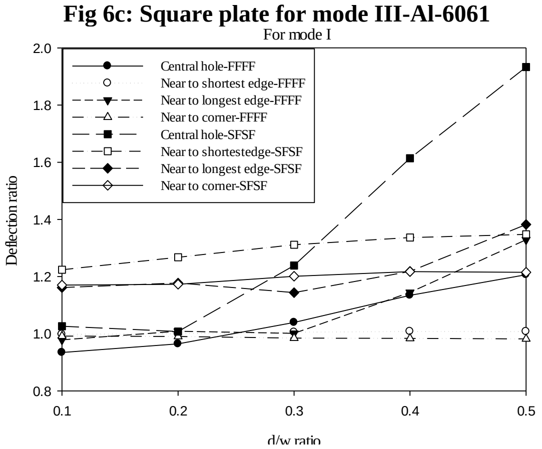

Fig 7a: Rectangle plate for mode I- Carbon/Epoxy

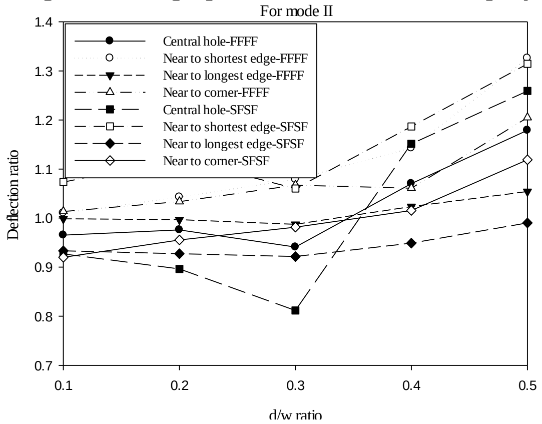

Fig 7b: Rectangle plate for mode II- Carbon/Epoxy

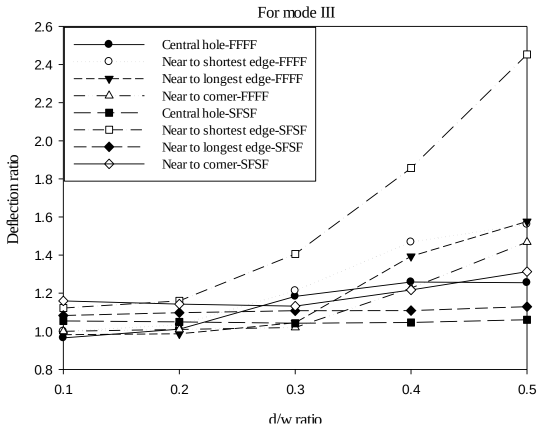

Fig 7c: Rectangle plate for mode III- Carbon/Epoxy

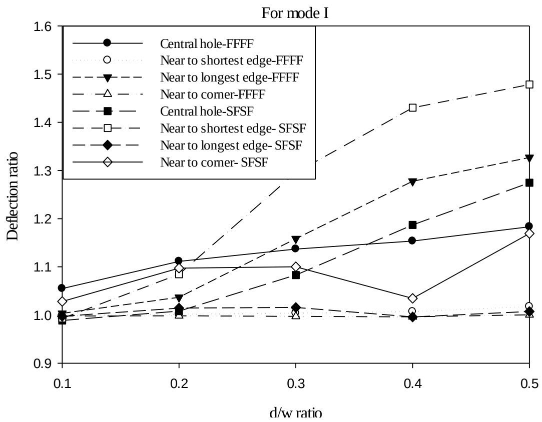

Fig 8a: Rectangle plate for mode I-Al-6061

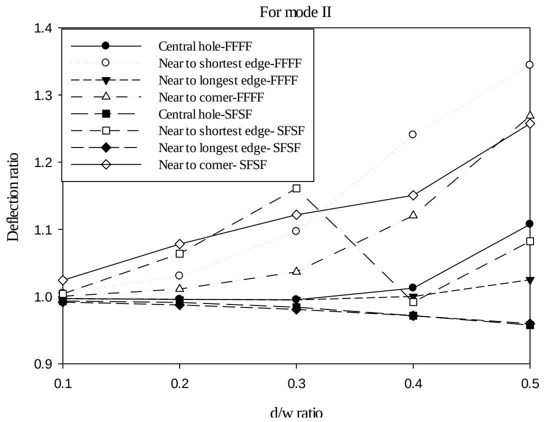

Fig 8b: Rectangle plate for mode II-Al-6061

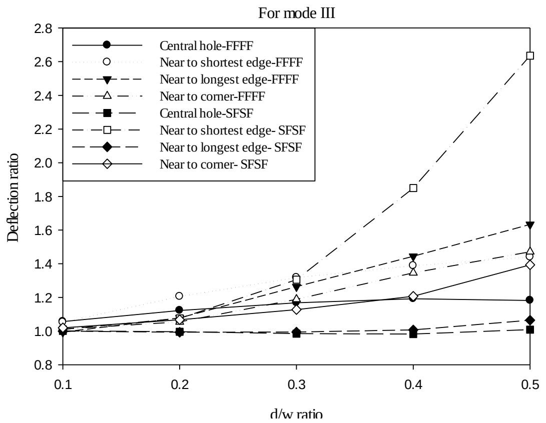

Fig 8c: Rectangle plate for mode III-Al-6061

The normalized deflections are plotted with respect to d/w ratio and are presented in fig 5a to8c. With increase in d/w ratio the deflection ratio is observed to be increasing for both rectangle as well as square plates in Carbon/Epoxy and Al-6061.

In the case of mode-I deflection ratio is observed to be maximum at d/w=0.5 in square plates with hole near to shortest edge subject to S-F-S-F & minimum at d/w ratio=0.1 with central circular hole subject to F-F-F-F, hole near to longest edge subject to S-F-S-F in both Carbon/Epoxy and Al-6061. In case of rectangular plates deflection ratio is observed to be maximum at d/w=0.5 with hole near to shortest edge subject to S-F-S-F in Al-6061 and central circular hole in Carbon/Epoxy & minimum at d/w ratio=0.1 with hole near to corner subject to F-F-F-F in both Carbon/Epoxy and Al-6061.

In the case of mode II deflection ratio is observed to be maximum at d/w=0.5 in square plates with hole near to shortest edge subject to S-F-S-F in both Carbon/Epoxy and Al-6061 & minimum at d/w ratio=0.1 with central circular hole subject to boundary condition-SFSF. In case of rectangular plates deflection ratio is observed to be maximum at d/w=0.5 with hole near to shortest edge subject to F-F-F-F in both Carbon/Epoxy and Al-6061 & minimum at d/w ratio=0.1 with central circular hole subject to boundary condition-SFSF in both the materials.

In the case of mode III deflection ratio is observed to be increasing with d/w ratio and the maximum is observed at d/w=0.5 with hole near to shortest edge subject to S-F-S-F in both square and rectangular plates in Carbon/Epoxy and rectangular plate in Al-6061 and in plate with central circular hole subject to F-F-F-F in Al-6061. The minimum is observed at d/w ratio=0.2 in square plate with hole near to corner subject to S-F-S-F in Carbon/Epoxy and at d/w=0.4 in rectangular plate with central circular hole subject to S-F-S-F in both Carbon/Epoxy and Al-6061. The minimum in rectangular plate made of Carbon/Epoxy is observed at d/w=0.1 with hole located at the centre of the plate subject to F-F-F-F.

