24-650 Applied Finite Element Analysis

Assignment 1

submitted by

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Objective

The goal of this assignment is to explore the steady-state thermal conductivity and temperature variations under different material and heat insulation settings. The main object is a casted iron pipe with inside and outside diameters are 70 mm and 90 mm, accordingly.

Model and Geometry

The cast iron pipe (see in Fig.1) has inside and outside diameters are 70 mm and 90 mm, accordingly. Moreover, a heat insulation foam with 5mm thick will be applied to the outside surface of the pipe (see in Fig.2).

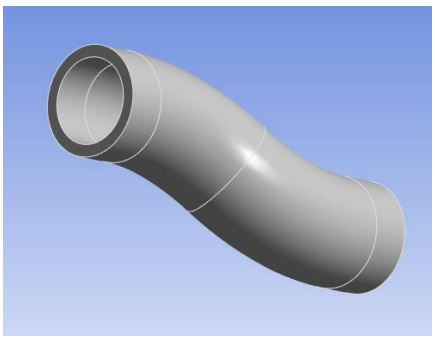


Figure 1. The curved pipe

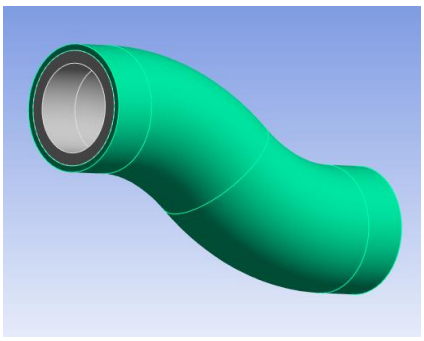


Figure 2. The pipe with foam insulation (green)

Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	1.e-002 m
Sizing	
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechanical
Target Element Quality	Default (5.e-002)
Smoothing	Medium
Mesh Metric	None

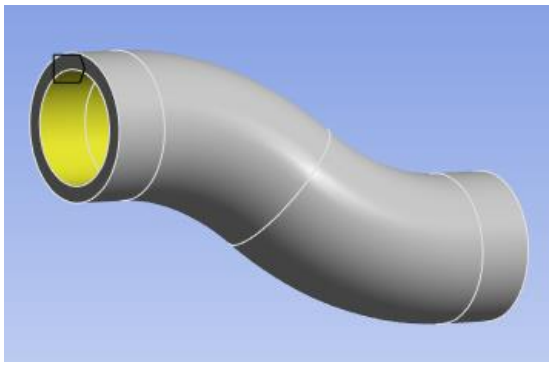
Mesh Settings

Boundary Conditions (Part A)

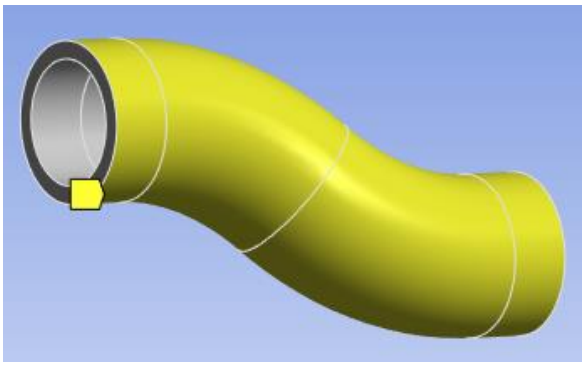
The thermal conductivity of the pipe is 52 W/m-C, and the pipe is carrying steam at 155 ℃, with an outside temperature of 20 ℃.

We assume that the pipe ends are adiabatic.

The inside surface has a convention coefficient of 20 W/m^2 -C, with an outside surface convention coefficient of 3.8 W/m^2 -C.

