A PROJECT REPORT ON

FINITE ELEMENTS METHOD

MASTER OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

(COMPUTATIONAL MECHANICS)

SUBMITTED BY

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(2024MEM1003)

UNDER GUIDANCE OF

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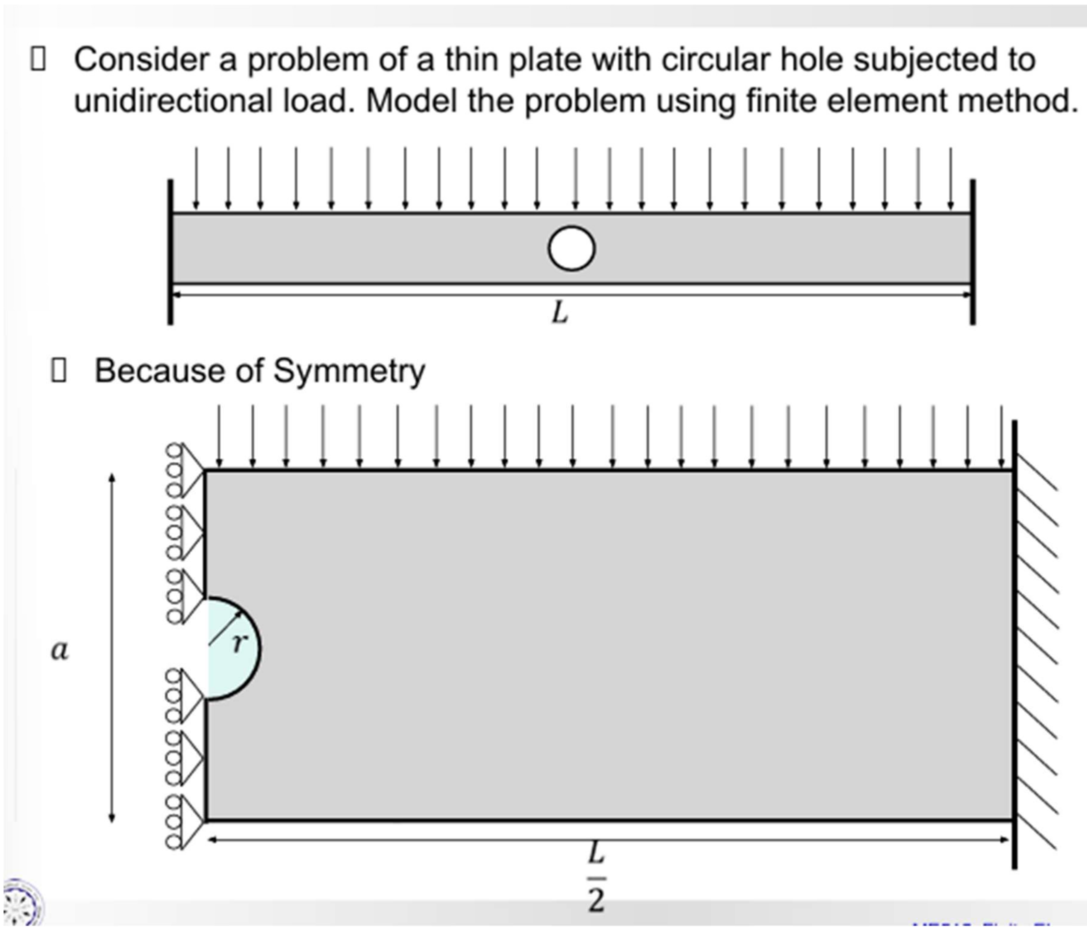
Project Title - Finite Element Analysis of a Plate with a Circular Hole

Ques- A



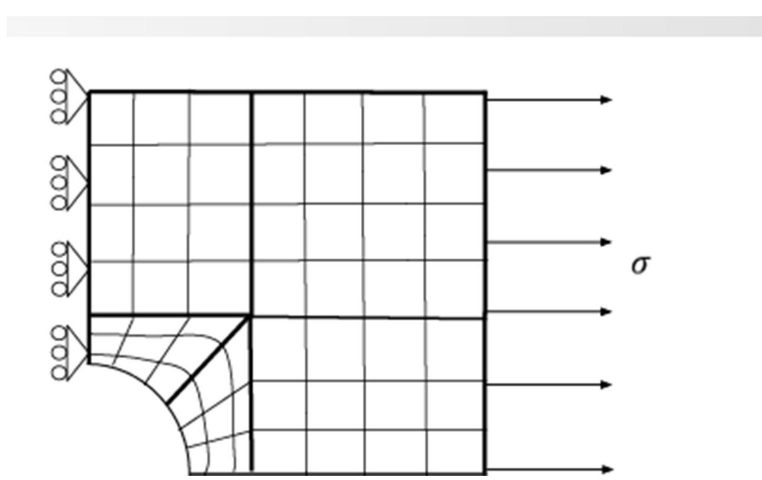
1. **Introduction** - This report presents a detailed analysis of the Finite Element Analysis (FEA) of a plate with a circular hole using MATLAB. The objective is to create a structured mesh for the plate, apply boundary conditions and external loads, and calculate the resulting displacements, strains, and stresses using the FEA approach.