C. Effect on stress concentration factor

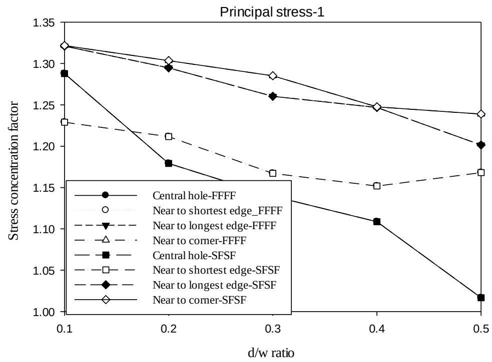

Fig 9a: Square plate for Carbon/Epoxy

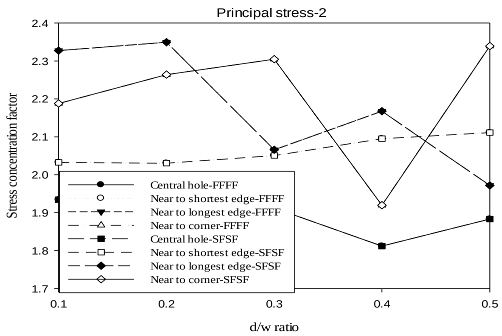

Fig 9b: Square plate for Carbon/Epoxy

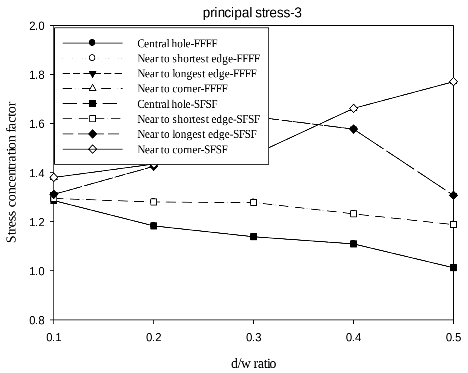

Fig 9c: Square plate for Carbon/Epoxy

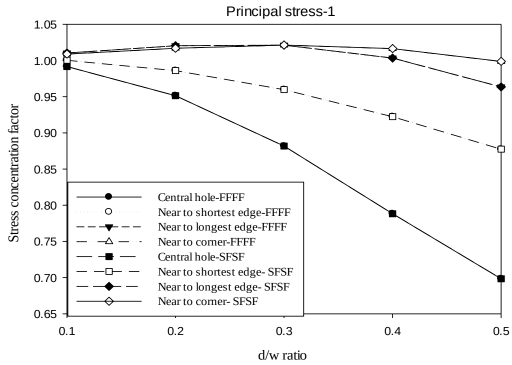

Fig 10a: Square plate Al-6061

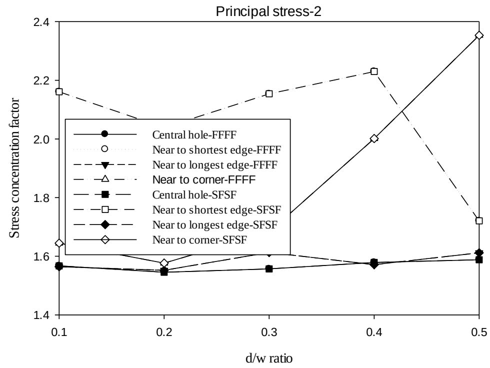

Fig 11b: Rectangle plate for Carbon/Epoxy

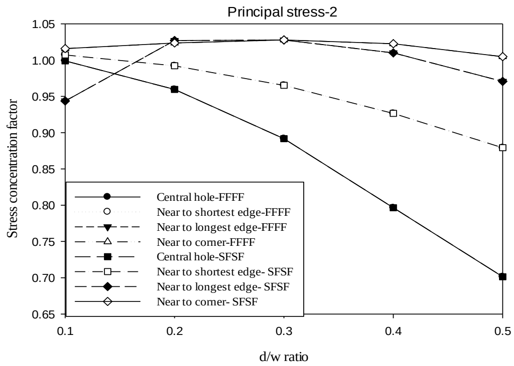

Fig 10b: Square plate for Al-6061

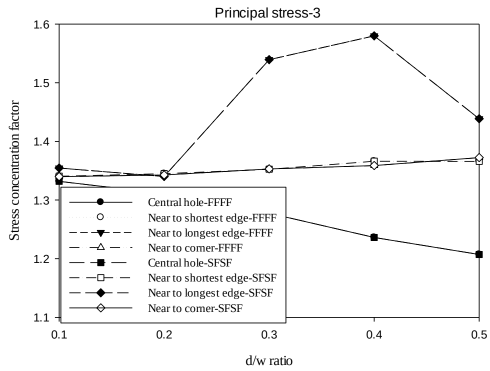

Fig 11c: Rectangle plate for Carbon/Epoxy

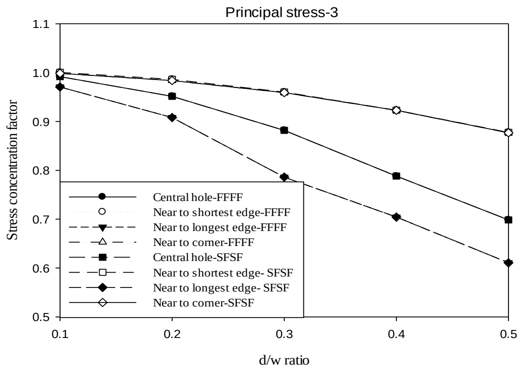

Fig 10c: Square plate Al-6061

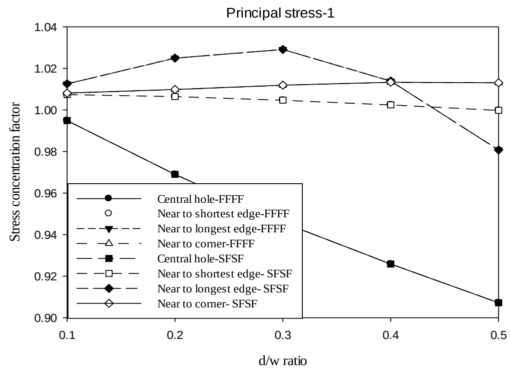

Fig 12a: Rectangle plate for Al-6061

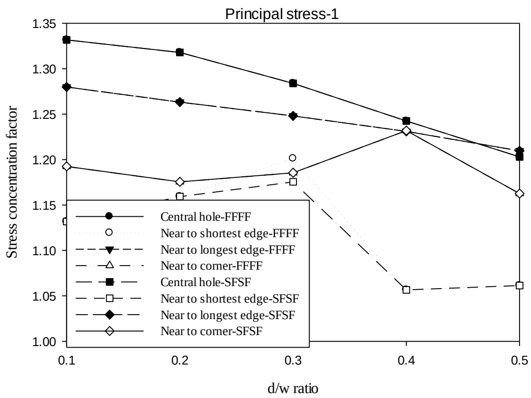

Fig 11a: Rectangle plate for Carbon/Epoxy

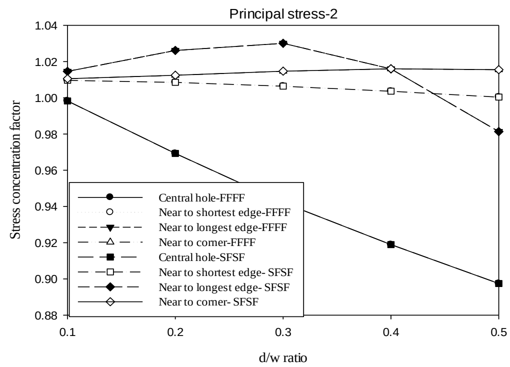

Fig 12b: Rectangle plate for Al-6061