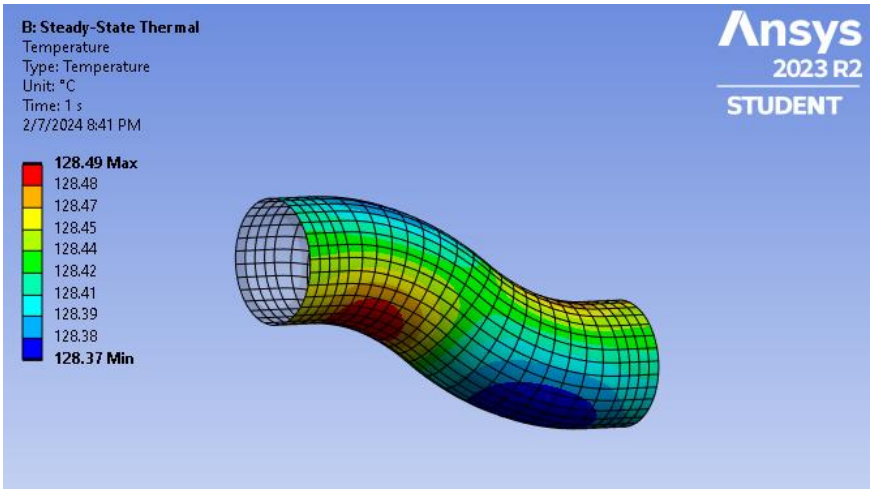


Type	Convection
Film Coefficient	20. W/m²·°C (step applied)
Ambient Temperature	155. °C (ramped)



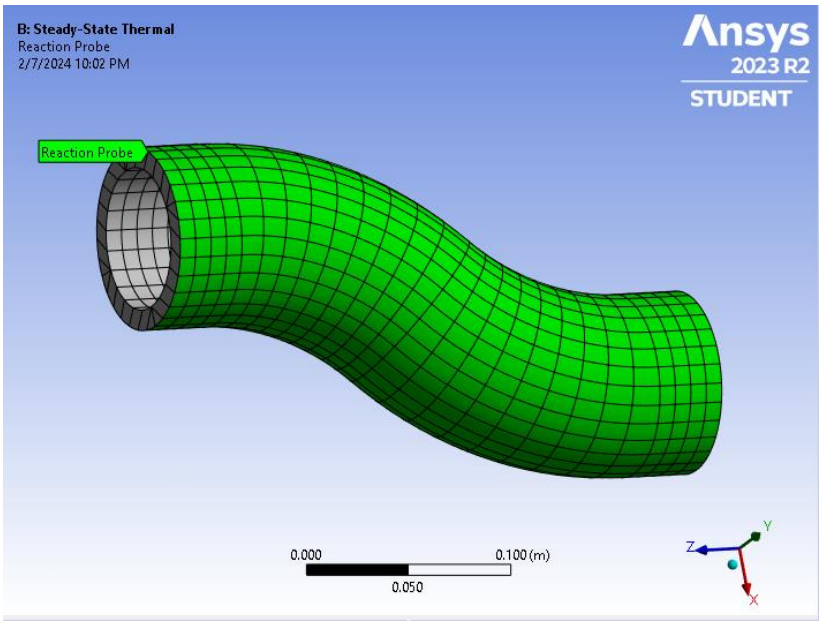
Type	Convection
Film Coefficient	3.8 W/m²·°C (step applied)
Ambient Temperature	20. °C (ramped)

Results (Part A)



Scope	
Scoping Method	Geometry Selection
Geometry	4 Faces
Definition	
Type	Temperature
By	Time
Display Time	Last
Separate Data by Entity	No
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	128.37 °C
Maximum	128.49 °C
Average	128.43 °C
Minimum Occurs On	CurvedPipe\Solid
Maximum Occurs On	CurvedPipe\Solid

A1 – The maximum outside temperature is **<u>128.5 ℃</u>**



Definition	
Type	Reaction
Location Method	Boundary Condition
Boundary Condition	Convection 2
Suppressed	No
Options	
Display Time	End Time
Results	
Maximum Value Over Time	
Heat	-35.354 W
Minimum Value Over Time	
Heat	-35.354 W

A2 – The rate of heat loss off the outside surface of the pipe is **<u>35.4 W</u>.**

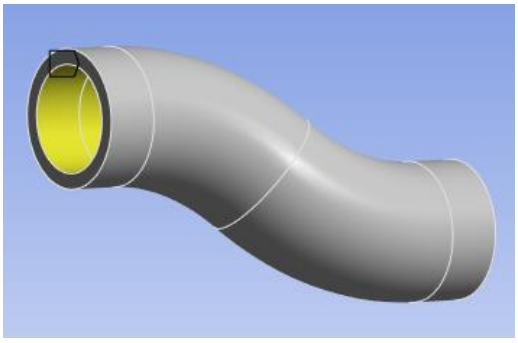
Boundary Conditions (Part B)

The thermal conductivity of the pipe is 52 W/m-C, and the pipe is carrying steam at 155 °C, with an outside temperature of 20 °C.