2. Problem Description

- The problem involves a square plate with a circular hole at the centre.
- The plate is subjected to a tensile load on the top edge while other boundaries have specific support conditions.
- The material properties are defined, and a structured mesh is generated for accurate analysis.

3. Methodology/problem formulation:

- **DISCRETIZATION.**
- **WEAK FORMULATION OR VARIATIONAL APPROACH.**
- **CO-ORDINATE TRANSFORMATION.**
- **NUMERICAL INTEGRATION.**
- **ASSEMBLY OF ELEMENTAL EQUATION AND BOUNDARY CONDITION IMPOSITION.**
- **SOLVING [K]{u} = [F]**



4. Analysis Steps-

- 4-Noded quadrilateral element has been taken to discretize all the zones.
- Find out coordinates of all the node points and numbering has been done for all the elements as well as for the node points.
- Element has been defined in the local coordinate system.
- Find out the local stiffness matrix and strain matrix for all the elements.
- Connectivity matrix has been formed to connect the local stiffness matrix to Global stiffness matrix.
- Define the material properties i.e. value of elasticity E **= 200** $GPa, Poisson\ ratio\ \nu$ **= 0.3**
- Numerical integration has been done for all the 2D Gauss points.
- Define the traction boundary condition.
- The above procedure has been repeated for all elements using 'for' loop and global traction stiffness matrix and global traction force vector has been calculated.
- Now displacement field for all the nodes has been calculated using traction force and displacement vector.
- From the displacement field we have calculated the strain for individual elements using shape function matrix.
- Finally, we have found out the stress field for individual elements.
- Normalization of stress and stress values and plotted.

5. **CONVERGENCE ANALYSIS -** Improves accuracy by using more, smaller elements. The general rule: increase the number of elements in regions where the field functions (like displacement or stress) change abruptly. In elasticity problems, abrupt changes correspond to regions with high gradients of strain and stress. Highly refined meshes are needed in regions with large stress and strain gradients. Coarser meshes can be used in regions away from these high-gradient zones. In this problem, abrupt stress/strain changes are expected near the

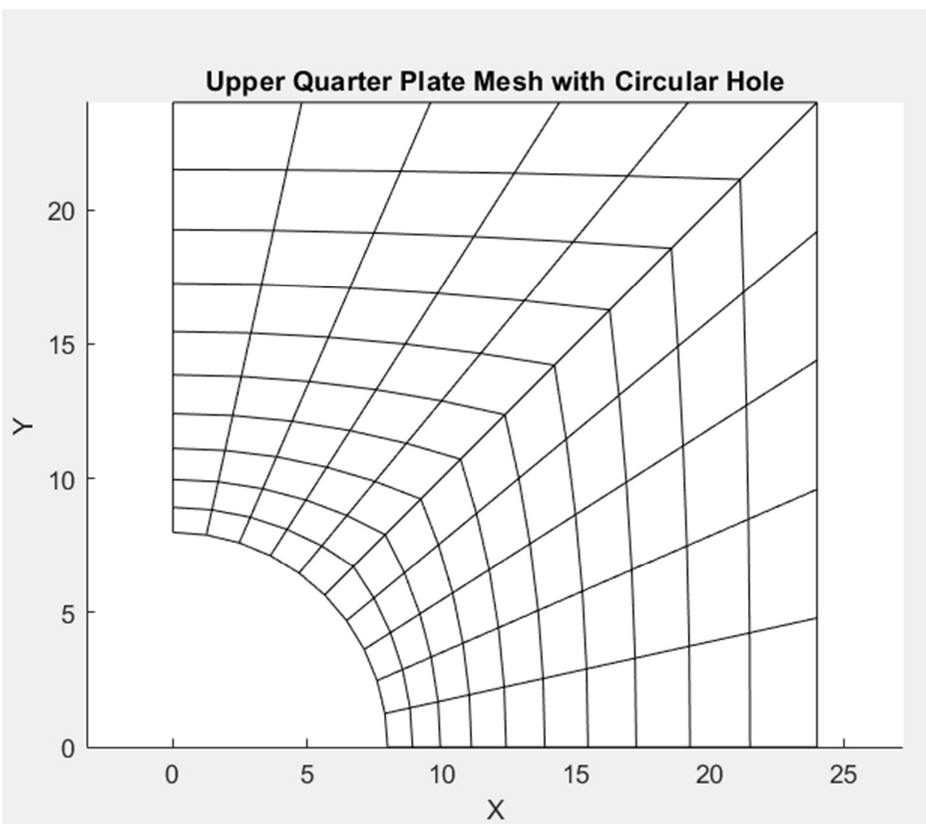
circular hole. To improve accuracy, the mesh has been refined across the entire quadrilateral region.

