Chapter 2:

Thermal Analysis of 15MeV Electron Beam Dump

1.INTRODUCTION

The objective of this project is to perform a thermal analysis of a cylindrical structure with an internal cone and external fins using Ansys software. The analysis investigates the thermal performance of the cylinder when constructed with copper material.

2. Geometry and Model Description

The geometry of the model consists of:

2.1 Outer Cylinder

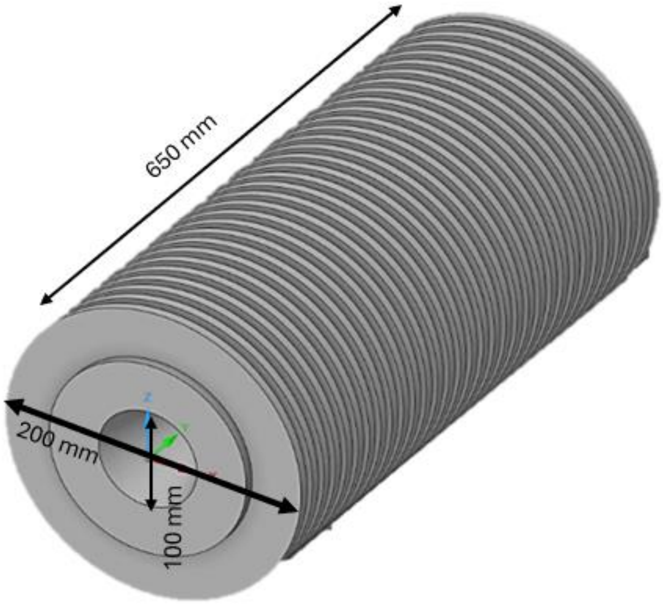
- A cylinder with a height of 650 mm and a diameter of 200 mm.

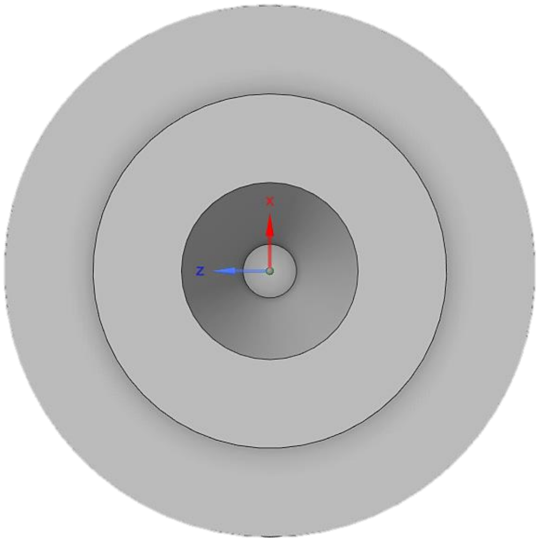
2.2 Internal Cone

- An internal cone mounted inside the cylinder, with the following dimensions:
    - Big end diameter: 100 mm
    - Small end diameter: 30 mm

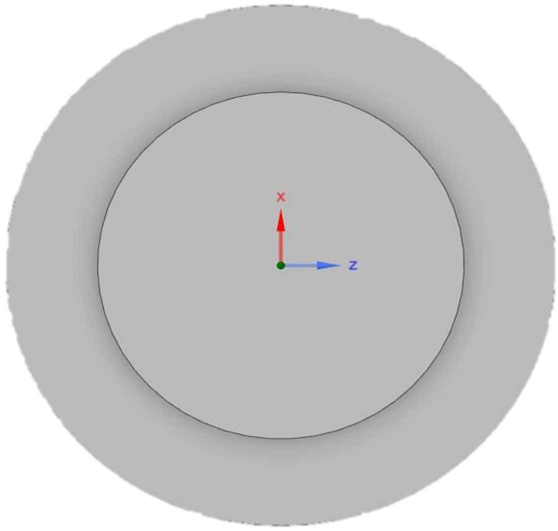
2.3 External Fins

- External fins mounted on the cylinder:
    - Total number of fins: 32
    - Height of fins: 50 mm
    - Gap between fins: 10 mm
    - Width of fins: 10 mm

