MET 440 Test 1 | Frank Nguyen

(1) Purpose - To determine a) Total heat rate from a single channel per unit length

b) Temperature T_s

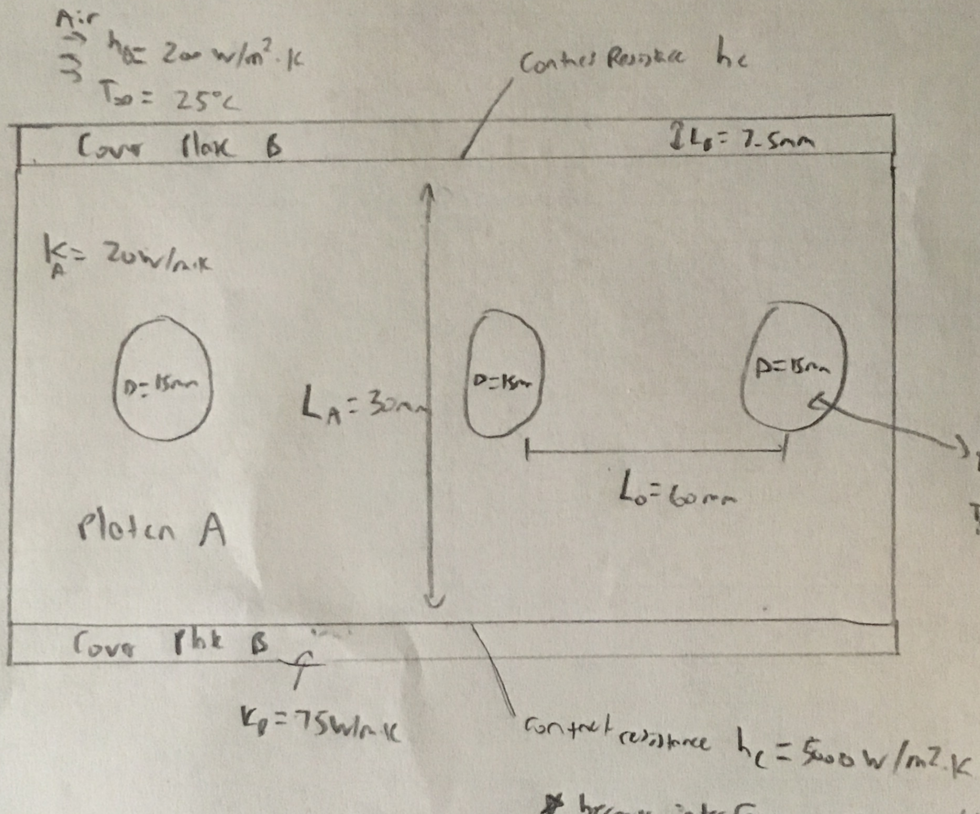
c) If the center-line spacing L_o is doubled, what would be the new total heat rate and temperature T_s

d) If we insulate the lower surface, the total heat rate would reduce in half? would temperature T_s increase or decrease.

e) If we attach one rectangular fin per channel on each cover plate, what would be the new heat rate.

f) Thermal circuits for both cases without the fins and with the fins

Drawings and Diagrams



* because interference conductance (h_c) is inversely proportional to contact resistance ($R_{contact}$) we can solve.

$(500\ W/m^2 \cdot K)^{-1} = R_{con} = .0002\ m^2 \cdot K/W$

Sources

· Bayazitoglu, Ozisik, N. "A textbook for heat Transfer Fundamentals". Begell House, Inc (2012)

Design Considerations

· Steady State · Constant properties. · 1D heat transfer.

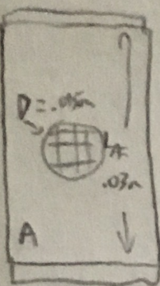
· No heat generation · Multidimensional heat transfer · Shape factor · Fins for part e

Data and variables - See diagram and drawing.