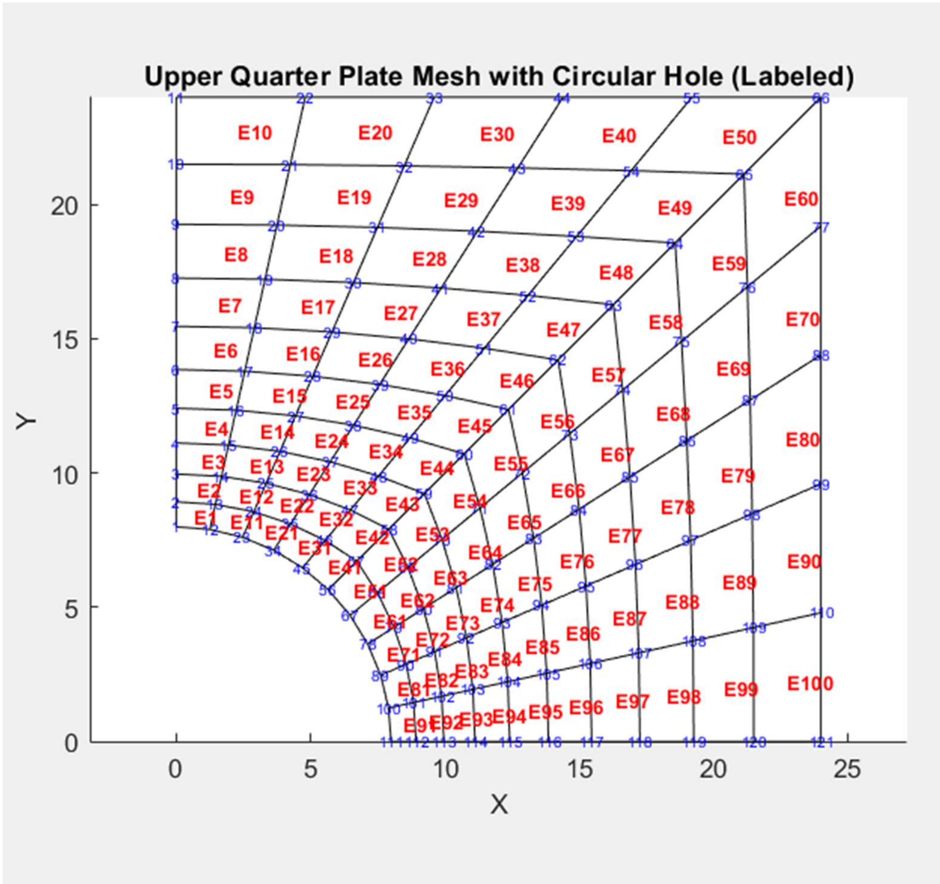
- **Boundary Conditions:**
  Left Boundary: Roller support (Ux = 0, Uy is free).
  Right Boundary: Fixed support (Ux = 0, Uy = 0).
  Top Boundary: Uniform distributed load of 50 N.