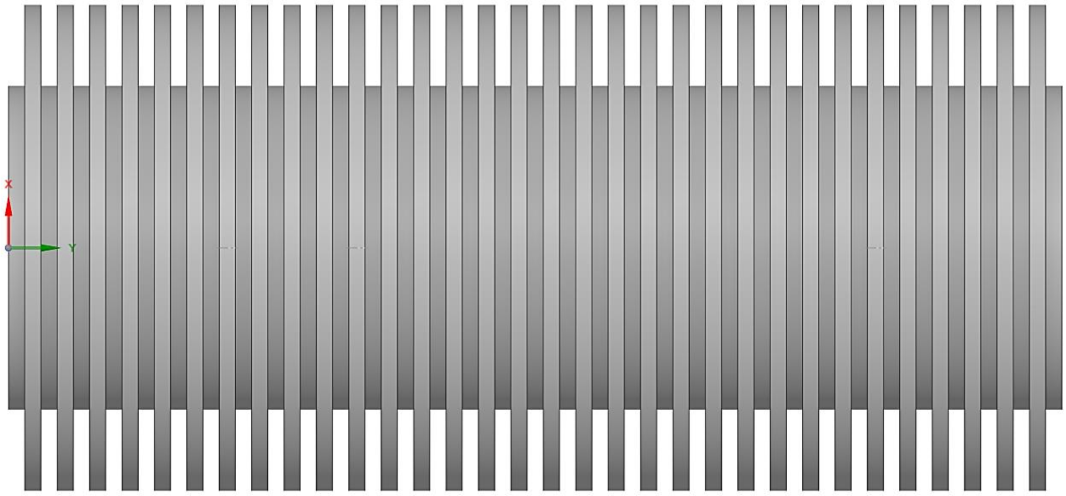




Top View of the Assembly



Bottom View of the Assembly



3D Model of the Beam Dump

Material Properties

Copper material is considered for the analysis:

1. Copper
   - Thermal conductivity: 398 W/m K
   - Density: 8960 kg/m³
   - Specific heat capacity: 385 J/kg K

Heat Transfer Coefficient

- Heat Transfer Coefficient has been calculated for different air velocities.

3. Modelling in ANSYS

3.1 Geometry Creation

The geometry was created in the FUSION 360 software. The following steps were taken:

1. **Cylinder Creation:** A cylindrical body with a height of 650 mm and a diameter of 200 mm was created.

2. **Cone Creation:** A conical body with a base diameter of 100 mm, a top diameter of 30 mm created inside the cylinder from its one end.
3. **Fin Creation:** 32 fins were created around the external surface of the cylinder. Each fin had a height of 50 mm, a width of 10 mm, and a 10 mm gap between adjacent fins.