2

Procedure and Calculations a)

- First we need to find the shape factor for the figure and simplify the geometry
- Because it's symmetrical lets focus on only one circular channel



Case 2 Shape factor table. $S = \frac{2\pi L}{\cosh^{-1}(z/D)}$ assume 1m for length

$$S = \frac{2\pi \cdot 1m}{\cosh^{-1}(2 \cdot .015m / .015m)} \qquad S = 4.77$$

- Calculate total resistance in the section by getting each individual resistance

initial surface: $R_i = \frac{1}{h_i\left(\frac{\pi D}{4}\right)}$; material A: $R_1 = \frac{1}{K_A S'}$; Contact resistance: $R_2 = \frac{R_{contact}}{\frac{L_o}{2}}$; material B: $R_3 = \frac{L_B}{K_B\left(\frac{L_o}{2}\right)}$; outer surface: $R_h = \frac{1}{h_o\left(\frac{L_o}{2}\right)}$

T_i — R_i — R_1 — R_2 — R_3 — T_s — R_h — T_∞

- $R_{total} = R_i + R_1 + R_2 + R_3 + R_h$

$$R_i = \frac{1}{h_i\left(\frac{\pi \cdot D}{4}\right)} = \frac{1}{1000\,w/m^2 k\left(\frac{\pi \cdot .015m}{4}\right)} = .084\ m \cdot k/w$$

$$R_1 = \frac{1}{K_A S'} = \frac{1}{(20\,w/mk)(1.19)} = .0420\,m \cdot k/w$$

S' = for $\frac{1}{4}$ section $S' = \frac{4.77}{4}$ $S' = 1.19$

$$R_2 = \frac{R_{con}}{\frac{L_o}{2}} = \frac{.0002\,m^2 \cdot k/w}{\frac{.06m}{2}} = .00666\,m \cdot k/w$$

$$R_3 = \frac{L_B}{K_B\left(\frac{L_o}{2}\right)} = \frac{.0075m}{(75\,w/m^2 k)\left(\frac{.06m}{2}\right)} = .00333\,m \cdot k/w$$

$$R_h = \frac{1}{h_o\left(\frac{L_o}{2}\right)} = \frac{1}{(200\,w/m^2 k)\left(\frac{.06m}{2}\right)} = .1666\,m \cdot k/w$$

$$R_{total} = .084 + .0420 + .00666 + .00333 + .1666$$

$$R_{total} = .3026\ m \cdot k/w$$

• Heat transfer (q_i) for a single channel from the quarter section

$$q_i = 4\frac{T_i - T_\infty}{R_{tot}} = 4\frac{150°C - 25°C}{.3026\ m \cdot K/W} \qquad q_i = 1652\ W \text{ or } 1.652\ kW$$

• Procedure and calculations for b)

From thermal circuit in part a, we can find T_s by arranging the equations:

$$T_s = T_\infty + \frac{q_i}{2L_o h_o} = 25°C + \frac{1652\ W}{2(.06)(200\ W/m^2 \cdot K)}$$

$$T_s = 93.8°C$$

Material for a and b

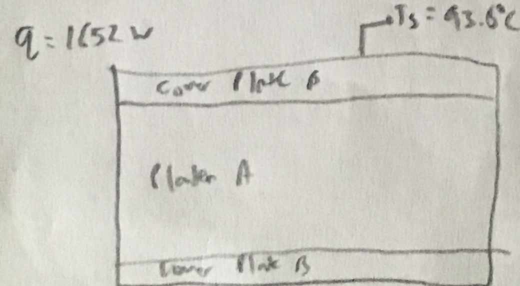
- material A
- material B
- cool air
- fluid
- Platen
- Cover Plate