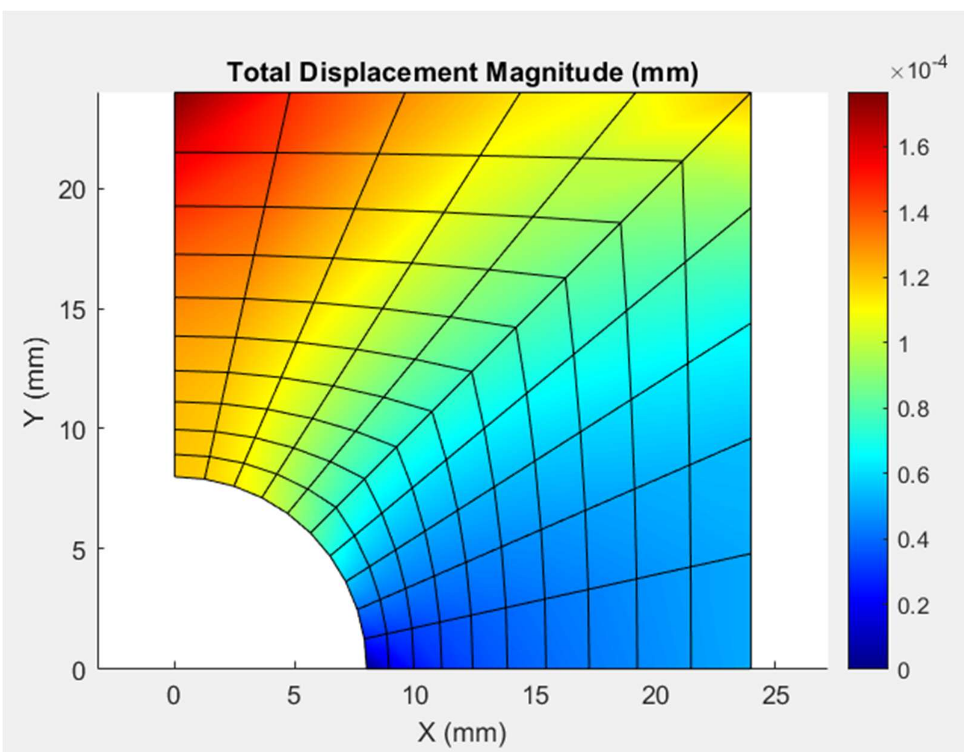
Ke Matrix –

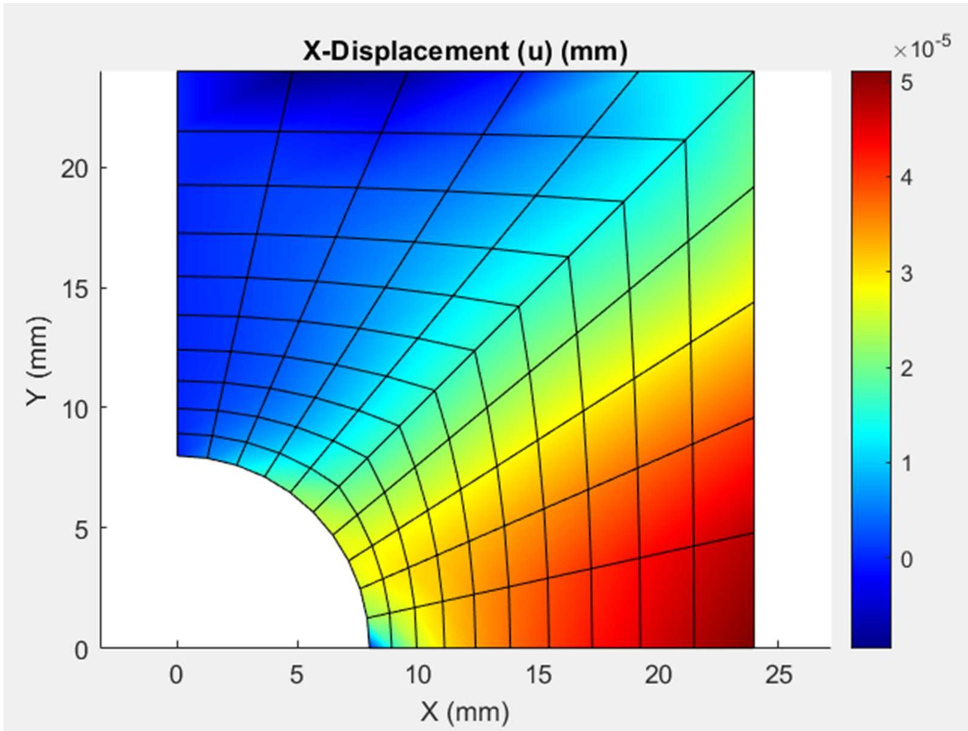
98901.1	35714.29	-60439.6	-2747.25	-49450.5	-35714.3	10989.01	2747.253
35714.29	98901.1	2747.253	10989.01	-35714.3	-49450.5	-2747.25	-60439.6
-60439.6	2747.253	98901.1	-35714.3	10989.01	-2747.25	-49450.5	35714.29
-2747.25	10989.01	-35714.3	98901.1	2747.253	-60439.6	35714.29	-49450.5
-49450.5	-35714.3	10989.01	2747.253	98901.1	35714.29	-60439.6	-2747.25
-35714.3	-49450.5	-2747.25	-60439.6	35714.29	98901.1	2747.253	10989.01
10989.01	-2747.25	-49450.5	35714.29	-60439.6	2747.253	98901.1	-35714.3
2747.253	-60439.6	35714.29	-49450.5	-2747.25	10989.01	-35714.3	98901.1

