Lab #10

Thermal Analysis of a Pipe Connector and a Heater

The City College of New York

Department of Mechanical Engineering

ME 37100 Computer Aided Design

Section 1EF

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Abstract

Steady state thermal analysis is explored through a pipe connector and heater by looking at resultant temperature distributions and heat flux. Flow of heat flux can be seen by obtaining vector plots to observe flow of heat. Thermal stresses on a body, due to the non-uniform temperature distributions, can be observed through a static study, where mesh refinement can be seen to be an important factor

Introduction

In this lab, thermal stress is analyzed under a steady state condition. SolidWorks allows for thermal analysis through a thermal study or by prescribing thermal conditions in a static study. The buildup of thermal stresses can be analyzed with static study under assumptions of steady state conditions.

Heat power indicates the net heat transfer gained or lost, depending on the resultant sign of the new power. Generation of electrical or mechanical power is to be resulted from heat power or vice versa. In the analysis of a heater, electrical power is able to convert to heat power to emit heat. With a steady state analysis, heat dissipation and heat entering the model should be able to cancel out.

Theoretical Background

Steady State thermal analysis can be done when observed temperature variations are seen to no longer change with time. Steady state assumes a sufficient time passed from when placed under the heat flow to no longer vary and allow the use if a static study.

Thermal stresses are a product of nonuniform thermal expansions on the model. Such movement restrained by either the temperature differential or a mechanical restraint causes a buildup of the stress in the material. Much like in a stress analysis, mesh refinement becomes an important factor in achieving accurate results.

Heat flux in a material is influenced by factors such as temperature gradients, material properties of studied material and the conditions of the flow. Such conditions can be simulated in a thermal study by setting boundary conditions of the ambient temperatures, prescribed surface temperatures, thermal or convection coefficients.

Graphical Demonstrations of SolidWorks Results

In the first portion of the lab, analysis of temperature, heat flux and thermal stresses are done with the following boundary conditions: prescribed temperature of 100, 80, 400 and 250 degrees Celsius on the left, top, right and bottom of pipe connector, respectively. Flow is assumed to be in steady state thermal and static study.

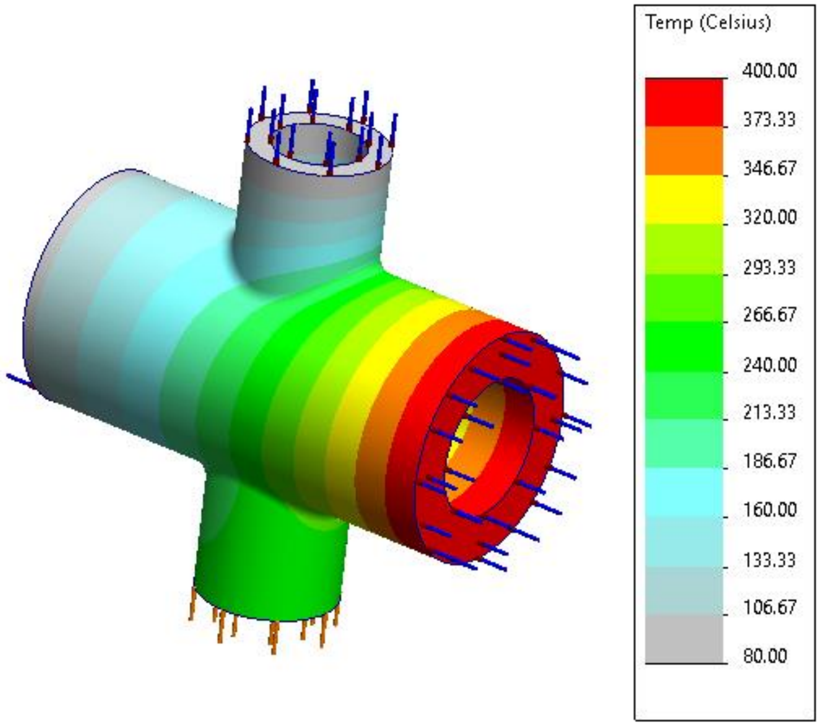


Figure 1: Temperature distribution on a piper connector through thermal analysis.