3.2 Meshing

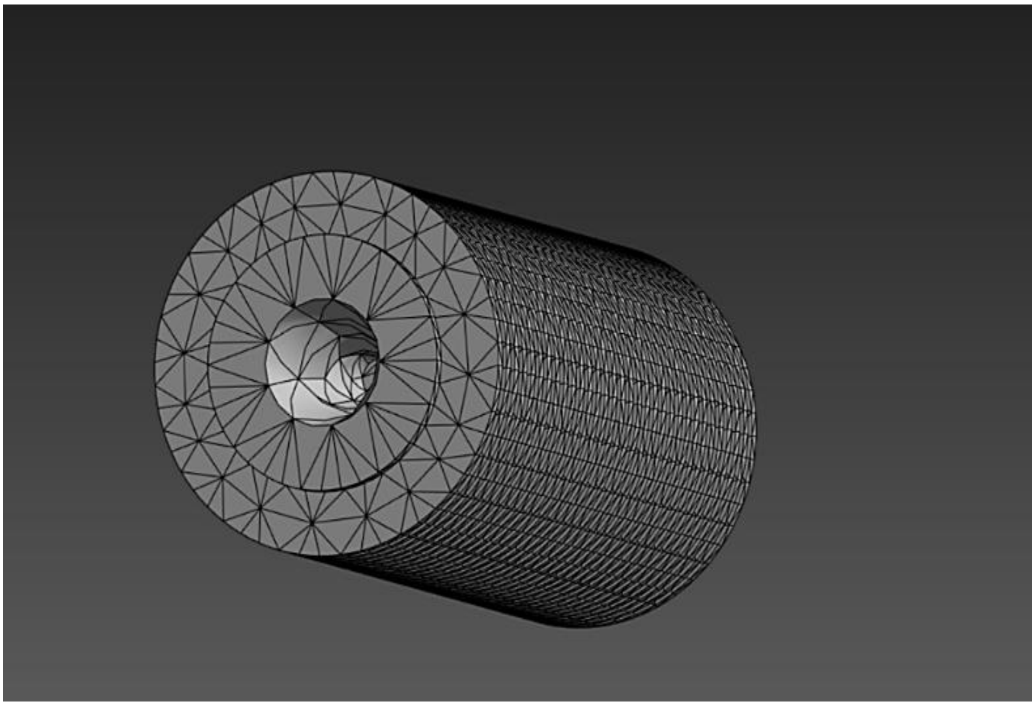
Meshing is a critical step to ensure accurate results. For this analysis, a refined mesh was used to capture the detailed geometry of the fins and the internal cone. The following meshing techniques were employed:

- The geometry was meshed to ensure accurate thermal analysis. The mesh was refined in areas around the fins and the internal cone to capture detailed thermal gradients.
- **Refinement**: A finer mesh was applied to regions with high gradients, such as the fins and the interface between the cone and the cylinder.
- **Element Type**: Tetrahedral elements were used for the complex geometry.