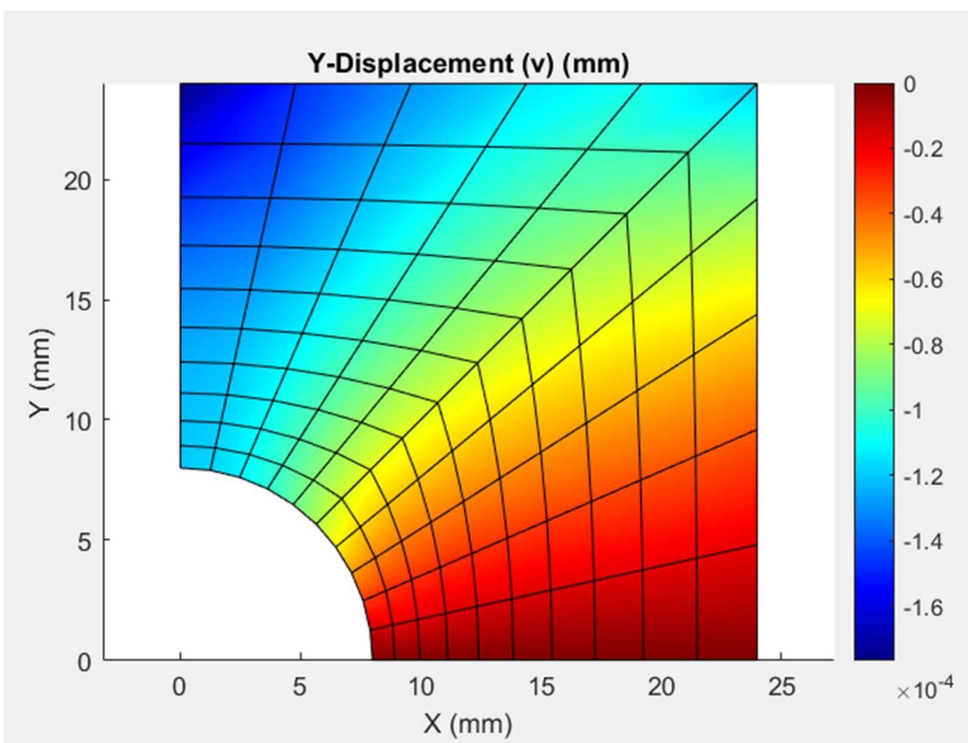
7.0 Results/Graph

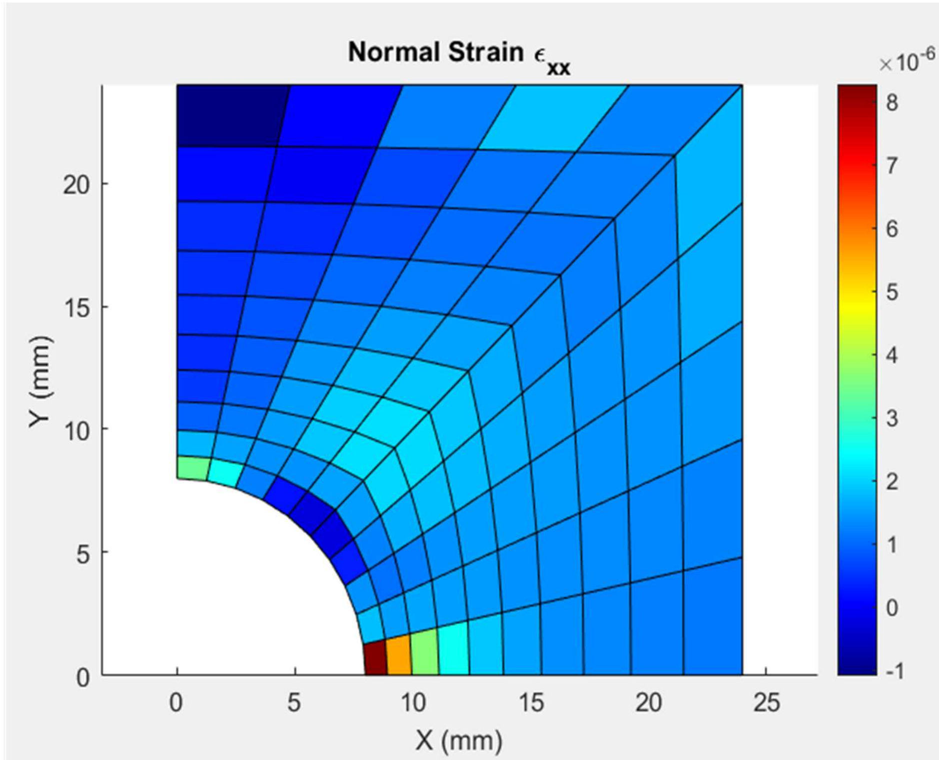



Upper Quarter Plate Mesh with Circular Hole (Labeled)
Y
X
0
5
10
15
20
25

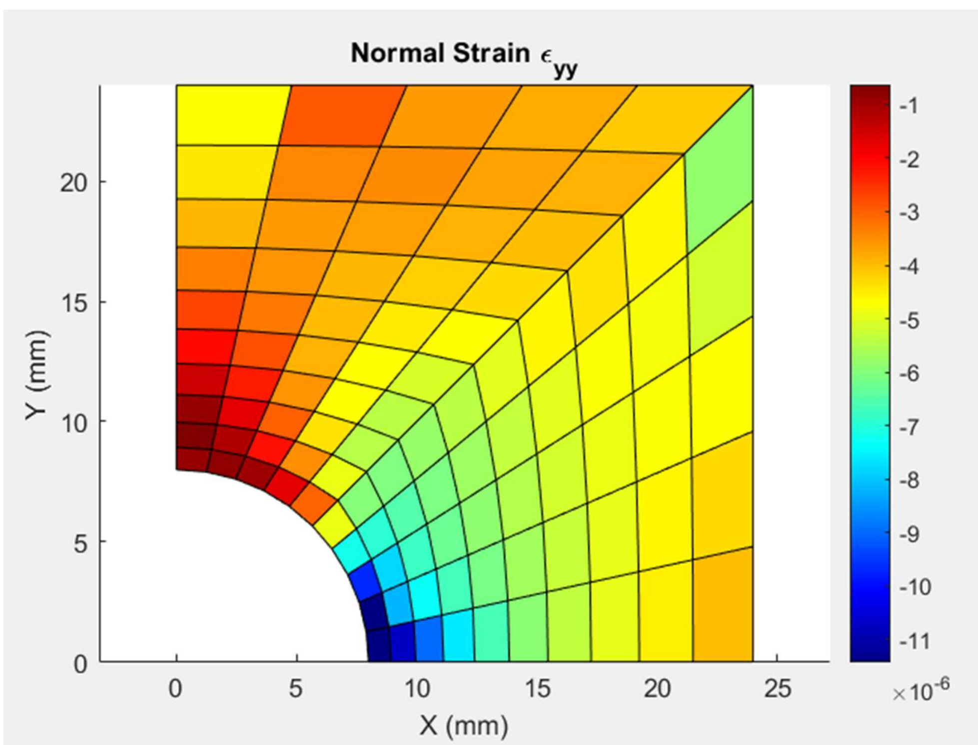

Total Displacement Magnitude (mm)
Y (mm)
X (mm)