Summary for a and b

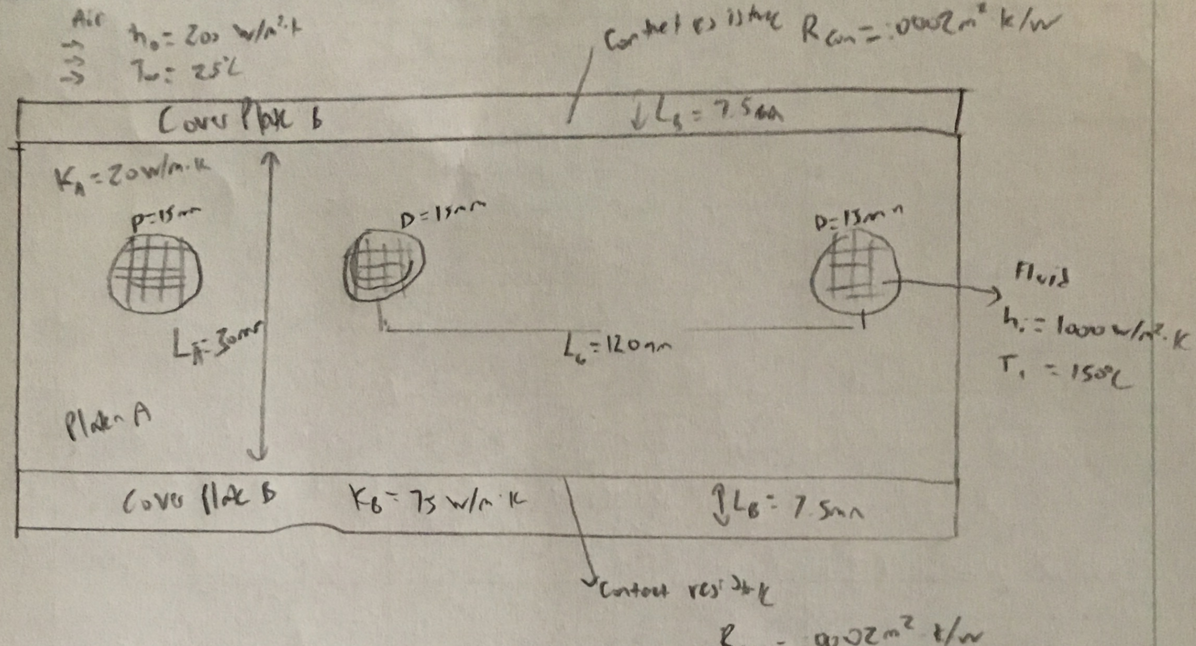
The heat transfer rate from a single channel per unit length is 1652 W and the surface temperature is 93.8°C

Analysis for a and b

The poor contact of platen A and cover plates B, should be resolved for the system to perform better. Here is a figure with the found surface temp and heat transfer rate.



Drawings and diagrams for part c)



Procedure and Calculations

- Thermal Circuit and Shape factor is the Same since we are using a quarter section of the figure.

$$R_{total} = R_i + R_1 + R_2 + R_3 + R_4$$

$$R_i = \frac{1}{h_i\left(\frac{\pi D}{4}\right)} = \frac{1}{(1000\ W/m \cdot K)\left(\frac{\pi \cdot .015m}{4}\right)} = .084\ m \cdot K/W$$

$$R_1 = \frac{1}{KS'} = \frac{1}{(20\ W/m \cdot K)(1.19)} = .0420\ m\,K/W$$

$$R_2 = \frac{R_{con}}{\frac{L_o}{2}} = \frac{.0002\ m^2 \cdot K/W}{\frac{.12m}{2}} = .00333\ m \cdot K/W$$

$$R_3 = \frac{L_B}{K_B\left(\frac{L_o}{2}\right)} = \frac{.0075m}{(75\ W/m \cdot K)\left(\frac{.12m}{2}\right)} = .001666\ m \cdot K/W$$

$$R_4 = \frac{1}{h_o\left(\frac{L_o}{2}\right)} = \frac{1}{(200\ W/m^2 \cdot K)\left(\frac{.12m}{2}\right)} = .08333\ m \cdot K/W$$

$$R_{total} = .084 + .0420 + .00333 + .001666 + .08333$$

$$R_{total} = .2143\ m \cdot K/W$$

$$q_i = 4\frac{T_i - T_\infty}{R_{tot}} = 4\frac{150°C - 25°C}{.2143\,m\cdot K/W}$$ $q_i = 2333.2\,W$ or $2.333\,kW$

$$T_s = T_\infty + \frac{q_i}{2L_o h_o} = 25°C + \frac{2333.2\,W}{2(.12\,m)(200\,W/m^2\cdot K)}$$

$T_s = 73.6°C$

Materials

- material A
- material B
- cool air
- hot fluid
- platen
- cover plate

Summary

The difference when doubling the center line space versus the original in part a.

