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Stress and Displacement Analysis of Rectangular Stainless Steel Plate with Elliptical Cut-out of Different Orientation

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Abstract— The study of stress and displacement analysis of rectangular stainless steel plate of size 300mm X 100mm X 10mm with elliptical cutout of size 40 mm major axis and 20mm minor axis at the centre of the plate with different orientation is carried out by using finite element formulation. The 3D plate is designed in CATIA V5 tool and analysis is carried out in ANSYS package. The plate with cutouts is often used in modern engineering like aerospace, mechanical and civil engineering applications. It is mainly focused on the study of stress concentration induced at the abrupt change of the cross section of the plate due to cutout. The changes of the stresses and displacements have been calculated for the different orientation of the cutout and are tabulated and discussed in this paper.

Keywords— Stress concentration, CATIA V5 and ANSYS.

INTRODUCTION

The plate with cutouts/openings is made into structure in order to full fill the requirement of service requirements in many engineering applications. Mainly in aerospace and marine applications high strength and low weight are the important parameters. So the basic structural members like plates with openings or cutouts are provided. But this cutouts leads to discontinuity in the cross section of the structural member and penetrates the strength. The flow of stress is disturbed with the discontinuity of the area and the concentration of the stress will be more at this critical area. This stress concentration increases the stress levels and it is high concern in the design of the total structure.

Stress Concentration:

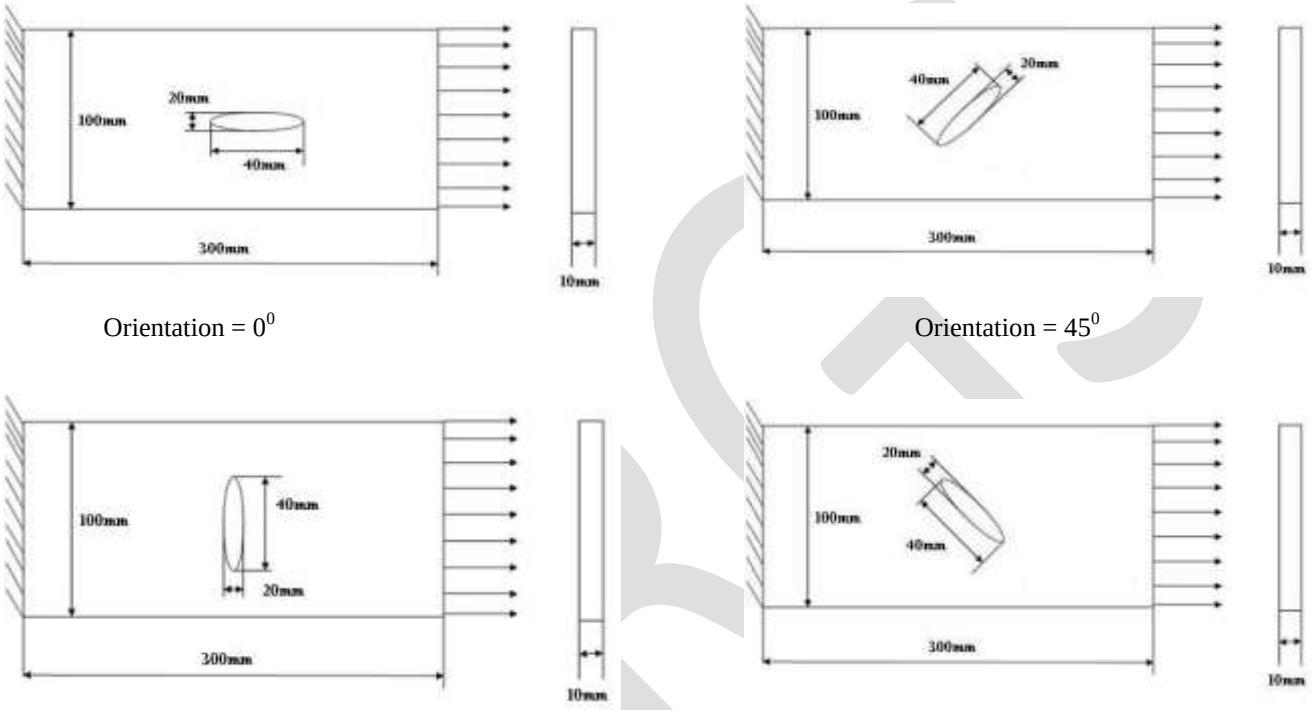
Stress concentration is localized high stress due to the abrupt change or irregularities present in the cross section of the structural member. The localized stresses are found out by a factor nothing but the stress concentration factor. It is denoted by K_t. The stress concentration factor Kt is defined as the ratio of maximum stress at the cutout edge and nominal edge.

