MECH 3655 Heat Sink Final Lab

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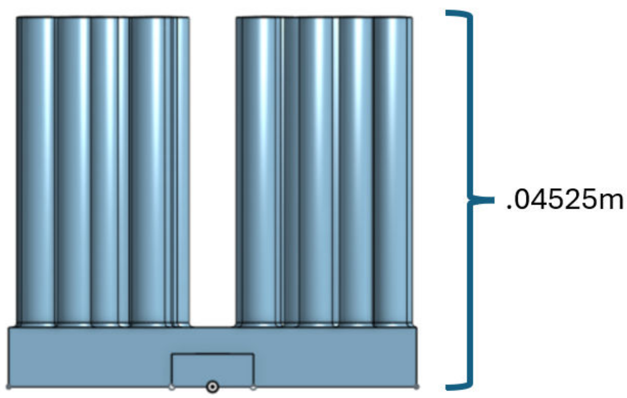
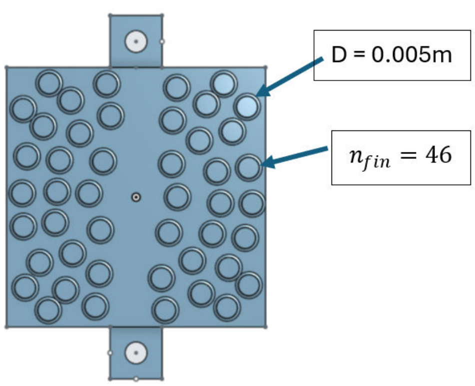
OnShape Link To Heat Sink: https://cad.onshape.com/documents/c673e787e011f79bab69ccfe/w/f450c74a4eccc78ba0366c2e/e/80abbc1ee4883264e70b9799?renderMode=0&uiState=66299b6a4f79e50426b41622

Now after testing the heat sink we have created, we have figured out that reducing the number of fins and creating a gap for the air to easily flow through reduced our total surface area of the heat sink and caused our FOM to go down in which we thought having a lower FOM was correct, but found out we wanted it higher.

Getting the correct dimensioning of our fins during the investment casting ended up being the biggest challenge of this whole project. Several resources have different opinions about thinnest dimensions that are castable. Overall, 5mm was a comfortable number we designed around.