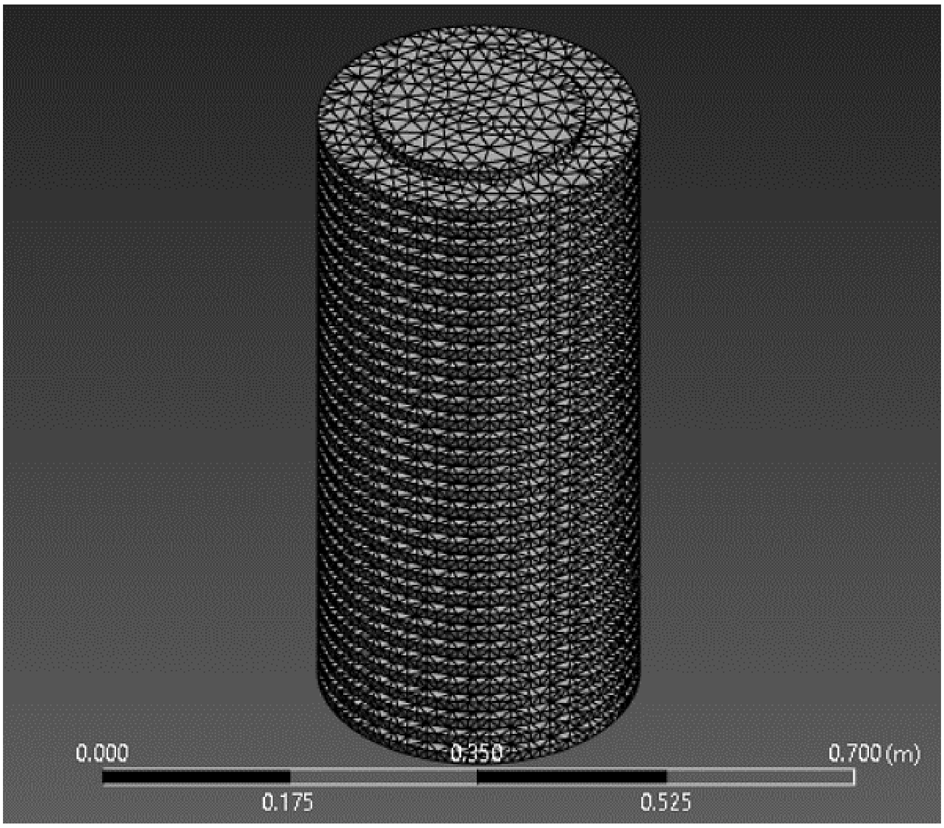
Mesh Size = 0.01m

Number of Nodes = 118213

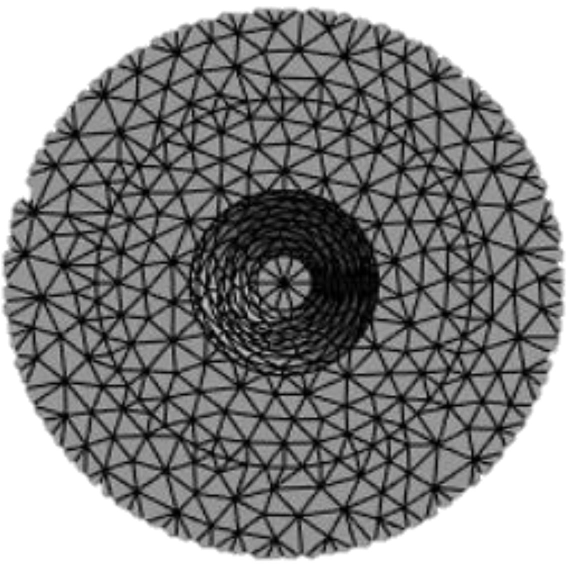
Number of Elements = 60999

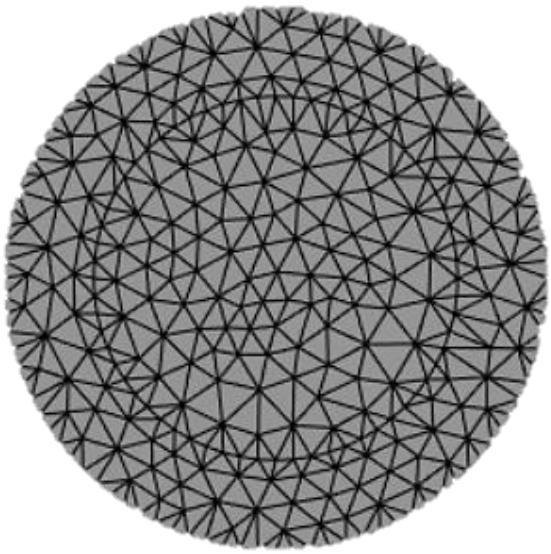


Meshed Structure 10 mm



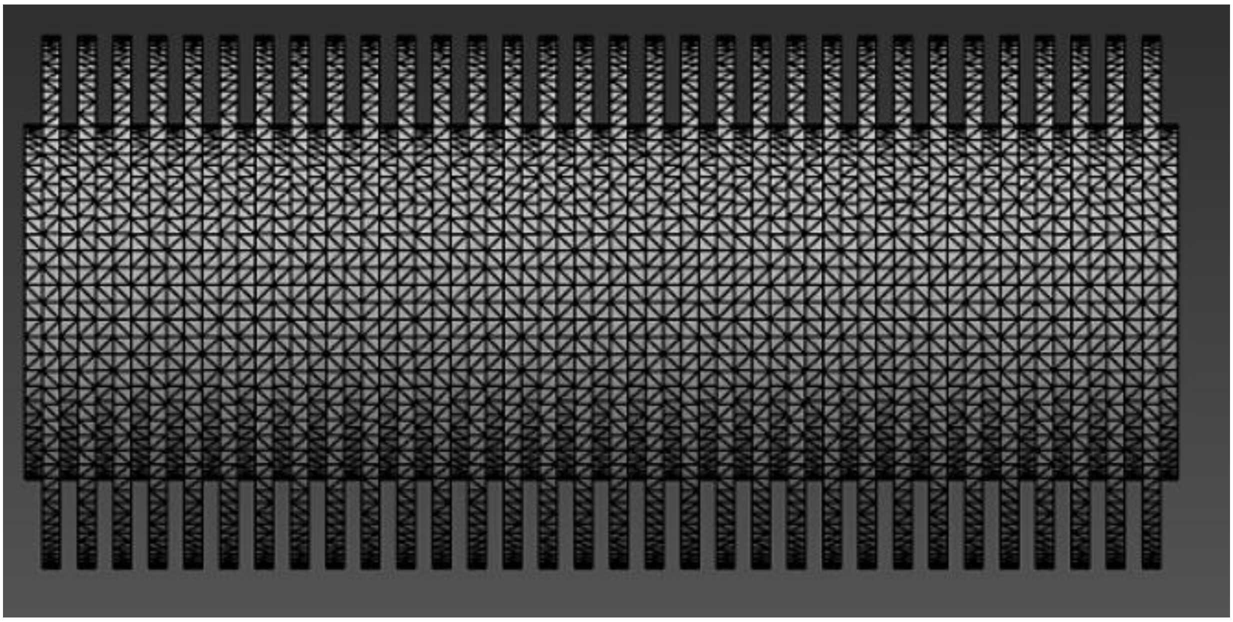
Side View





Top View of the Assembly

Bottom View of the Assembly



Meshed Assembly

4. Boundary Conditions

- Heat transfer coefficient is calculated for different air velocities.
- Ambient temperature: Assumed constants for all cases
- Convection boundary condition applied to the outer surfaces of the cylinder and fins