$$K_t = \frac{Maximum\ stress}{Nominal\ stress} = \frac{\sigma_{max}}{\sigma_{nom}}$$

DESCRIPTION OF THE PROBLEM

A rectangular plate of dimensions 300mmX100mmX10mm with an elliptical hole of size 40mm in major diameter and 10mm in minor diameter oriented at 0, 45, 90 and 135 degrees is located at the centre of the plate. This plate is subjected with a tensile load along the length of the plate at one end and constrained at the other end. The stresses developed at the vicinity of the elliptical hole. The solid body is designed by using CATIA V5 and the analysis is carried out by ANSYS software. The actual analysis is done is shown in the figure 1. The plate with cutout is subjected with the same load but stress developed and displacements for the each plate varies as the orientation of the elliptical cutout. As per the orientation of the elliptical cutout, the stress flows in the plate are different so that we can find out the critical orientation in which the stress levels will be more. The plate material considered in this problem is stainless steel. The dimensions and mechanical properties for the stainless steel are tabulated below.

Plate Material	Stainless Steel
Plate Dimensions	Length = 300 mm; Width =100 mm; Thickness=10 mm
Elliptical Cutout Dimensions	Major diameter = 40 mm; Minor Diameter = 20 mm
Young's Modulus	1.93e+11 Pa
Poisson's Ratio	0.31
Density	7750 kg/m^3
Tensile Yield Strength	2.07e+8 Pa
Tensile Ultimate Strength	5.86e+8 Pa



Orientation = 0^0 Orientation = 45^0

Orientation = 90^0 Orientation = 135^0

Figure1. The rectangular plate with elliptical cutouts with different orientations

MODELLING:

Introduction to CATIA V5

As per the dimensions taken, the plate is designed in 3D model using CATIA V5 software. CATIA [5- 7] (Computer Aided Three Dimensional Interactive Application) in 1980's in later implementation this company improved its feasibility and released the latest versions one by one i.e., V5R5, V5R7, V5R8…….V5R19, V5R21.CATIA is much faster and more accurate. Once a design is completed. 2D and 3D views are readily obtainable. The ability to changes in late design process is possible. It provides a very accurate representation of model specifying all other dimensions hidden geometry etc. It provides clear 3D models, which are easy to visualize and understand. CATIA provides easy assembly of the individual parts or models created it also decreases the time required for the assembly to a large extent. The designed plate is saved in IGS format so that the designed model can be easily opened in the ANSYS software.

The Sketcher workbench is a set of tools that helps to create and constrain 2D geometries. Features (pads, pockets, shafts, etc...) may then be created solids or modifications to solids using these 2D profiles. The part modeled in this paper is shown in the figure 2. The rectangular plate with elliptical cutout at the centre is created using simple profiles, lines and arcs. The geometries are constrained to conform to certain dimensions like lengths and diameters.