Final Design

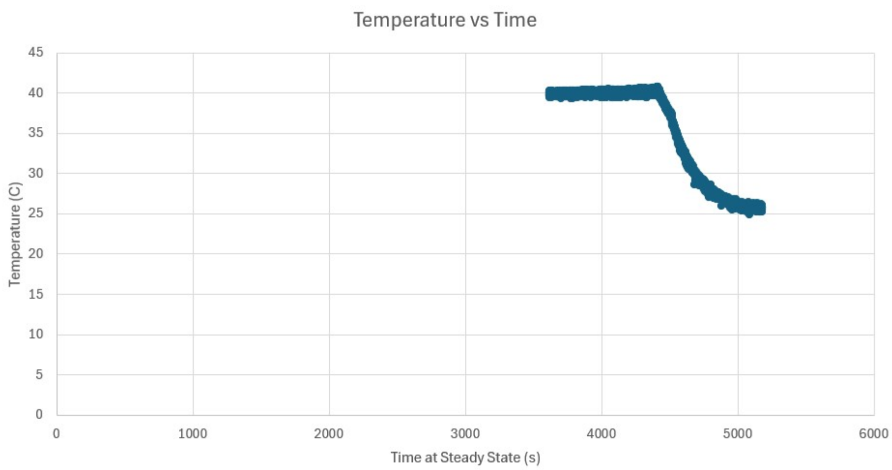




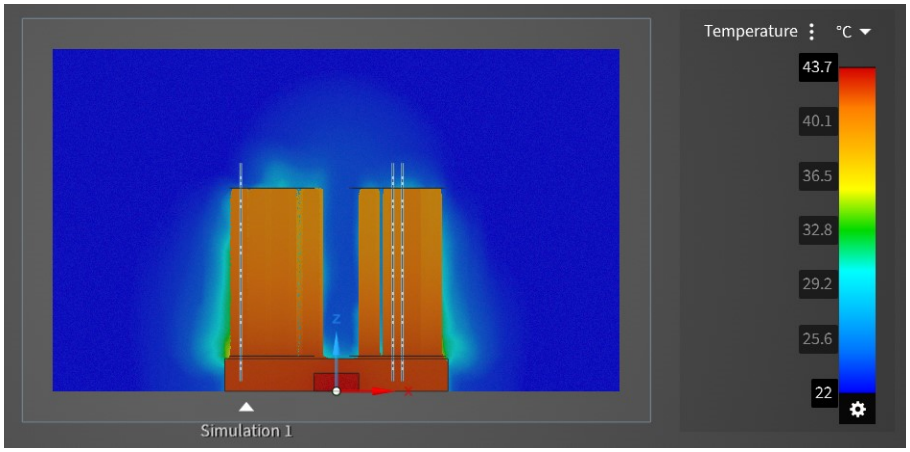
Final Simulation Images

We were able to run the simulation at the 1.5 and 6.5 m/s velocities and get data about 50 percent above the temp values recorded. If we dropped the Total heat in to 4 Watts then accurate simulations occurred. While that is a bit above an expected result, we concluded that the power supply wasn't sufficient.

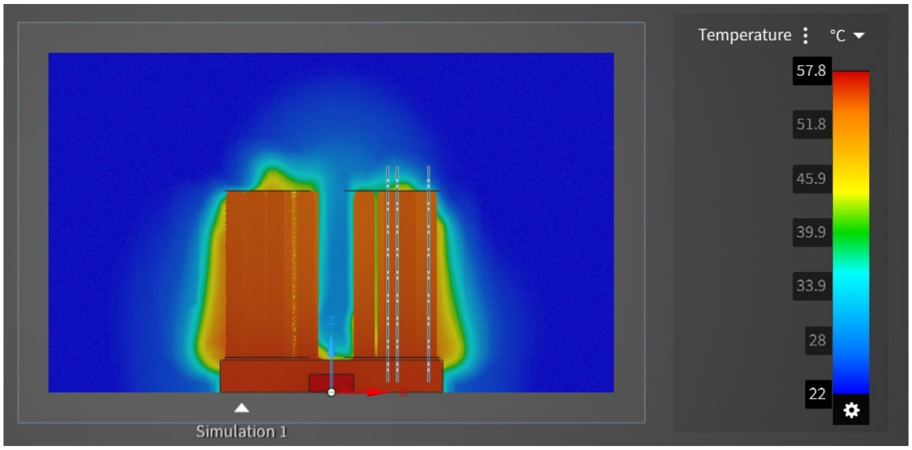
Experimental Data



$V_1 = 6.5\frac{m}{s}$



$V_2 = 1.5\frac{m}{s}$



Assumptions/Known:

$\dot{Q}_{\text{in}} = 16W$

$h = 30 \dfrac{W}{m^2 * K}$ for air at $1.5 \dfrac{m}{s}$

$h = 130 \dfrac{W}{m^2 * K}$ for air at $6.5 \dfrac{m}{s}$

$k = 168 \dfrac{W}{m * K}$ for cast aluminum

$\rho = 2790 \dfrac{\text{kg}}{m^3}$ for the cast aluminum

$T_\infty = 23^\circ C$

$\text{Volume}_{\text{hs}} = 4.0825 * 10^{-5}\, m^3$

$m_{\text{hs}} = 2790 \dfrac{\text{kg}}{m^3} * 4.0825 * 10^{-5}\, m^3 = 0.1139\,\text{kg}$