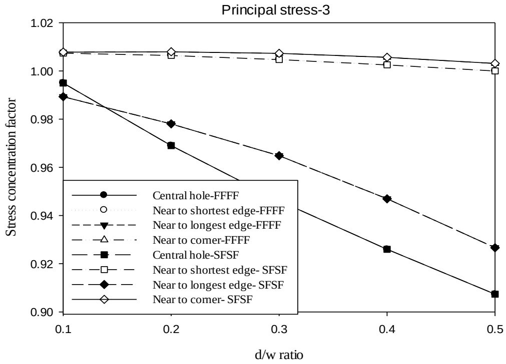

Fig 12c: Rectangle plate for Al-6061

The stress concentration factors (SCF) are plotted with respect to d/w ratio and are presented in fig 9a to 12c. With the increase in the d/w ratio, the SCF is observed to be decreasing with maximum at d/w=0.1 and minimum being at d/w=0.5. This trend is observed for all the boundary conditions. This is because of decrease in the effective area resisting the forces resulting in decrease of stiffness as well strength. Ultimately the plate will fail in tearing mode.

D. SCF based on Principal Stress-1

In case of square plate, maximum SCF is observed at d/w=0.1 with hole near to corner subject to boundary condition-SFSF in Carbon/Epoxy and at d/w=0.3 with hole nearer to corner subject to S-F-S-F boundary condition in Al-6061 and lowest SCF is observed at d/w=0.5 for central circular hole with S-F-S-F boundary condition for Al-6061than compared with Carbon/Epoxy.