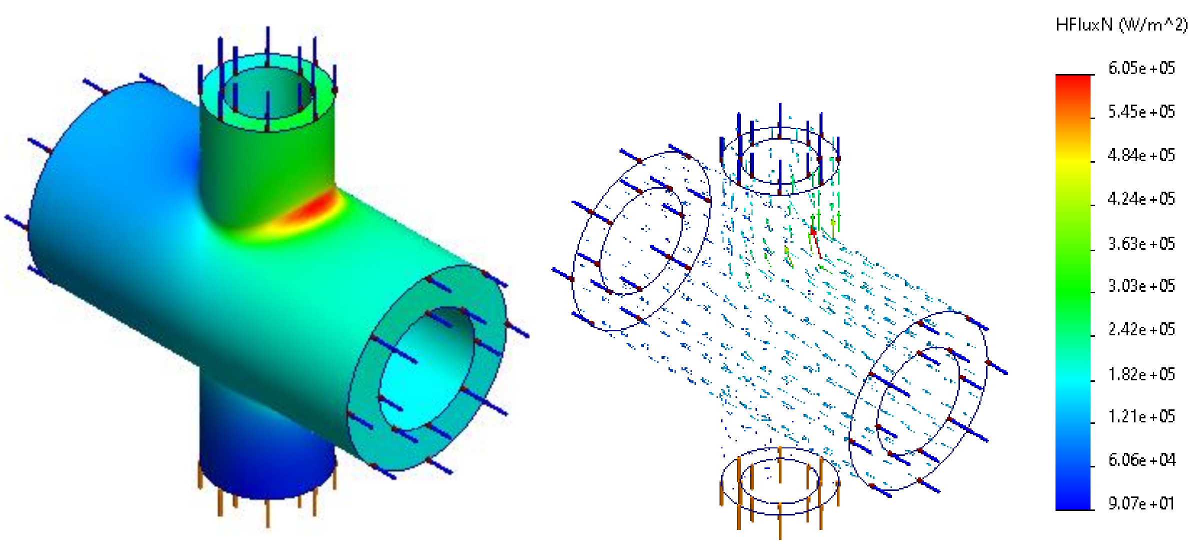


Figure 2: Heat flux plot on pipe connector through thermal analysis. Vector plot is displayed on the left to represent flow direction. Scale representative of both plots.

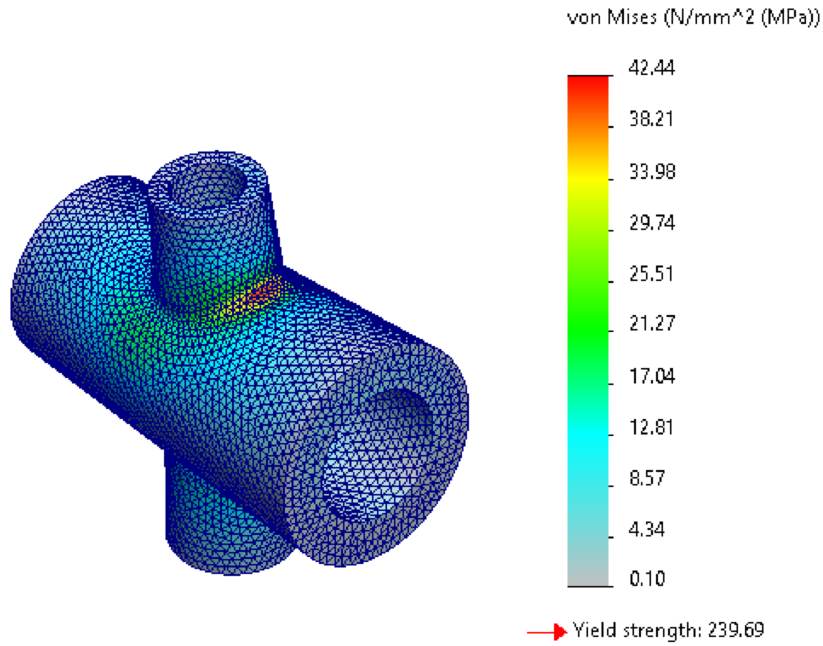


Figure 3: Von Mises stress plots of Thermal stress distribution of pipe connector with 16 element mesh