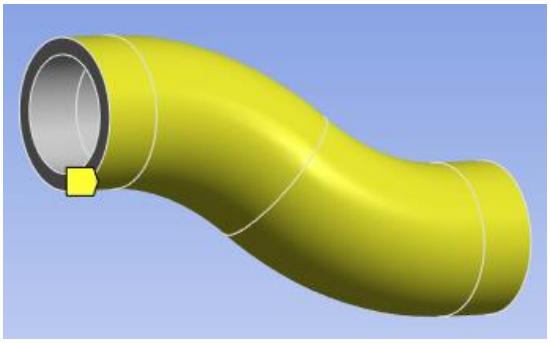
We assume that the pipe ends are adiabatic.

The foam has a thermal conductivity of 0.20 W/m-C, and the inside surface has a convention coefficient of 20 W/m^2 -C, with an combined surface convention coefficient of 3.4 W/m^2 -C, calculated by:

$$h_{eq} = \frac{1}{R_{total}A} = 3.4 \ {}^{W}/_{m^2\text{-}C}$$

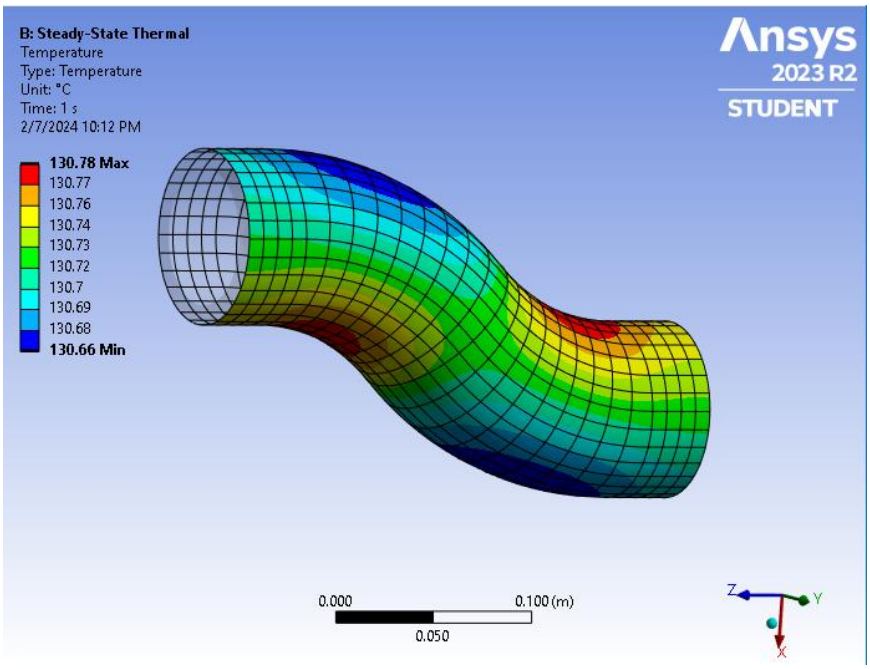


Type	Convection
Film Coefficient	20. W/m²·°C (step applied)
Ambient Temperature	155. °C (ramped)



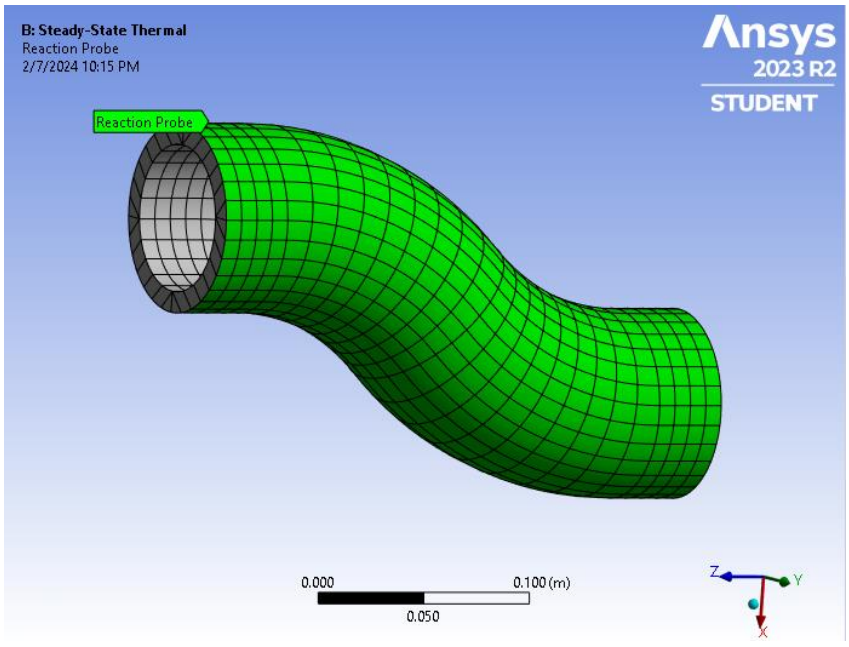
Type	Convection
Film Coefficient	3.4 W/m²·°C (step applied)
Ambient Temperature	20. °C (ramped)