In case of rectangular plate, SCF is observed to be maximum at d/w=0.1 with central circular hole subject to S-F-S-F in Carbon//Epoxy and d/w=0.3 with hole nearer to corner subject to S-F-S-F in AL-6061 whereas minimum is observed at d/w=0.5 for both Al-6061 and Carbon/Epoxy with central circular hole subject to S-F-S-F and with hole nearer to shortest edge subject to F-F-F-F and S-F-S-F boundary conditions respectively.

E. SCF based on Principal Stress-2

In case of square plate, the SCF is gradually decreased with increase in d/w ratio in Al-6061 whereas the variation is non-uniform in Carobn/Epoxy. The maximum SCF is observed at d/w=0.2 in the plate with central circular hole and nearer to longest edges subject to F-F-F-F in Carbon/Epoxy, whereas at d/w=0.3 with hole nearer to corner, shortest edge subject to F-F-F-F and longest edge subject to S-F-S-F in Al-6061. The minimum SCF is observed at d/w=0.5 in both Carbon/Epoxy and Al-6061 with central circular hole subject to F-F-F-F and S-F-S-F respectively.

In case of rectangular plate, the variation of SCF is non-uniform with increase in d/w ratio made of Carbon/Epoxy whereas uniform decrease is observed in plate made of Al-6061. The maximum of SCF is observed at d/w=0.5 with hole nearer to shortest edge in Carbon/Epoxy and at d/w=0.3 with hole nearer to longest edge and central circular hole subject to F-F-F-F. The minimum of SCF is observed at d/w=0.2 and at d/w=0.5 in plate with central circular hole subject to S-F-S-F in both Carbon/Epoxy and Al-6061 respectively.

Also, it has been observed that the SCF is increased slightly at all d/w ratios in Al-6061 with hole nearer to corner and shortest edge subject to F-F-F-F and S-F-S-F conditions respectively.

F. SCF based on Principal Stress-3

In case of square plate, the variation of SCF is gradually decreasing with increase in d/w ratio in both Carbon/Epoxy and Al-6061 materials. But in case of hole positions nearer to corner and shortest edge subject to S-F-S-F and F-F-F-F respectively, the SCF increased gradually with increase in d/w ratio. The maximum of SCF is observed at d/w=0.5 with hole nearer to corner and shortest edge subject to S-F-S-F and F-F-F-F respectively in Carbon/Epoxy and at d/w=0.1 for all boundary conditions in Al-6061. The minimum is observed at d/w=0.5 in both square and rectangular plates with central circular hole subject to F-F-F-F and S-F-S-F respectively and also hole nearer to longest edge subject to S-F-S-F in Al-6061.

In case of rectangular plate, the SCF decreased rapidly with d/w ratio in plate with central circular hole subject to F-F-F-F in Carbon/Epoxy and with central circular hole subject to S-F-S-F, nearer to longest edge subject to F-F-F-F boundary conditions. The maximum of SCF is observed at d/w=0.1 for all hole positions and boundary conditions in both Carbon/Epoxy and Al-6061. The minimum is observed at d/w=0.5 for all boundary conditions and hole positions in Carbon/Epoxy and Al-6061.