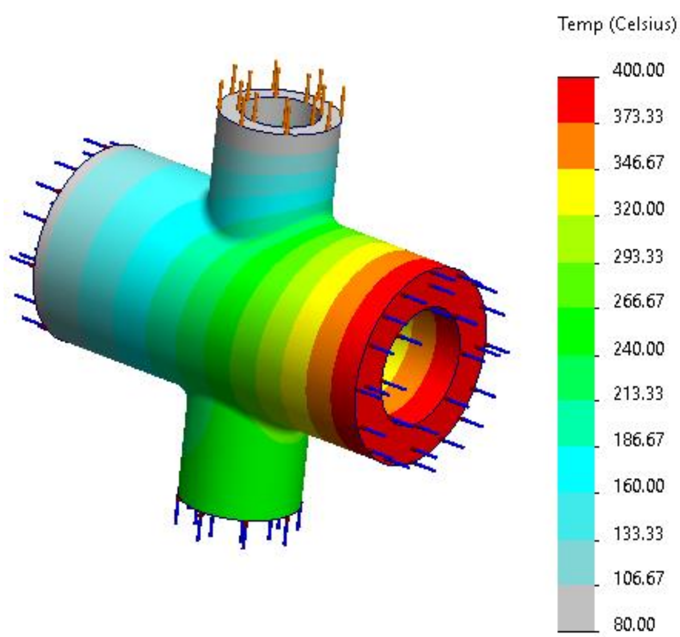


Figure 4: Temperature distribution on a piper connector through thermal analysis of 32 element mesh.

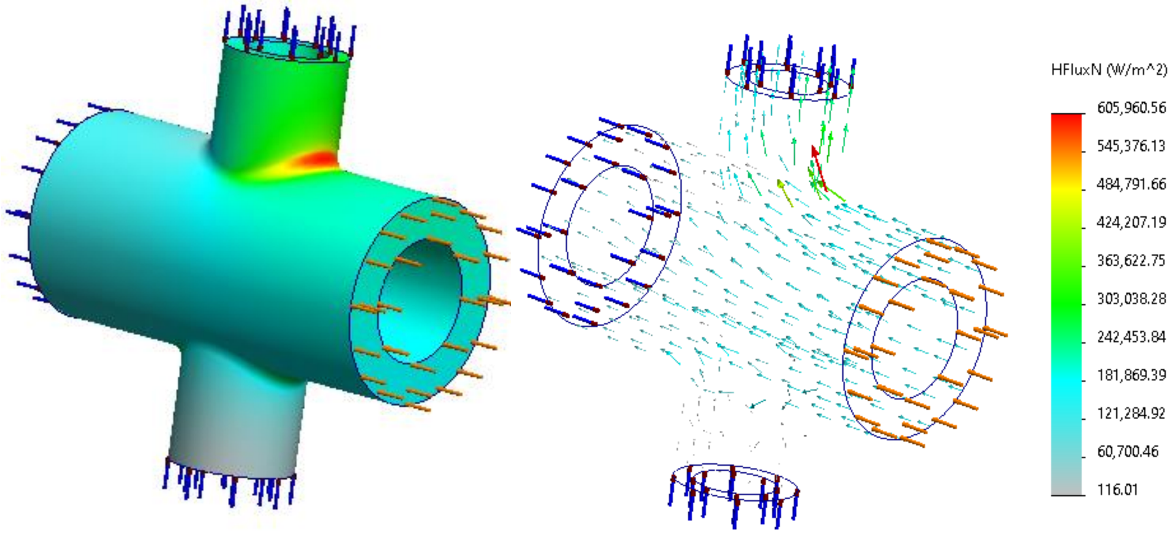


Figure 5: Heat flux plot on pipe connector through thermal analysis. Vector plot is displayed on the left to represent flow direction. Scale representative of both plots, on the 32 element mesh.