	L_o at 60 mm	L_o at 120 mm
q =	1652 W	2333 W
T_s =	93.8°C	73.6°C

Analysis

Resistance is inversly related to the center line spacing that's why the heat rate increased. The surface temperature decreased slightly when center line spacing is doubled. As we can see heat rate increases when center line space is increased.

Procedure and Calculations d)

no need to run calculations, explanation in Summary and analysis

Materials

- material A
- material B
- cool air
- hot fluid
- plates
- Cover plate

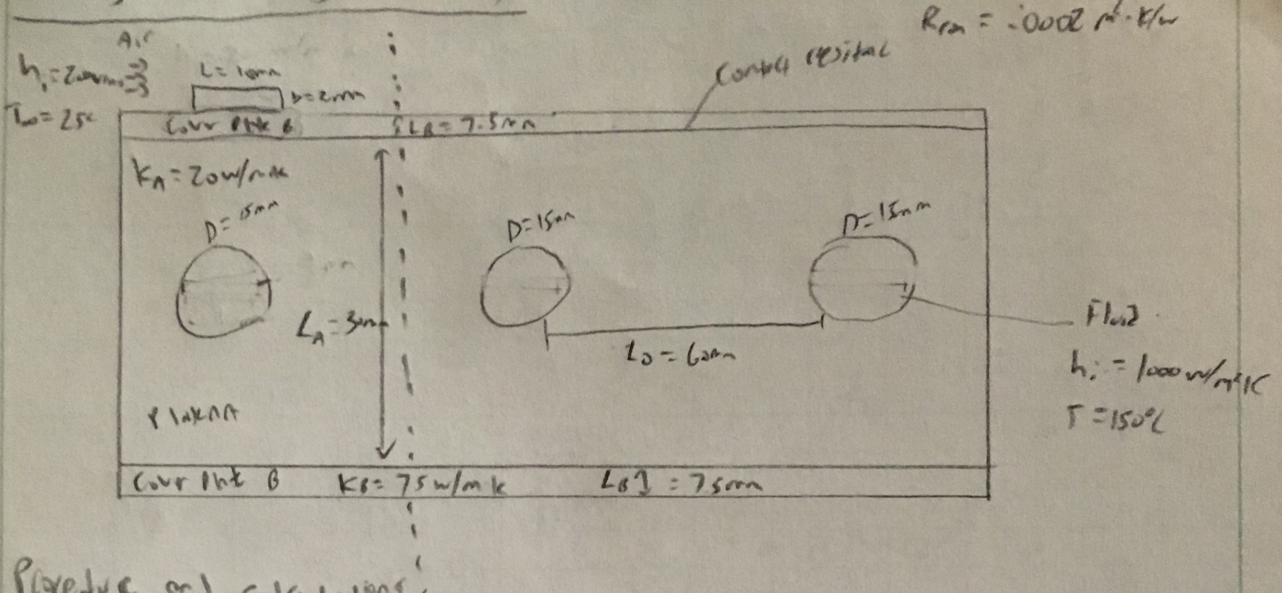
Summary

If we insulate the lower surface the heat rate would reduce in half. Because surface convection is larger that resistance. The temperature T_s would increase because of effect on T_0 and the insulated lower surface.

Analysis

Insulating the lower surface leads to a higher surface temperature. Seeing as it is already in poor contact with cover plates B and plate A; we need another solution other than insulating the lower surface. Maybe look at new material for A and B.