×10^-4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6


X-Displacement (u) (mm)
×10^-5
5
4
3
2
1
0
Y (mm)
20
15
10
5
0
0
5
10
15
20
25
X (mm)

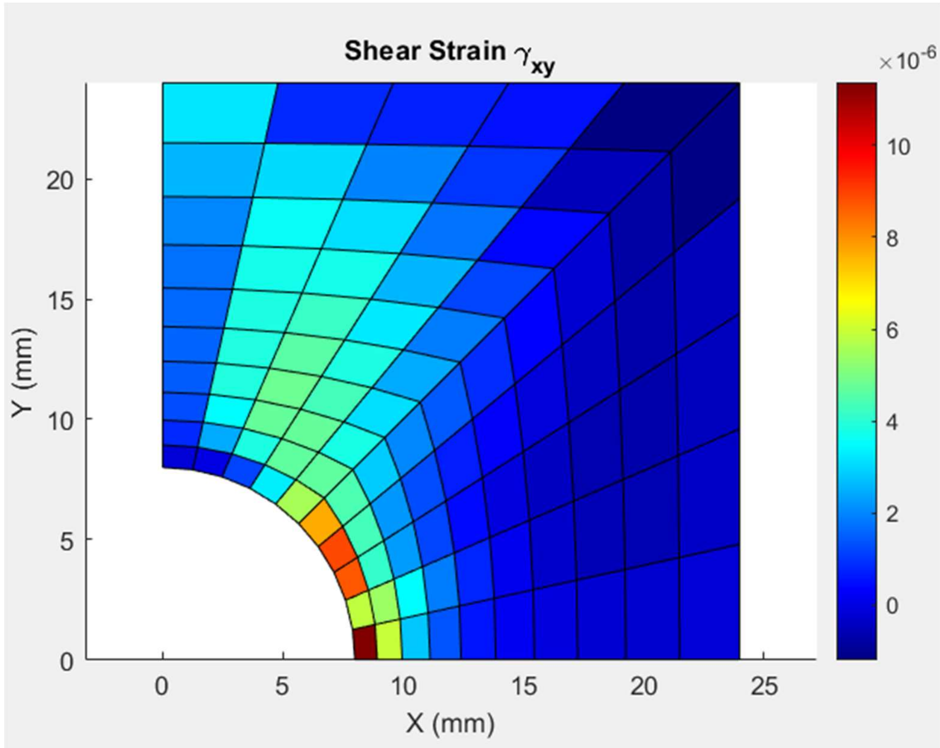

Y-Displacement (v) (mm)
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
×10^-4
Y (mm)
20
15
10
5
0
0
5
10
15
20
25
X (mm)