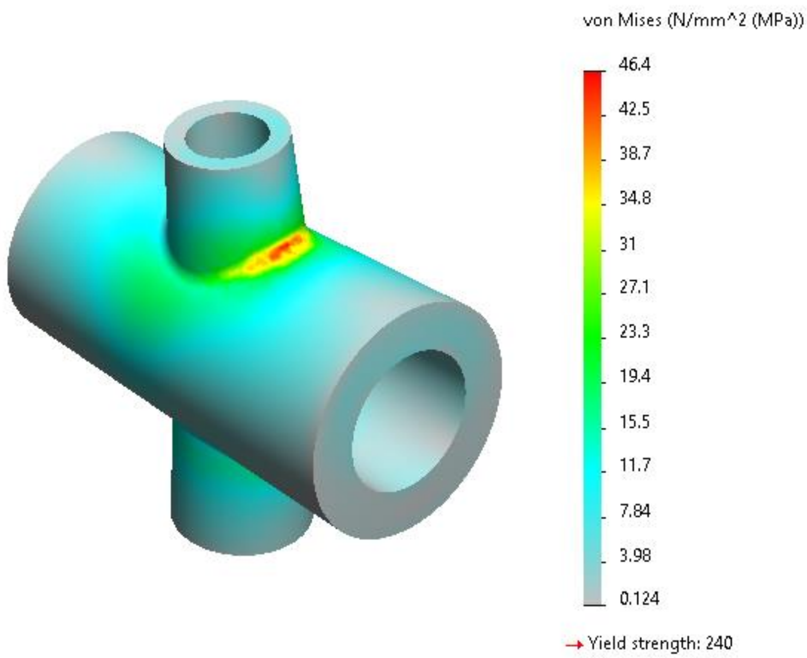


Figure 6: Von Mises stress plots of Thermal stress distribution of pipe connector with 32 element mesh

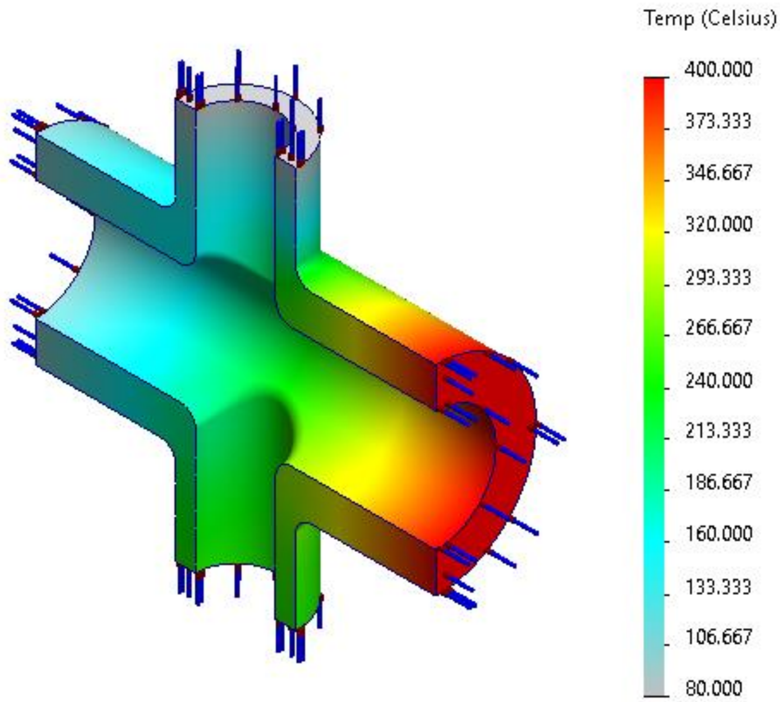


Figure 7: Temperature distribution plot of half model of the pipe connector model