G. Effect on frequency ratio

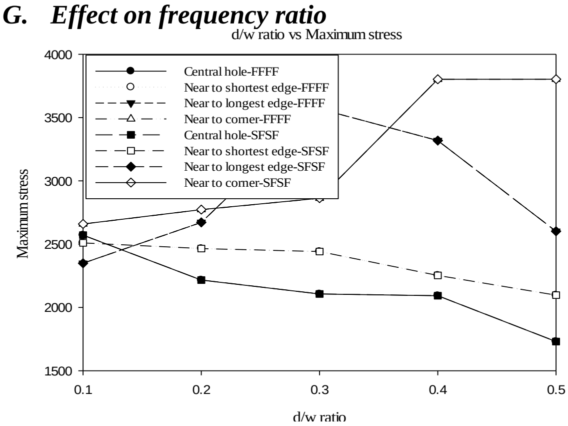

Fig 13a: Square plate - σ_{max}-Carbon/Epoxy

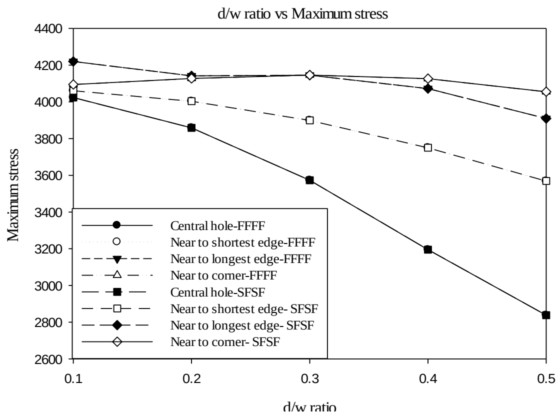

Fig 13b: Square plate- σ $_{max}$ - Al-6061

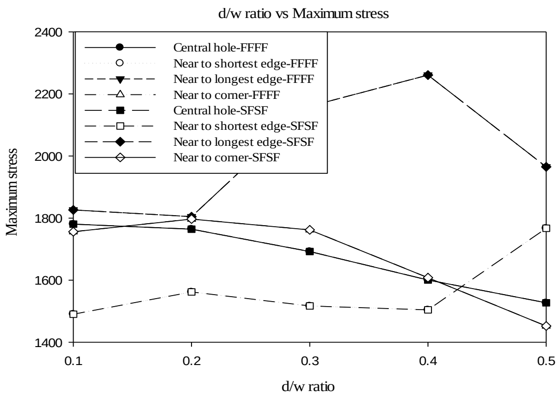

Fig 14a: Rectangle plate- σ $_{max}$ -Carbon/Epoxy

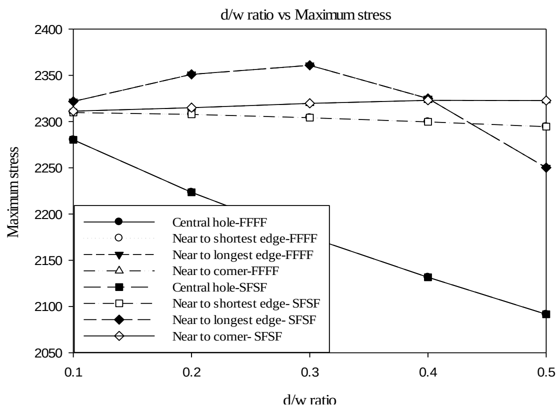

Fig 14b: Rectangle plate- σ $_{max}$ - Al-6061

The obtained maximum stresses are plotted against d/w ratio's for various conditions as shown in fig 13a to 14b. In Al-6061, the maximum stress decreased gradually in both square as well as rectangular plates whereas in rectangular plates, the maximum stress first increased and then decreased.

In case of square plate, the highest of maximum stress is observed at d/w=0.5 in the plate with hole nearer to the corner subject to S-F-S-F in Carbon/Epoxy where the maximum is observed at d/w=0.1 with hole nearer to corner subject to S-F-S-F and nearer to longest edge subject to F-F-F-F in AL-6061. The lowest is observed at d/w=0.5 with hole nearer to corner subject to S-F-S-F in both Carbon/Epoxy and Al-6061.

In case of rectangular plate, the highest is maximum stress is observed at d/w=0.4 with hole nearer to the longest edge subject to S-F-S-F as well as central circular hole subject to F-F-F-F in Carbon/Epoxy whereas at d/=0.3 with hole nearer to longest edge subject to both F-F-F-F and S-F-S-F in Al-6061. The lowest is observed at d/w=0.5 in S-F-S-F boundary condition with hole located nearer to corner in Carbon/Epoxy whereas at central circular hole in Al-6061 respectively.