Results (Part B)



Scope	
Scoping Method	Geometry Selection
Geometry	4 Faces
Definition	
Type	Temperature
By	Time
Display Time	Last
Separate Data by Entity	No
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	130.66 °C
Maximum	130.78 °C
Average	130.72 °C
Minimum Occurs On	CurvedPipe\Solid
Maximum Occurs On	CurvedPipe\Solid

B1 – The maximum outside temperature is **<u>130.8 ℃</u>**



Definition	
Type	Reaction
Location Method	Boundary Condition
Boundary Condition	Convection 2
Suppressed	No
Options	
Display Time	End Time
Results	
Maximum Value Over Time	
Heat	-32.302 W
Minimum Value Over Time	
Heat	-32.302 W

B2 – The rate of heat loss off the outside surface of the pipe is **<u>32.3 W</u>.**

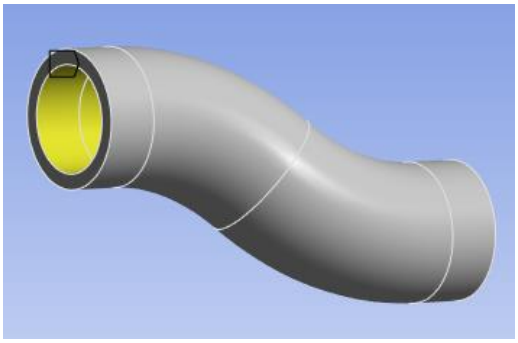
B3 – The heat loss is **<u>smaller</u>** than compared to A2, as the heat insulation material prevented some heat loss of that pipe.

Boundary Conditions (Part C)

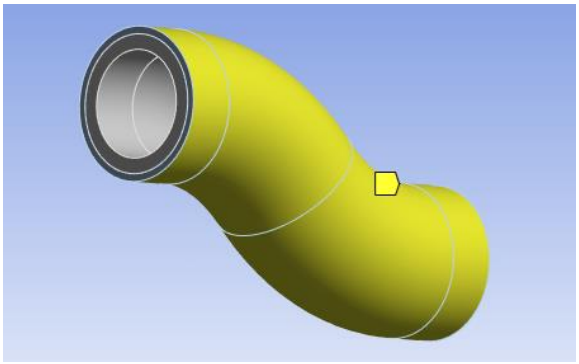
The thermal conductivity of the pipe is 52 W/m-C, and the pipe is carrying steam at 155 ℃, with an outside temperature of 20 ℃.

We assume that the pipe ends are adiabatic.

The foam has a thermal conductivity of 0.20 W/m-C, and the inside surface has a convention coefficient of 20 W/m^2 -C, with an outside surface convention coefficient of 3.8 W/m^2 -C, calculated by:

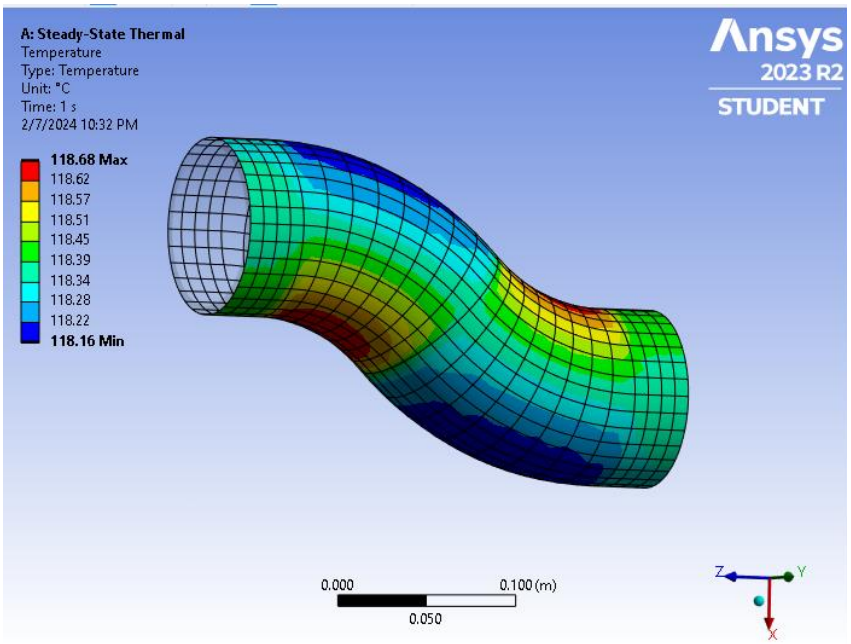


Type	Convection
Film Coefficient	20. W/m²·°C (step applied)
Ambient Temperature	155. °C (ramped)



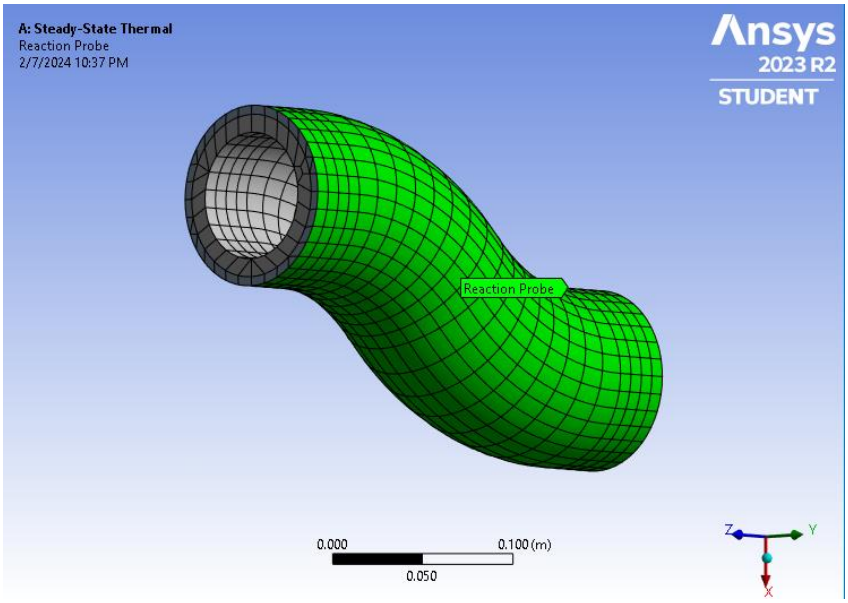
Type	Convection
Film Coefficient	3.8 W/m²·°C (step ap...

Results (Part C)



Scope	
Scoping Method	Geometry Selection
Geometry	4 Faces
Definition	
Type	Temperature
By	Time
Display Time	Last
Separate Data by Entity	No
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	118.16 °C
Maximum	118.68 °C
Average	118.39 °C
Minimum Occurs On	SYS\Solid
Maximum Occurs On	SYS\Solid

C1 – The maximum outside temperature is **<u>118.7 ℃</u>**



Definition	
Type	Reaction
Location Method	Boundary Condition
Boundary Condition	Convection
Suppressed	No
Options	
Display Time	End Time
Results	
Maximum Value Over Time	
Heat	-35.636 W
Minimum Value Over Time	
Heat	-35.636 W

C2 – The rate of heat loss off the outside surface of the pipe is **35.6 W.**

C3 – The heat loss comparison is listed below:

A2	B2	C2
35.4W	**32.3W**	**35.6W**

As one can read from the table above that **Part B** has the **lowest** heat loss, and **Part C** has the **highest** heat loss, one possible reason is due to the increase of surface area (heat insulation material has thickness therefore enlarged the outside surface area), and the influence of surface area overrides the heat insulation effect. Under the situation of outside surface area remain unchanged (Part A and B), the heat insulation does reduce the heat loss.