5. Analysis

The thermal analysis was conducted for three configurations of the internal cone:

- Cone with big end diameter of 100 mm

The given configuration was analyzed for copper.

5.1 Table for value of 'h' for different values of air velocity

v(m/s)	Re	Nu	h (W/((m^2) K)
6	12498.75	40.35	29.08
8	16665	50.79	36.60
10	20831.25	60.72	43.76
12	24997.5	70.25	50.63
14	29163.75	79.48	57.28

6. Results

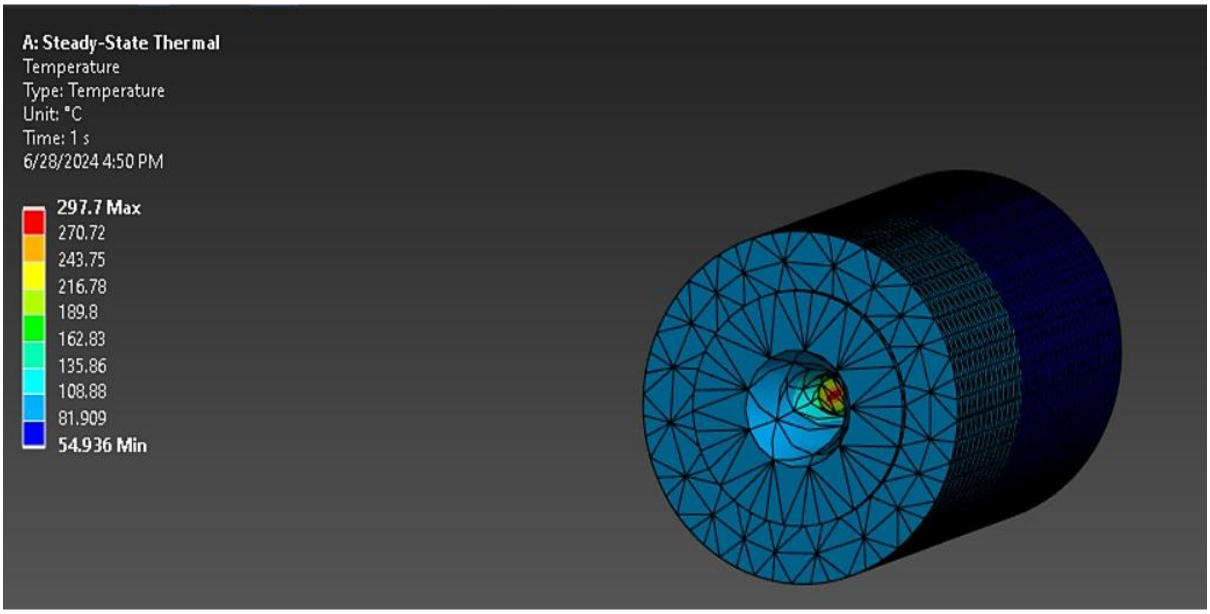
The results are presented in terms of temperature distribution for given configuration and material.