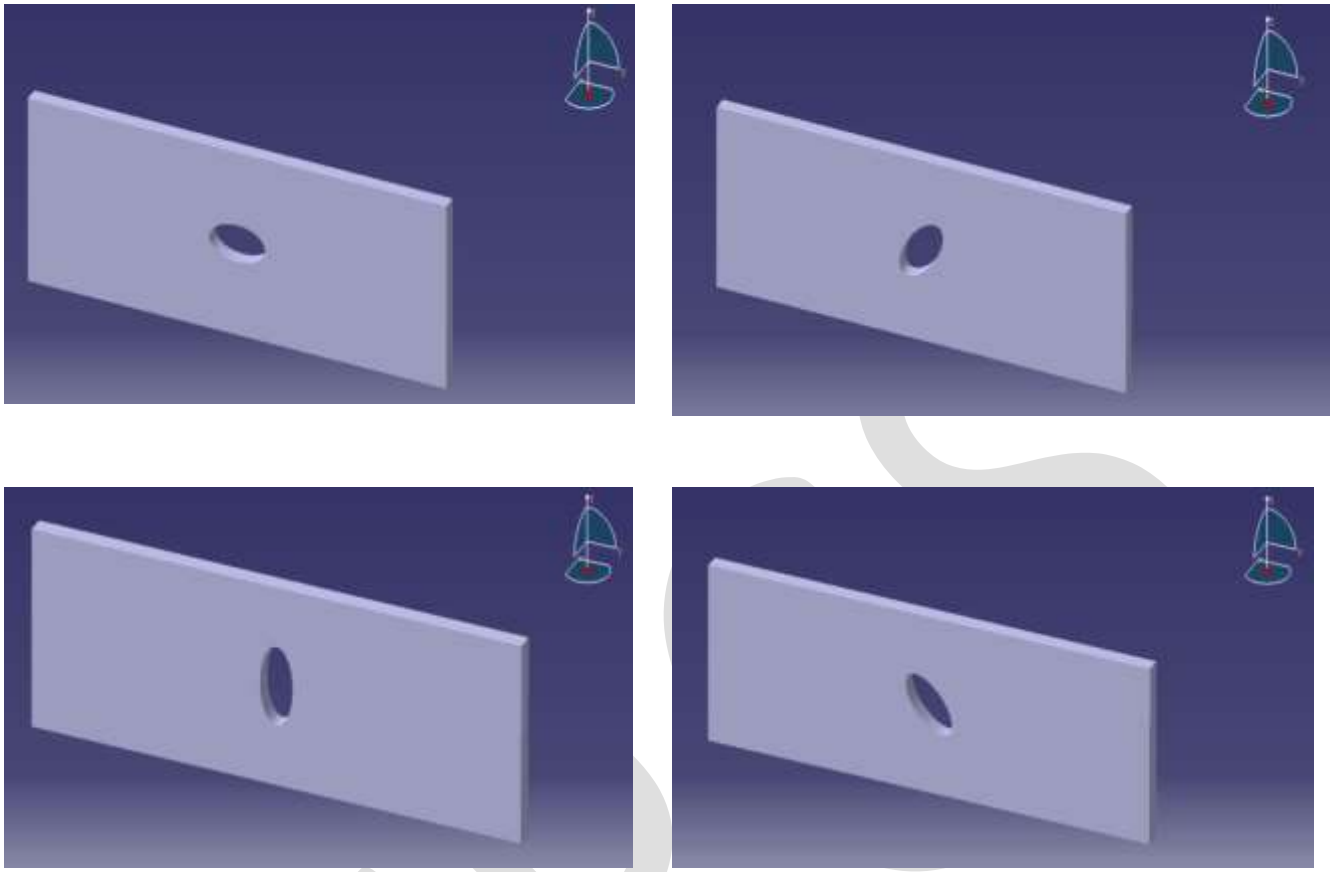


Figure2. Rectangular plate with elliptical cutout solid model design in CATIA V5

ANALYSIS:

Introduction to ANSYS

ANSYS is computer simulation software, mostly used for doing the analysis in the field of structural Mechanics, Multi physics, Fluid Dynamics, Explicit Dynamics, Electromagnetic, Hydrodynamics.

The following are the analysis steps involved in the ANSYS. They may be

Preprocessing

- Define element type, real constants, and material properties
- Define geometry Processors

Solution

- Define type of analysis
- Set boundary conditions
- Apply loads
- Initiate finite element solution

Post processing

• Review results using graphical displays and tabular listings

• Verify against analytical solutions

The modeled plate is opened in the ANSYS tool and static analysis is carried out by applying a force 3KN at the one of the plate. The other end is fully constrained by keeping all degrees of freedom is zero. The material properties like Young's modulus (E) for the plate is 1.93e+11 Pa, Poisson's ratio =0.31 and Density 7750 kg/m^3 are given. The meshing operation is done and applied loads and displacements according to the requirements.