H. Effect on Equivalent stress (Von-Mises stress)

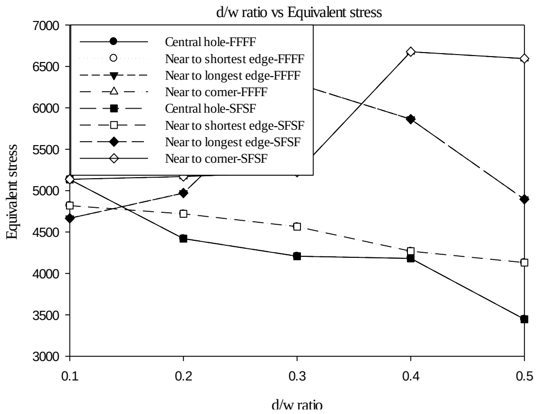

Fig 15a: Square plate - σ $_{equi}$ -Carbon/Epoxy

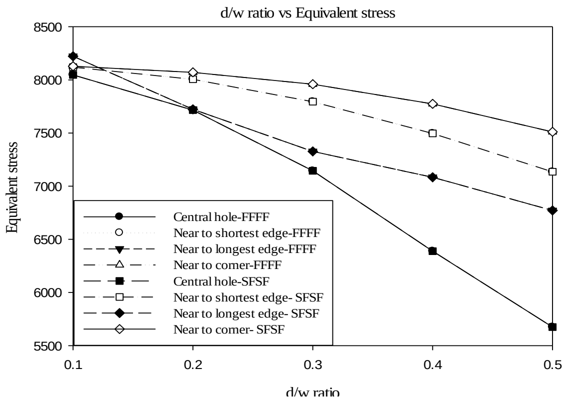

Fig 15b: Square plate - σ $_{equi}$ - Al-6061

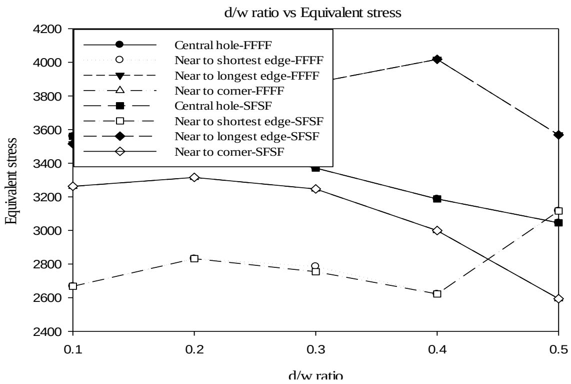

Fig 16a: Rectangle plate - σ_{equi} - Carbon/Epoxy

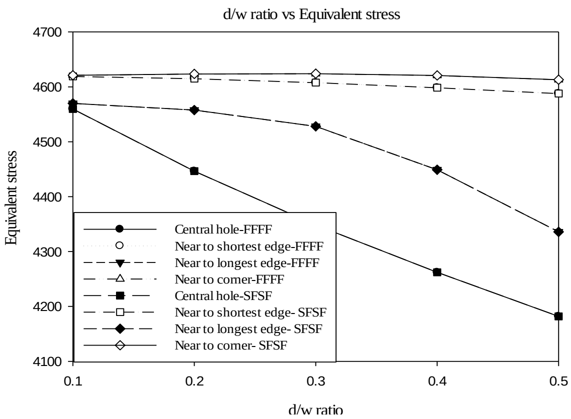

Fig 16b: Rectangle plate - σ_{equi} - Al-6061

The obtained maximum stresses are plotted against d/w ratio's for various conditions as shown in fig 15a to 16b.

With the increase in d/w ratio, the equivalent stress decreased gradually in the case of square plate for all conditions except for the central circular hole subject to F-F-F-F condition where a sudden decrease in the value is observed in Al-6061. The maximum is observed in the plate with hole nearer to longest edge subject to F-F-F-F at d/w=0.1. But in rectangular plate the equivalent stress decreased rapidly for some boundary conditions and slightly in some conditions but the maximum is observed at d/w=0.3 in the plate with hole nearer to the corner subject to S-F-S-F condition. In the plate of Carbon/Epoxy, the equivalent stress fluctuated with increase in the d/w ratio. In the case of square plate, the maximum value is observed at d/w=0.4 with hole position nearer to the corner subject to S-F-S-S as well as hole nearer to shortest edge subject to F-F-F-F. The minimum is observed at central circular hole subject to S-F-S-F. In the case of rectangular plate, the maximum is observed at d/w=0.4 in the plates with hole nearer to longest edge subject to S-F-S-F and F-F-F-F conditions. The minimum is observed at d/w=0.5 in the plate with hole located nearer to shorter edge and corner subject to S-F-S-F conditions respectively.