Neglect The Radiation and Contact Resistance

First Design Analysis:

$$\text{FOM} = \frac{1}{m_{\text{hs}}(R_1 - R_5)} = \frac{1}{(0.1139) * (1.2603 - 0.3524)} = 5.444$$

$$R_1 = \frac{T_b - T_\infty}{\dot{Q}}$$

$$R_5 = \frac{T_b - T_\infty}{\dot{Q}}$$

Convection Heat Transfer:

$$m = \sqrt{\frac{h * p}{k * \mathrm{Ac}}}$$

$$M = \sqrt{h * p * k * \mathrm{Ac}} * (T_b - T_\infty)$$

Fin Heat Transfer Rate:

$$T_b = \frac{\dot{Q}_{\mathrm{in}}}{\sqrt{h * p * k * \mathrm{Ac}} * \left(\frac{\sinh(\mathrm{mL}) + \left(\frac{h}{\mathrm{mk}}\right)\cosh(\mathrm{mL})}{\cosh(\mathrm{mL}) + \left(\frac{h}{\mathrm{mk}}\right)\sinh(\mathrm{mL})}\right)} + T_\infty$$

From the fin efficiency equation and Newton's cooling law we found a few areas to design around to maximize heat dissipation. To maximize the heat transfer coefficient, we determined that a circular pattern with staggered sinks would be best. We also initially thought it was also good to space the sinks out more to promote air flow through the fins.

Finally, the fin length was a contributing factor for design. After careful analysis, a longer fin length would have increased the dissipation. Due to the smaller volume, it was hard to make changes elsewhere to compensate.

```
format long
Qdot_in = 16;                                      %[W]
h_1 = 30;                                          %[W/m^2*K]
h_5 = 130;                                         %[W/m^2*K]
k = 168;                                           %[W/m*K]
rho = 2790;                                        %[kg/m^3]
T_inf = 23;                                        %[C]
D = 0.005;                                         %[m]
r = D/2;                                           %[m]
L = 0.038;                                         %[m]
Num_fin = 46
```

```
Num_fin =
    46
```

```
p = pi*D                                           %[m]
```

```
p =
   0.015707963267949
```

```
Ac = (pi/4)*(D)^2                                  %[m^2]
```

```
Ac =
     1.963495408493621e-05
```

```
mhs = .1139;                                       %[kg]

m_1 = sqrt(h_1*p/(k*Ac))
```

```
m_1 =
  11.952286093343936
```

```
m_5 = sqrt(h_5*p/(k*Ac))
```

```
m_5 =
  24.880667576405965
```

```
M_Big_1 = sqrt(h_1*p*k*Ac)*Num_fin
```

```
M_Big_1 =
   1.813627045109068
```

```
M_Big_5 = sqrt(h_5*p*k*Ac)*Num_fin
```

```
M_Big_5 =
   3.775365755515778
```

```
A_1 = sinh(m_1*L)+(h_1/(m_1*k))*cosh(m_1*L)
```

```
A_1 =
   0.486472125531701
```

```
A_5 = sinh(m_5*L)+(h_5/(m_5*k))*cosh(m_5*L)
```

```
A_5 =
   1.138824375839559
```

```
B_1 = cosh(m_1*L)+(h_1/(m_1*k))*sinh(m_1*L)
```

```
B_1 =
   1.111949600761481
```

```
B_5 = cosh(m_5*L)+(h_5/(m_5*k))*sinh(m_5*L)
```

```
B_5 =
   1.515240475007713
```

```
Tb_1 = (Qdot_in)/(M_Big_1)*(B_1/A_1) + T_inf
```

```
Tb_1 =
  43.165042509769677
```

```
Tb_5 = (Qdot_in)/(M_Big_5)*(B_5/A_5) + T_inf
```

```
Tb_5 =
  28.638787894315367
```

```
R_1 = (Tb_1-T_inf)/Qdot_in
```

```
R_1 =
   1.260315156860605
```

```
R_5 = (Tb_5-T_inf)/Qdot_in
```

```
R_5 =
   0.352424243394710
```

```
FOM = 1/(mhs*(R_1+R_5))
```

```
FOM =
   5.443924327822184
```

Here, the use of common fin configurations (pin fins on a rectangular profile) allowed for the use of the cylinder equations to help retreive the overall fin effectiveness which shows that the number calculated of 5.2758 is much greater than 1 which states that the fins are enhancing the heat transfer. The ratio of the perimeter (p) over the cross sectional area (Ac) is a large number of 800 which is one of the goals of creating effective fins.