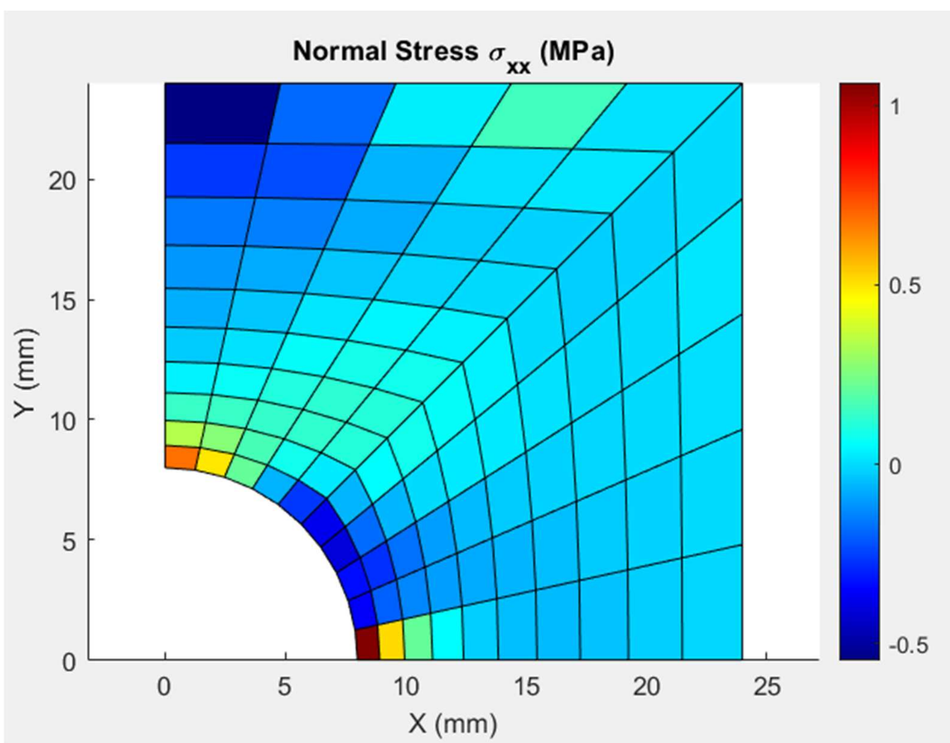


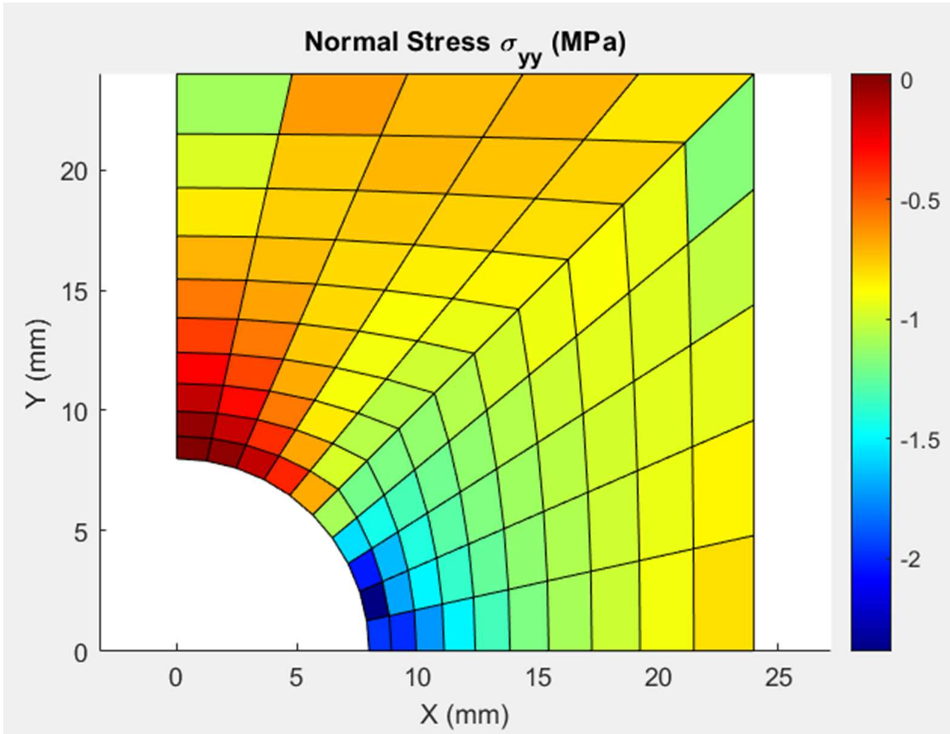
Normal Strain ϵ_{xx}
$\times 10^{-6}$
8
7
6
5
4
3
2
1
0
-1
Y (mm)
20
15
10
5
0
X (mm)
0
5
10
15
20
25