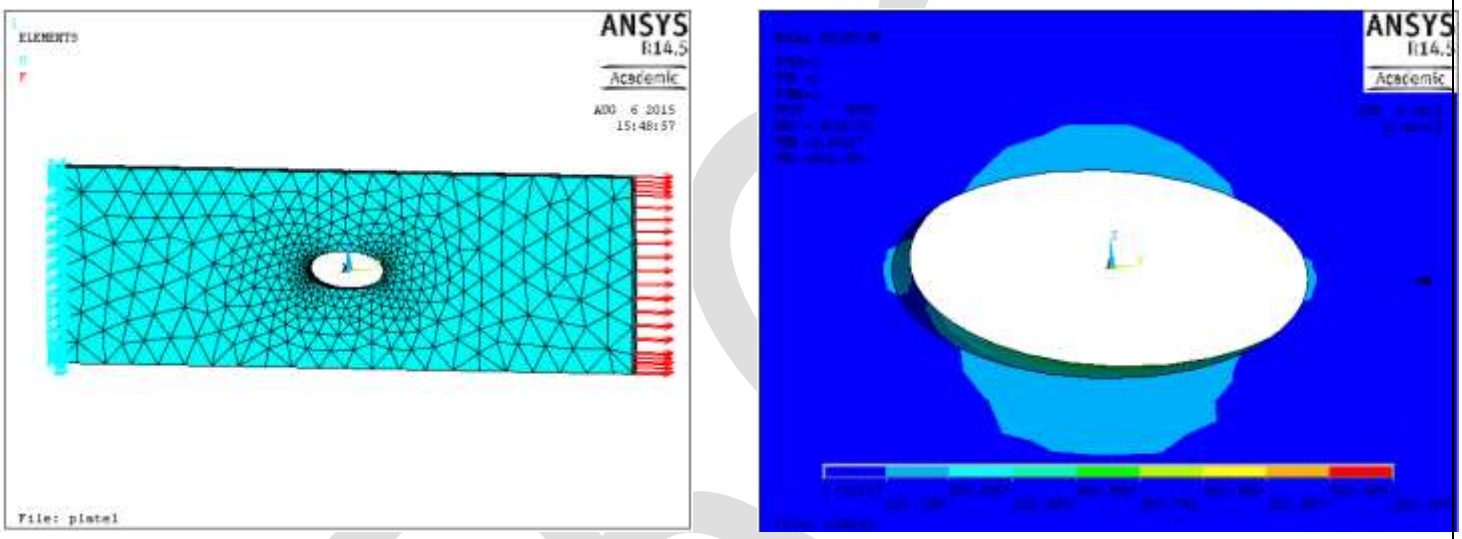


Figure 3: Plate with elliptical cutout with an orientation of 0 degrees and its stress distributions

The analysis of the rectangular plate with elliptical cutout with 0 degree orientation is done. The maximum displacement 0.431E-5 m and maximum stress of 958.51 Pa is obtained.