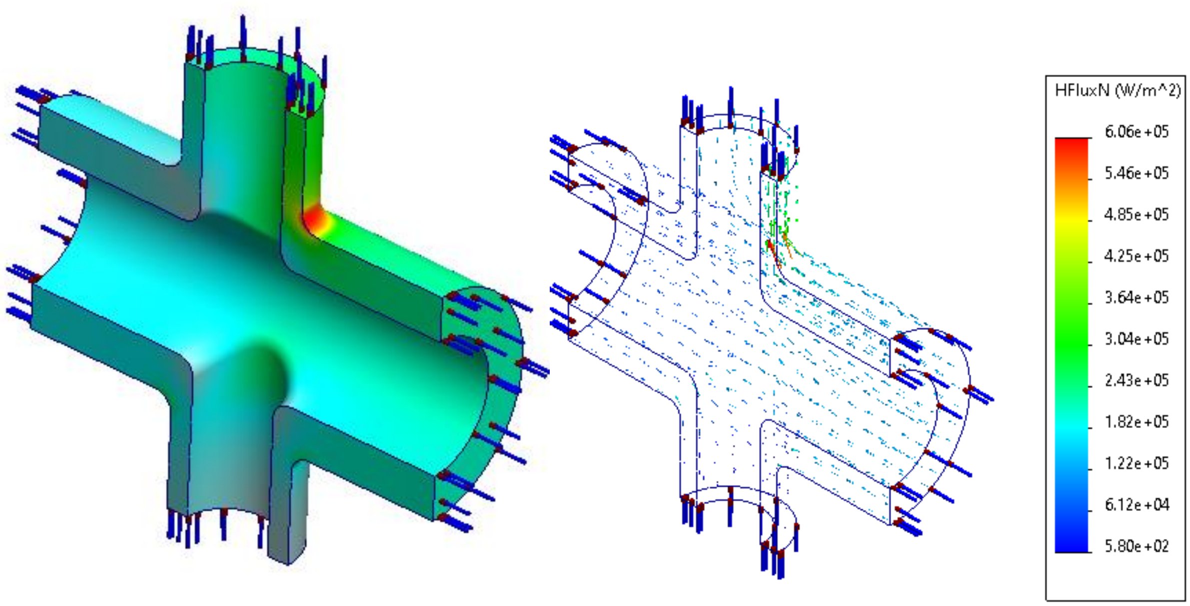


Figure 8: Heat flux plot of half model of the pipe connector model. Vector plot is displayed on the right to show direction of fluid flow. Scaling applies to both views of heat flux.

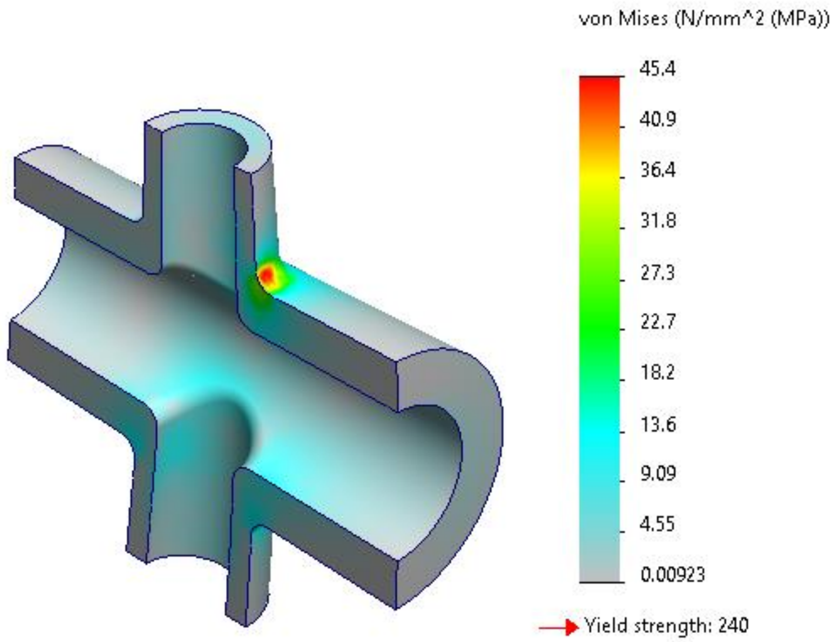
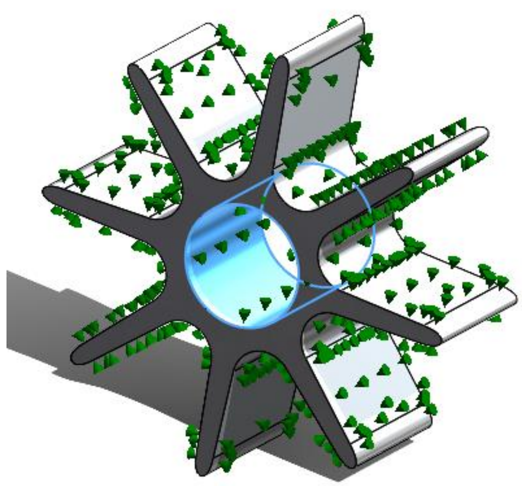
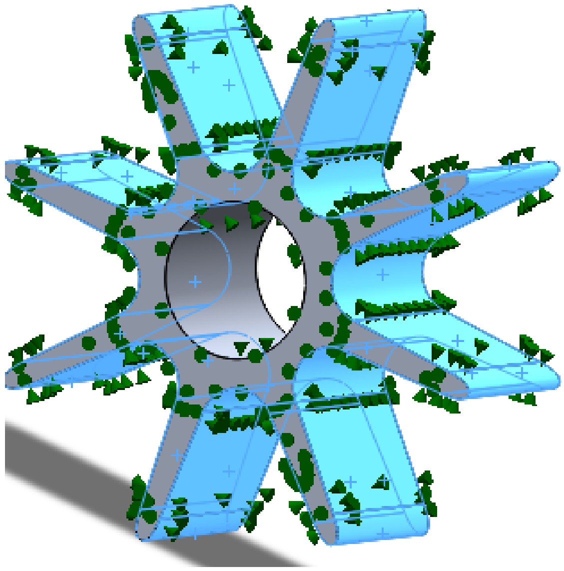