6.1 Copper Cylinder with Internal Cone

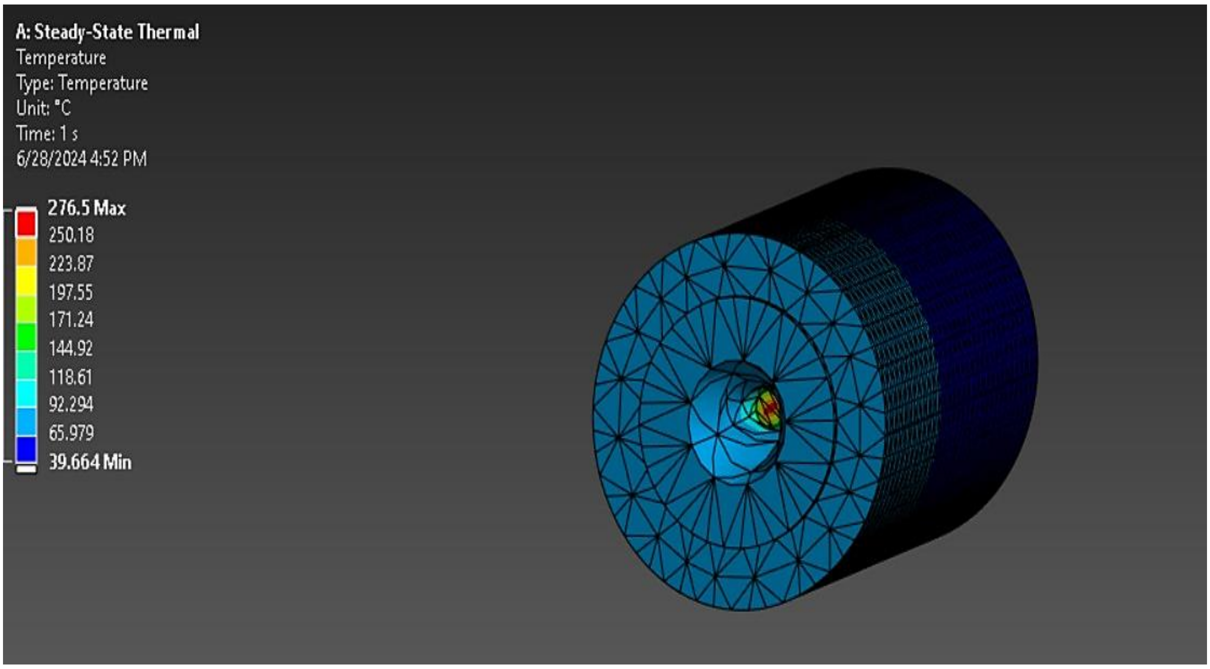
1. **Cone with 100 mm Diameter**

- Temperature distribution showed higher temperatures at the base of the cone and near the fins.
- Copper, due to its higher thermal conductivity, exhibited better thermal performance
- The presence of fins significantly enhanced the heat dissipation capability of the cylinder.