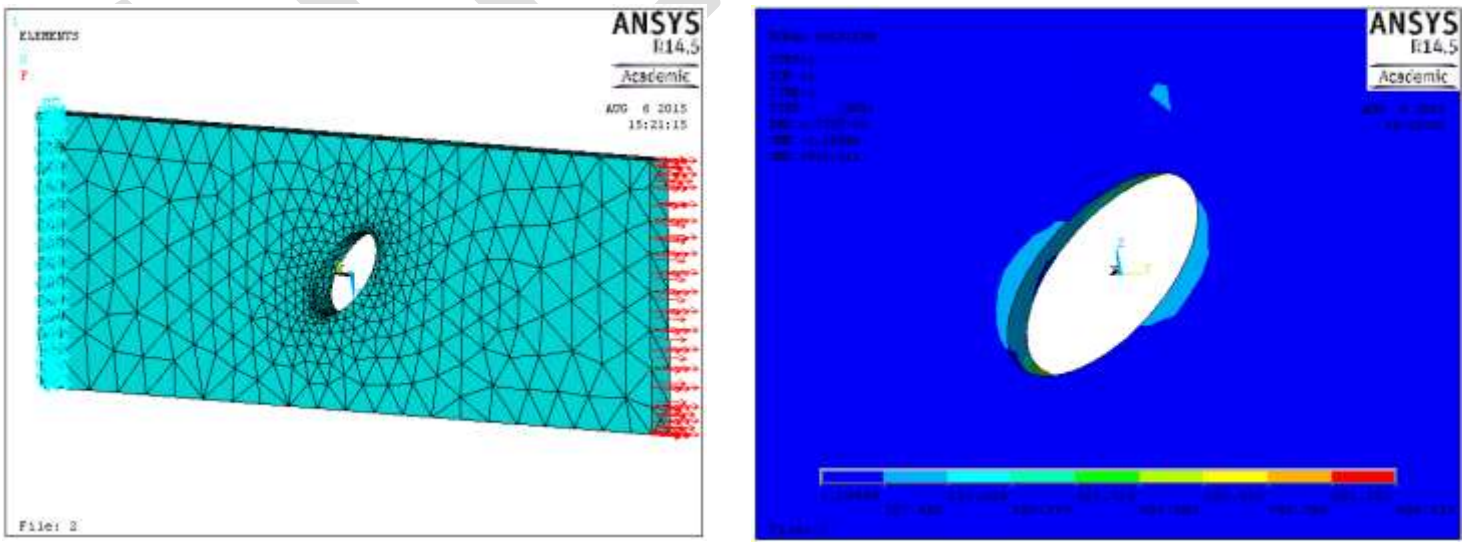


Figure 4: Plate with elliptical cutout with an orientation of 45 degrees and its stress distributions

The analysis of the rectangular plate with elliptical cutout with 45 degree orientation is done. The maximum displacement 0.776E-5 m and maximum stress of 902.3 Pa is obtained.

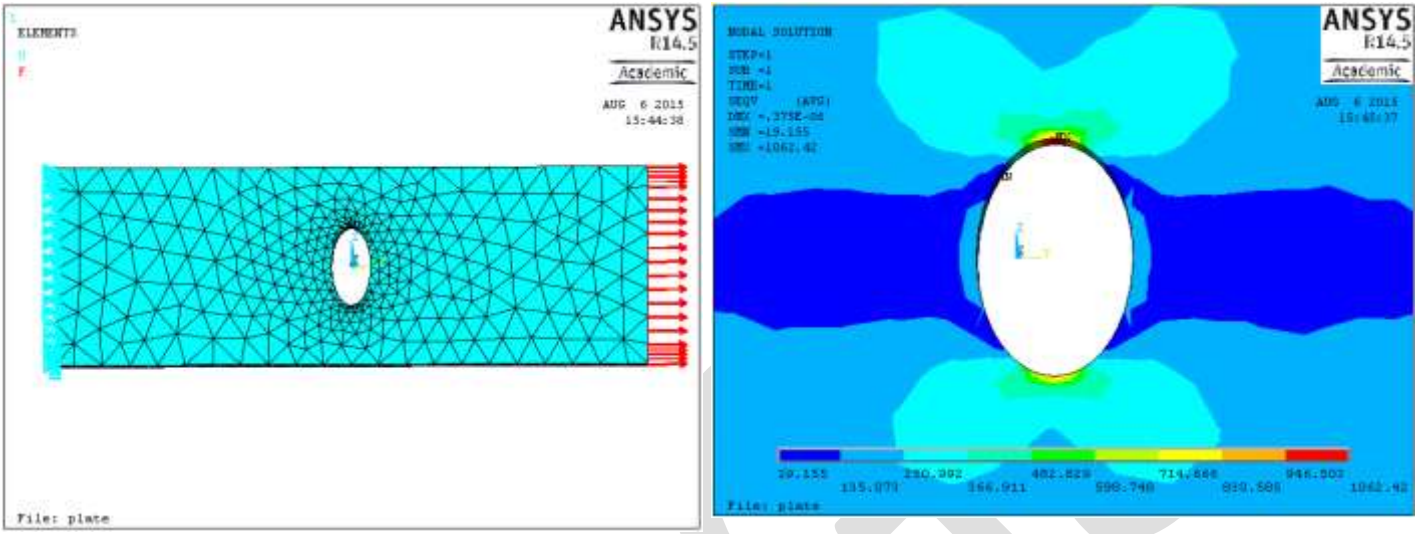


Figure 5: Plate with elliptical cutout with an orientation of 90 degrees and its stress distributions

The analysis of the rectangular plate with elliptical cutout with 90 degree orientation is done. The maximum displacement 0.375E-6 m and maximum stress of 1062.42 Pa is obtained.