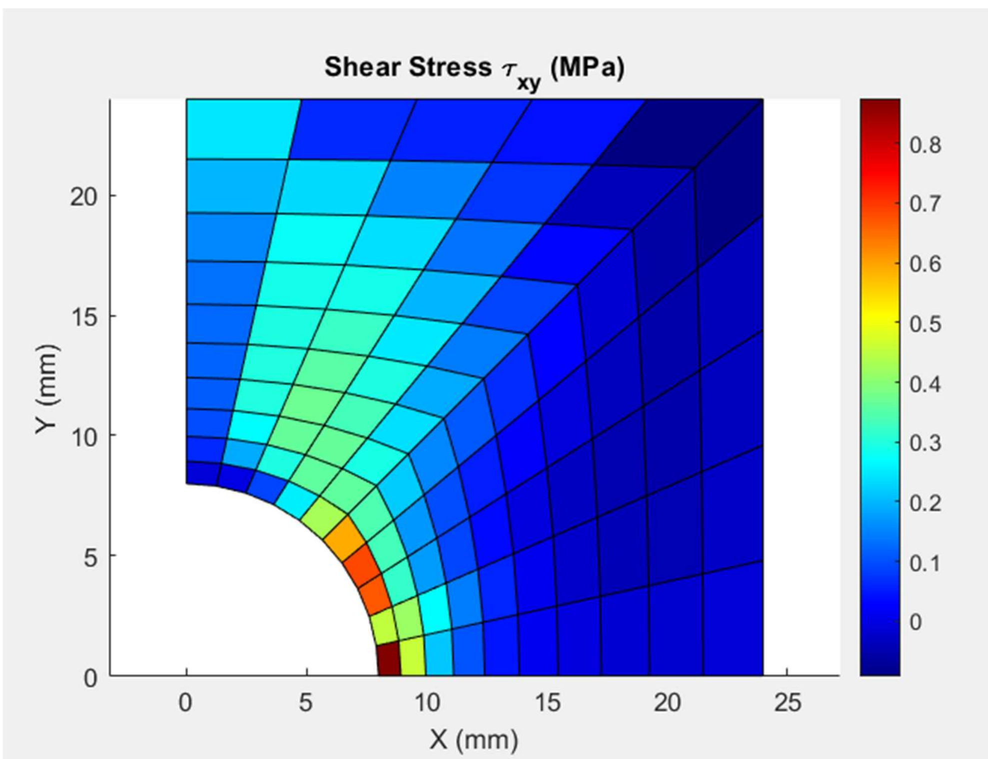


Normal Strain ϵ_{yy}
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
$\times 10^{-6}$
Y (mm)
20
15
10
5
0
X (mm)
0
5
10
15
20
25


Shear Strain γ_{xy}
$\times 10^{-6}$
Y (mm)
X (mm)
0
5
10
15
20
25
0
2
4
6
8
10


Normal Stress σ_{xx} (MPa)
Y (mm)
X (mm)
0
5
10
15
20
25
-0.5
0
0.5
1


Normal Stress σ_{yy} (MPa)
Y (mm)
X (mm)
0
5
10
15
20
25
0
-0.5
-1
-1.5
-2


Shear Stress τ_{xy} (MPa)
Y (mm)
X (mm)
0
5
10
15
20
25
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

7.1 Results and Visualization

Deformed Mesh

- The deformed shape of the plate is plotted to visualize displacement.
- A scale factor is used to exaggerate displacements for better visualization.

7. Stress Distribution

- Von Mises stress distribution is calculated and displayed using a colour map.
- Stress concentrations are clearly visible around the hole.

8. Conclusion

This FEA model successfully simulates the stress distribution in a plate with a circular hole under tensile loading. The model can be further refined for higher accuracy by increasing the mesh density or using higher-order elements.