Drawing and diagram for e)



Procedure and Calculations:

- Thermal circuit with the fin, we are also examining from a quarter section

$$T_i \;-\; \underset{\text{internal Distre}}{R_i} \;-\; \underset{\text{Material A}}{R_1} \;-\; \underset{\text{Contact resistance}}{R_2} \;-\; \underset{\text{Fin resistance}}{R_{fin}} \;-\; \underset{\text{Material B}}{R_3} \;-\; \underset{\text{outer surface}}{R_{h}} \;-\; T_\infty$$

$$\frac{1}{h_i\left(\frac{\pi D}{4}\right)} \qquad \frac{1}{K_A S'} \qquad \frac{R_{con}}{\frac{L_0}{2}} \qquad \frac{1}{\eta_{fin} h a} \qquad \frac{L_B}{K_L\left(\frac{L_0}{2}\right)} \qquad \frac{1}{h_o\left(\frac{L_0}{2}\right)}$$

$$R_i = \frac{1}{h_i\left(\frac{\pi \cdot D}{4}\right)} = \frac{1}{(1000\ W/m^2K)\left(\frac{\pi \cdot .015m}{4}\right)} = .084\ m\cdot K/W$$

$$R_1 = \frac{1}{K_A S'} = \frac{1}{20\ W/m K\ (1.19)} = .0420\ m\cdot K/W$$

$$R_2 = \frac{R_{con}}{\frac{L_0}{2}} = \frac{.0002\ m^2\cdot K/W}{\frac{.06m}{2}} = .00666\ m\cdot K/W$$

$$R_{fin} = \frac{1}{\eta_f h a} = \frac{1}{1_{fin}(200\ W/m^2 K)(.01m \cdot .002m)} = 250\ m\cdot K/W$$

$$R_3 = \frac{L_B}{K_L\left(\frac{L_0}{2}\right)} = \frac{.0075m}{(75\ W/m^2 C)\left(\frac{.06m}{2}\right)} = .00333\ m\cdot K/W$$

$$R_h: .084 + .0420 + .00666 + 250 + .00333\ m\cdot K/W$$

$$R_{total} = 250.136\ m\cdot K/W$$

$$q = 4\,\frac{T_i - T_\infty}{R_{tt}} = 4\,\frac{150°C - 25°C}{250.136\ m\cdot K/W}$$

$q = 1.999\ W$

Materials

- material A
- material B
- coolant
- fins
- Cover plate
- Platen
- fluid

Summary

Here is a table of the heat rates

	L_o at 60mm	L_o at 120 mm	with fin
q	1652 w	2333 w	1.999 w

Analysis

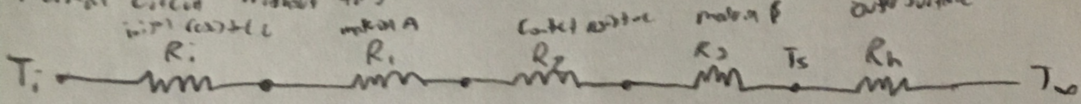
The heat rate dropped significantly when attatching the fins. This is because extended surfaces removes heat by convection and the rate increases.

Drawings and diagrams Part f

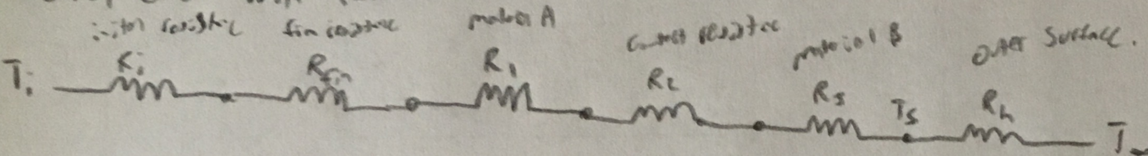
refer to drawings and diagrams from part a and e

Procedure and Calculations

Thermal Circuit without fins



Thermal circuit with fins



materials

- material A
- material B
- Cover
- fluid
- fins
- Cover plate
- platen

Summary

when attaching a fin to the cover plate we need to put the resistance for fin on the thermal circuit.

Analysis

The thermal circuit with the fin has a lower rate of heat transfer than the thermal circuit without the fins. Attaching the fins is a good way to remove the heat.