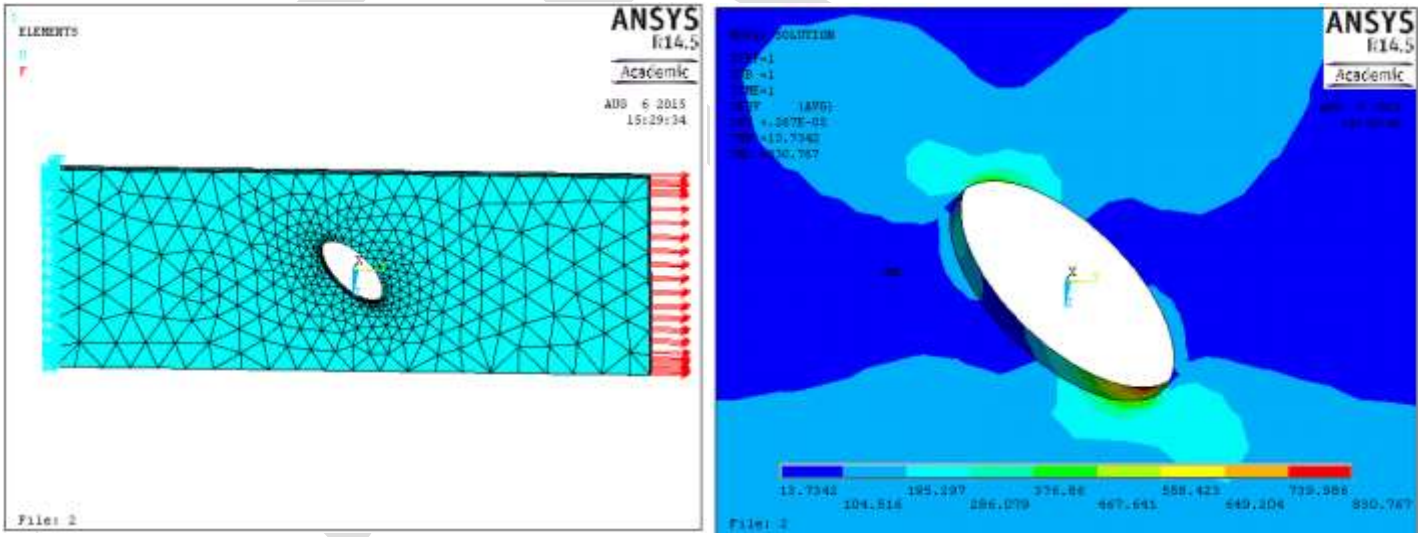


Figure 6: Plate with elliptical cutout with an orientation of 135 degrees and its stress distributions

The analysis of the rectangular plate with elliptical cutout with 135 degree orientation is done. The maximum displacement 0.267E-5 m and maximum stress of 830.7 Pa is obtained.

RESULTS

After analysis is done the values of the maximum stress values and maximum displacements are observed and tabulated below.

Table 1: Von-Mises stress and displacements in the rectangular plate with elliptical cutout

S.NO	Cutout Orientation	Stress Values (Pa)	Displacements (m)
1	0^0	958.51	0.431E-5
2	45^0	902.3	0.776E-5
3	90^0	1062.42	0.375E-6
4	135^0	830.7	0.267E-5

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CONCLUSION

After successful completion of the analysis the following conclusions can be made.

- ANSYS provides a very suitable way of determining stress induced in any body.
- The maximum stress concentration observed at the corners of the elliptical hole.
- As expected, the maximum stresses concentrated in the case of elliptical hole at 90^0 orientations.
- The maximum displacements observed in the plate with elliptical cutout at 45^0 orientations.
- ANSYS gives a more intuitive feel to the designer by displaying stress contours throughout the plate.

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