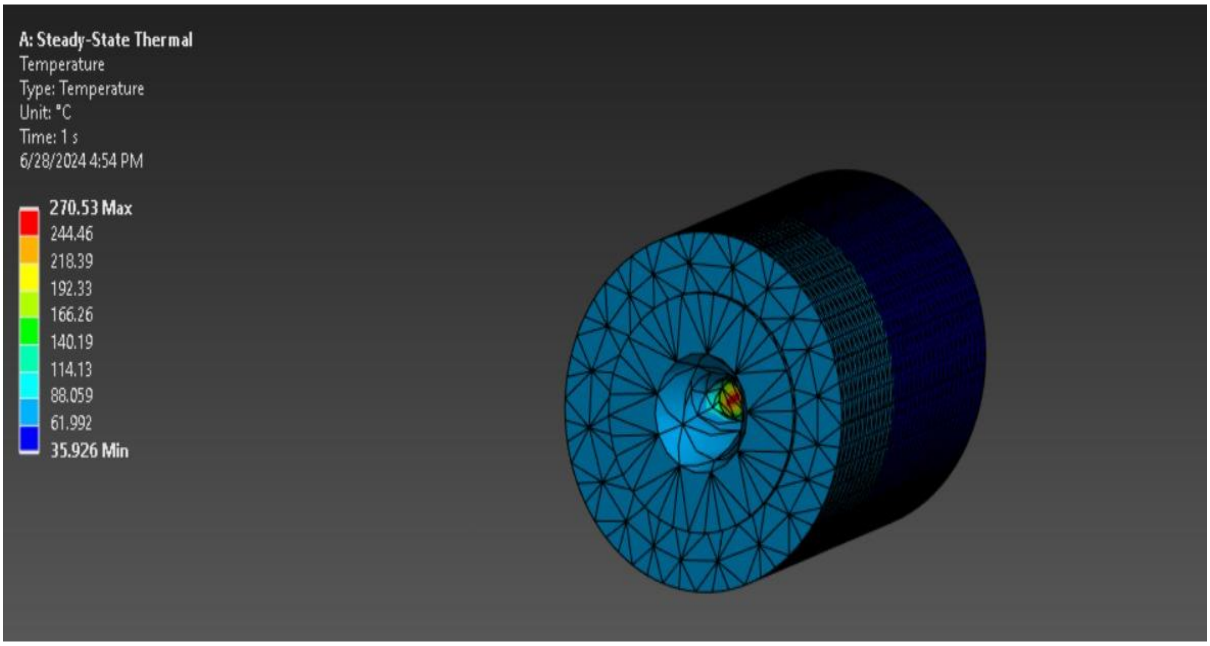
7.Results and Discussion



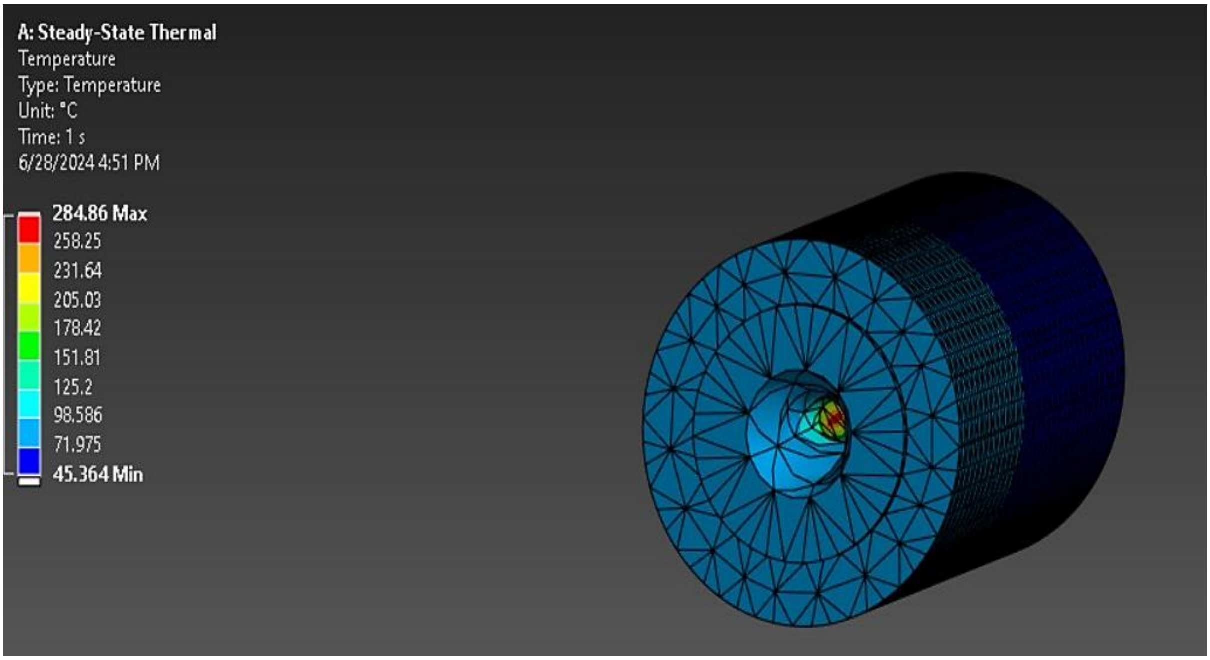
For h = 29.08 W/((m^2)K)