<u>Equations Used Below</u>:

$$m_1 = \sqrt{\frac{4 * h_1}{k * D}} = \sqrt{\frac{4 * 30}{168 * 0.005}} = 11.952$$

$$m_5 = \sqrt{\frac{4 * h_5}{k * D}} = \sqrt{\frac{4 * 130}{168 * 0.005}} = 24.881$$

$$L_c = L + \frac{D}{4} = 0.038 + \frac{0.005}{4} = 0.03925\, m$$

$$A_{\text{fin}} = \pi * D * L_c = 6.165375 * 10^{-4}\ m^2$$

$$\eta_{\text{fin},1} = \frac{\tanh(m_1 * L_c)}{m_1 * L_c} = \frac{\tanh(11.952 * 0.03925)}{11.952 * 0.03925} = 0.9364 * 100\% = 93.64\%$$

$$\eta_{\text{fin},5} = \frac{\tanh(m_5 * L_c)}{m_5 * L_c} = \frac{\tanh(24.881 * 0.03925)}{24.881 * 0.03925} = 0.7802 * 100\% = 78.02\%$$

$$\frac{p}{\text{Ac}} = \frac{.01571}{1.963 * 10^{-5}} = 800$$

$$\varepsilon_{\text{fin,overall},1} = \frac{A_{\text{unfin}} + n_{\text{fin}}\eta_{\text{fin},1}A_{\text{fin}}}{A_{\text{nofin}}} = \frac{2.697 * 10^{-3} + (46 * 0.9364 * 6.1654 * 10^{-4})}{0.0036} = 8.1266$$

$$\varepsilon_{\text{fin,overall},5} = \frac{A_{\text{unfin}} + n_{\text{fin}}\eta_{\text{fin},5}A_{\text{fin}}}{A_{\text{nofin}}} = \frac{2.697 * 10^{-3} + (46 * 0.7802 * 6.1654 * 10^{-4})}{0.0036} = 6.896$$

```
A_nofin = 0.0036;
A_unfin = A_nofin - Num_fin*pi*(r)^2
```

```
A_unfin =
   0.002696792112093
```

```
Lc = L + (D/4)
```

```
Lc =
   0.039250000000000
```

```
A_fin = pi*D*Lc
```

```
A_fin =
     6.165375582669970e-04
```

```
m_com_1 = sqrt((4*h_1)/(k*D))
```

```
m_com_1 =
  11.952286093343936
```

```
m_com_5 = sqrt((4*h_5)/(k*D))
```

```
m_com_5 =
  24.880667576405965
```

```
n_fin_1 = (tanh(m_com_1*L)/(m_com_1*L))
```

```
n_fin_1 =
   0.936474734831827
```

```
n_fin_5 = (tanh(m_com_5*L)/(m_com_5*L))
```

```
n_fin_5 =
   0.780275256113397
```

```
ratio = p/Ac
```

```
ratio =
     8.000000000000001e+02
```

```
eff_fin_over_1 = (A_unfin+(Num_fin*n_fin_1*A_fin))/(A_nofin)
```

```
eff_fin_over_1 =
   8.126638068367372
```

```
eff_fin_over_5 = (A_unfin+(Num_fin*n_fin_5*A_fin))/(A_nofin)
```

```
eff_fin_over_5 =
   6.896101712885323
mhs =
   0.120388500000000
Vmax_5 =
     1.400000000000000e-04
Vmax_1 =
     2.800000000000000e-05
ReD_5 =
   0.043532338308458
ReD_1 =
   0.008706467661692
NuD_5 =
   0.294040596094034
NuD_1 =
   0.154461160252888
h_D_5 =
   1.521954125382720
h_D_1 =
   0.799490965468946
As =
   0.002120575041173
mdot_5 =
   0.001222200000000
mdot_1 =
     2.444400000000000e-04
Qdot_5 =
   0.025845863400000
Qdot_1 =
   0.005169172680000
bigratio =
```

```
     8.000000000000001e+02
lilratio =
   800
```