Assignment 1 - Steady State Thermal Analyses of a Curved Pipe

Figure 1 shows a curved cast iron pipe. Inside and outside diameters are 70 mm and 90 mm, respectively, and its thermal conductivity is 52 W/m-C.

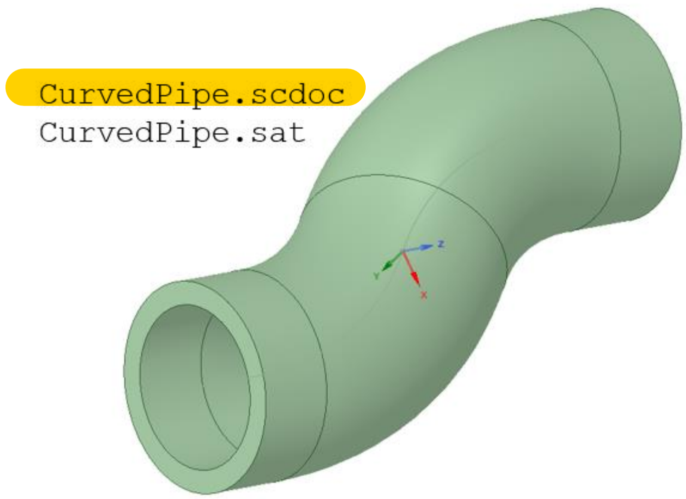

Figure 1

~~For~~ parts A, B, and C, the pipe is carrying steam at 155 C with an inside surface convection coefficient of 20 W/m^2 -C, and the outside ambient temperature is 20 C. Assume the pipe ends are adiabatic.

Part A - The pipe is not insulated, and the outside convection coefficient is 3.8 W/m^2 -C.

A1- Determine the maximum outside surface temperature of the cast iron pipe. Express your answer in degrees C and to the nearest tenth of a degree C.

A2 - Determine the rate of heat loss off the outside surface of the pipe. Express your answer in Watts and to the nearest tenth of a Watt.

Part B - The pipe's outside surface is insulated with 5 mm of foam (K = 0.20 W/m-C). It is correct to assume that the total heat resistance (R_{total}) due to the insulation and the heat resistance from external surface convection act in series, as indicated in Figure 2.

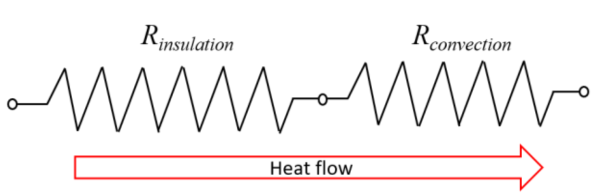

Figure 2

This means

$$R_{total} = R_{insulation} + R_{convection}$$

It is relatively easy to show that R_{total} = 0.29/A where A is the total exterior surface area of the pipe. The equivalent exterior convection coefficient (h_{eq}) is easily determined from

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

which accounts for the added insulation and replaces the exterior convection coefficient used in Part A.

B1- Determine the maximum outside surface temperature of the cast iron pipe. Express your answer in degrees C and to the nearest tenth of a degree C.

B2 - Determine the rate of heat loss off the outside surface of the pipe. Express your answer in Watts and to the nearest tenth of a Watt.

B3 – Explain the change in heat loss compared to A2.

Part C - The pipe's outside surface is insulated with 5 mm of foam (*K* = 0.2- W/m-C). Instead of approximating an equivalent convection film coefficient, this time model the 5-mm thick insulation with finite elements. In so doing, you will need to add a second part to the given model. And you will need to add a second material (Foam Insulation) to the Engineering Data tool. The convection coefficient is 3.8 W/m^2 -C and is applied to the outside surface of the insulation, and the outside ambient temperature remains at 20 C.

C1- Determine the maximum outside surface temperature of the cast iron pipe. Express your answer in degrees C and to the nearest degree C.

C2 - Determine the rate of heat loss off the outside surface of the insulation. Express your answer in Watts and to the nearest tenth of a Watt.

C3 – Explain the change in heat loss compared to A2. Explain the change in heat loss compared to B2. Do these changes make sense and why or why not?

Assumptions and Additional Guidance

1) Heat transfer is steady state.

2) Thermal properties are constant.

3) For Part C, the thermal contact resistance at the interface between the metal and the insulation is negligible. In other words, use default Mechanical settings.

4) Radiation can be ignored.

5) Accurate, convergence results in terms of your mesh are expected.

6) It might be useful and efficient to employ a ½-symmetry model.