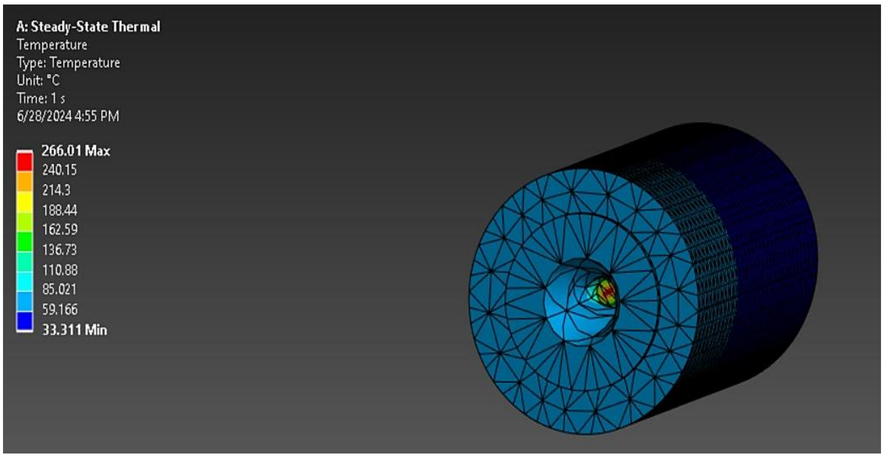
For h = 36.60 W/((m^2)K)



For h = 43.76 W/((m^2) K)



For h = 50.63 W/((m^2) K)



For h = 57.28 W/((m^2) K)

7.1 Temperature Distribution

The temperature distribution across the heat sink was obtained from the simulation. The results showed higher temperatures near the internal cone, gradually decreasing towards the outer fins, indicating effective heat dissipation.

7.2 Heat Dissipation Efficiency

The fins significantly improved heat dissipation due to the increased surface area. The effectiveness of the fins was evident from the lower temperature gradient observed across the outer surface of the cylinder.

Critical Areas: The analysis identified potential hotspots near the base of the internal cone. These areas require attention for further thermal management, possibly through enhanced fin design or additional cooling mechanisms.

8. Conclusion

The thermal analysis of the cylinder with an internal cone and external fins demonstrated that increasing the number of fins improves thermal performance. Copper, being a better thermal conductor, provided superior results. The use of fins was effective in enhancing heat dissipation.

9. Recommendations

- Further studies can be conducted to optimize the fin design for maximum heat dissipation.
- Experimental validation of the simulation results can be performed to ensure accuracy.
- Analysis can be extended to include other materials and configurations for a comprehensive study.

10. References

- Product Catalogue of Klystron
- Ansys Workbench
- Frank P. Incropera and David P. Dewitt, Fundamental of Heat and Mass Transfer, Chapter- 8