I. Effect on buckling load factor

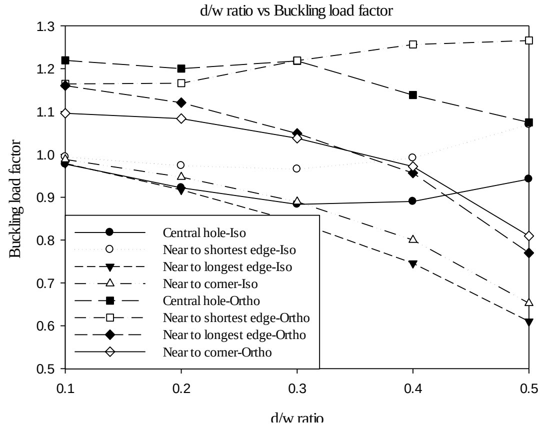

Fig 17a:squareplate -buckling load factor

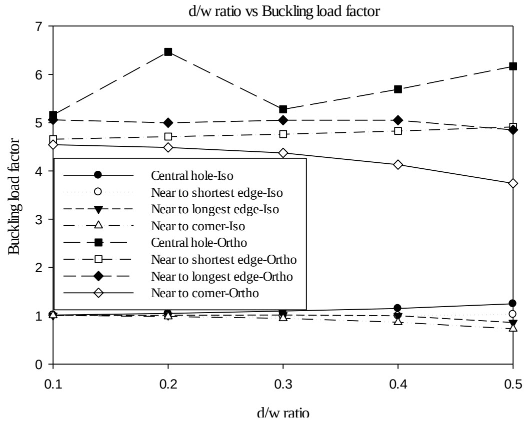

Fig 17b:Rectangleplate -buckling load factor

After the analysis the following parameters are presented graphically for both rectangular as well as square plates, from fig 17a to fig 17b. The graphs are plotted for both Al-6061 and Carbon/Epoxy and the conclusions are drawn.

J. Square Plate:

It has been observed that with increase in d/w ratio, the buckling load factor is decreasing from d/w 0.1 - 0.2 for all hole positions and decreased further to lower value upto d/w=0.5 except for plate with central circular hole and hole nearer to shortest edge in Al-6061 and hole nearer to longest edge in the Carbon/Eopxy. The maximum value of buckling factor is observed in a square plate with the hole nearer to the shortest edge in the Carbon/Epoxy plate with d/w=0.5 leading to the tearing of the plate resulting in permanent failure.

K. Rectangular plate:

With the increase in the d/w ratio, the buckling factor remained constant from d/w=0.1 to 0.3 and then slightly varied in the plate made of Al-6061 for all the positions of the holes. With the increase in the d/w ratio, the buckling factor remained constant from d/w=0.1 to 0.4 and then converged to a point at d/w=0.5 in the plate made of Carbon/Epoxy for the position of holes nearer to the shorter and longest edges.

The effect of the d/w ratio in the buckling phenomenon in a Carbon/Epoxy plate with a hole nearer to the longest edge is negligible. The curve is observed to be a straight line. The maximum buckling factor occurs in a Carbon/Epoxy plate with d/w=0.2 and d/w=0.5 for the hole located at the centre of the plate.

IV. CONCLUSION

Structural analysis has been performed on the square and rectangular plates with circular cutouts a different locations subject to various boundary conditions. Plate materials are Al-6061 and Carbon/Epoxy. The effect of d/w ratio, hole location and support conditions on the response of the plate are studied in detail. With the increase in d/w ratio,

- the stress concentration factor and the buckling load factor decreases
- the frequency ratio and deflection ratio are increasing
- At lower d/w ratio (<0.1), all the frequency ratios are independent of boundary condition and hole location
- all the parameters are observed to be approaching higher values in the plate with *hole nearer to the shortest* edge subject to boundary condition with S-F-S-F. Even if a crack initiate, it has to travel larger length behind the hole which needs larger forces. Hence the designs with holes nearer to the shorter edges are recommended.
- If the hole is nearer to the longer edge and if a crack initiates, the crack has to travel shorter distance equal to the width of the plate. This results in the tearing of the plate thereby decreasing the actual service life.

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