Figure 9: Von Mises stress plots of Thermal stress distribution of half model pipe connector with 32 element mesh



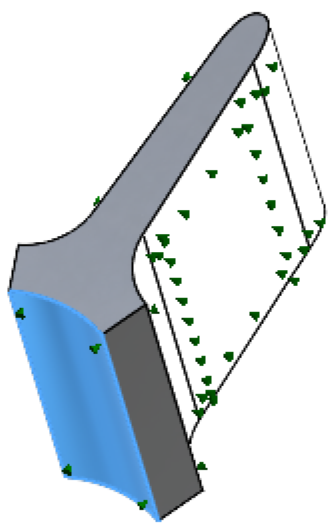
Entities	Power In (Watt)	Power Out (Watt)	Net Power (Watt)
Face<1>	51.378	0.	51.378

Figure 10A: total heat power in of central face of heater



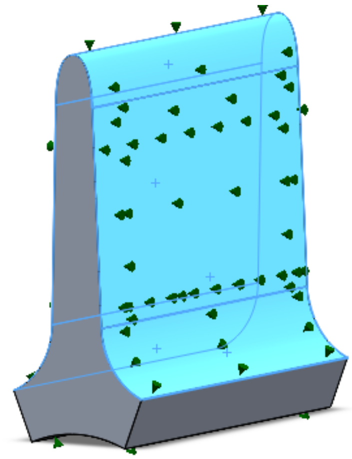
Sum	Selection	Entire Model
Power In	0.	55.336
Power Out	51.031	55.336
Net Power	-51.031	8.0268E-05

Figure 10B: total heat power out through fins of heater



Entities	Power In (Watt)	Power Out (Watt)	Net Power (Watt)
Face<1>	6.4222	0.	6.4222

Figure 11A: Total heat power in from central face of heater using symmetrical analysis of just one fin



Sum	Selection	Entire Model
Power In	0.	6.4222
Power Out	6.4222	6.4221
Net Power	-6.4222	1.4346E-06

Figure 11B: Total heat power out of fin surface of heater using symmetrical analysis of just one fin.

Model	Element Mesh	Max von Mises Thermal Stress (MPa)	Max heat flux (W/m^2)
Pipe Connector Full Model	16	42.44	6.05 E5
	32	46.4	6.05E5
Pipe Connector half model	32	45.4	6.06 e5

Figure 12: Tabulated heat flux and max thermal von mises stress of pipe connector.

Model	Power in (W)	Power out (W)
Heater Full	51.031	-51.031
Heater Section (one)	6.4222	- 6.4222

Figure 13: Tabulated power in and out of the heater central and fin surface.

Discussion and Interpretation of Results

Element size refinement is important in analyzing thermal stresses due to stress concentrations at fringes. Similar to structural analysis. From figures 12, it can be observed that the total max stress observed at a 32-element mesh was greater by 4 MPa than that of the 16-element mesh. The fringes may be observed to see whether refinement is needed. Observing the area of stress build up in figures 3 and 7, it can be seen that the irregularity would mean mesh refinement would be able to capture the stresses more accurately. Heat flux and temperature distributions are seen to not be affected as heavily by mesh refinement as tabulated in figures 12. Its important to note that the thermal analysis done in this lab may not be useful in the observation of real scenarios due to simplified conditions, though an good way to see thermal analysis conditions.

In the analysis of a heater, heat power is observed by comparing an full heat section versus use of symmetry to observe a portion of the heater. This analysis observes the heat dissipation due to the addition of fins. In the tabulations of the power observed from the central fin and of the dissipation out of fins, it can be seen the values are the same but of different signs. This is expected as heat gained by the fluid must match that of the heat lost to the air from the fins.

Symmetry can be used to simplify and reduce calculations time. Through the pipe connector, using held the model can be used to observed in both thermal and static study. Use of circular symmetry is useful with proper constraints for the heater and accounting for the total heat power by multiplying by total number of repeating elements.

Conclusions

This lab looked to determine the use of mesh refinement in thermal stresses. Heat flux and temperature distributions is observed from simplified boundary conditions of a pipe connector to show process of thermal analysis. Heat power is explored through a heater with fins. To determine the accuracy of results, looking at the net in and out power can be used.

References

[1] Engineering Analysis with SolidWorks Simulation 2024, by Paul Kurowski (2024), ISBN-10: 1630576298.
[2] A First Course in the Finite Element Method, Enhanced Edition, 6th Ed., by Daryl Logan (2022), ISBN-10: 0357884140.