Liquid Cooling of Heat Sink

ME 334- Heat and Mass Transfer

Group - L

Presented by

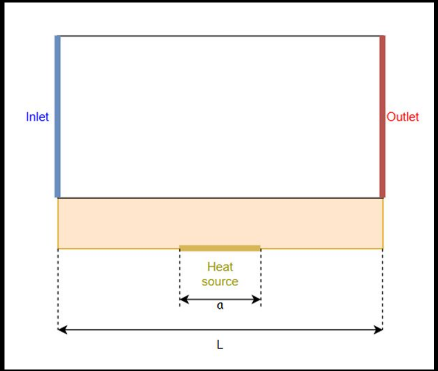
Kommanapalli Hemanth (23110170)

Korada Kusal Sai Charan (23110171)

Pilla Karthik Naidu (23110246)

Problem Statement

- A copper base plate with a rectangular cooling channel receives heat from a square heat source.
- Water enters the channel at a known temperature and different velocities.
- Fins of fixed height are added above the heat source in configurations of 1, 4, 9, and 16 fins (1 cm spacing) to enhance cooling.
- Our Goal is to Predict and simulate how fin count and inlet velocity affect solid temperature and overall heat transfer.



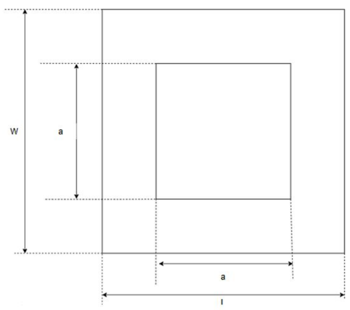


Figure 2

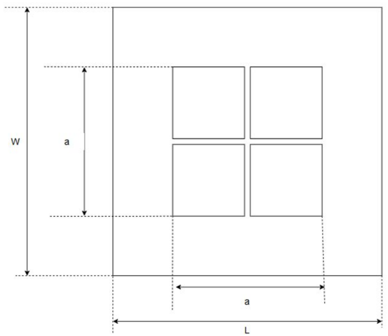


Figure 3

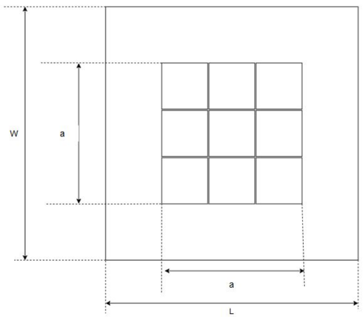


Figure 4

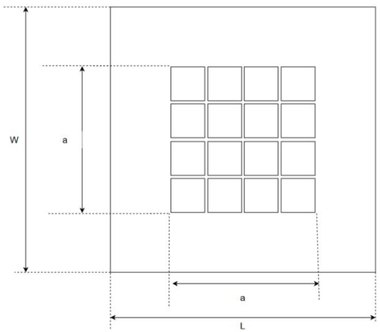


Figure 5

Formulae Used in Our Analysis

Assumptions (Same Theory for All Cases)

- Steady-state heat transfer
- One-dimensional conduction along fin length
- Uniform fin cross-section
- Constant material properties (k, h)
- Convection along fin surface **and tip**
- Temperature excess: $\theta = T - T_\infty$

Governing Fin Equation (Same for All 1,4,9,16 fin cases)

$$\boxed{\frac{d^2\theta}{dx^2} - m^2\theta = 0}$$

$$m^2 = \frac{hP}{kA_c}$$

Energy Balance on Fin Element

$$\text{Conduction in} = \text{Conduction out} + \text{Convection loss}$$

$$\Rightarrow \frac{d^2\theta}{dx^2} - \frac{hP}{kA_c}\theta = 0$$

Boundary Conditions

- **Base:** $\theta(0) = T_b - T_\infty$
- **Tip:** $-kA_c \left.\frac{d\theta}{dx}\right|_{x=L} = hA_c\theta(L)$

Temperature Profile & Mean Temperature (Using Same Theory for n Fins)

Temperature Profile

$$\frac{\theta(x)}{\theta_b} = \frac{\cosh[m(L-x)] + \left(\frac{h}{mk}\right)\sinh[m(L-x)]}{\cosh(mL) + \left(\frac{h}{mk}\right)\sinh(mL)}$$

Mean Fin Temperature

$$\bar{\theta} = \frac{1}{L}\int_0^L \theta(x)\,dx$$

$$\bar{T} = T_\infty + (T_b - T_\infty)\frac{\sinh(mL) + \left(\frac{h}{mk}\right)(\cosh(mL)-1)}{mL\left[\cosh(mL) + \left(\frac{h}{mk}\right)\sinh(mL)\right]}$$

How Geometry Enters for n Sub-Fins

When one fin is split into n fins:

$$A_c \to \frac{A_c}{n}, \qquad P \to \frac{P}{\sqrt{n}}$$

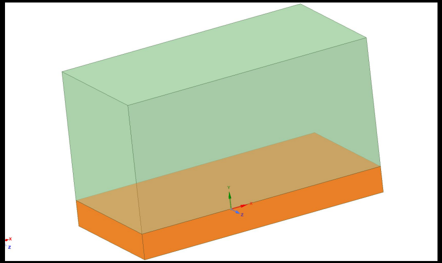
So the **fin parameter becomes:**

$$m_n^2 = \frac{h\,(P/\sqrt{n})}{k\,(A_c/n)} = m^2\sqrt{n}$$

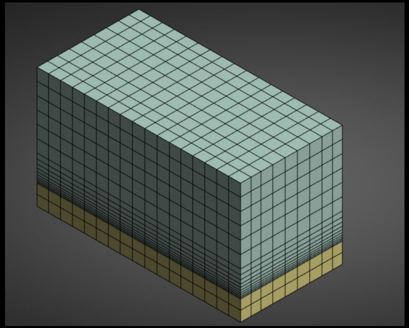
The formula stays the same, we only substitute the new m_n.

No Fin Case:

Mandatory Results (i)



Geometry



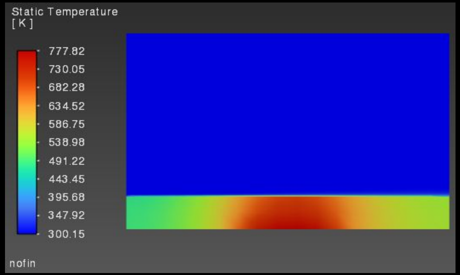
Mesh

Maximum temperature: 777.82 K

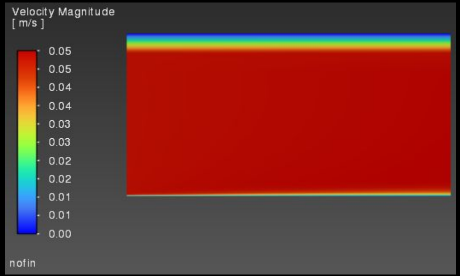
Solid average temperature : 592.36 K

Fluid average temperature: 300.9 K

Surface heat transfer coefficient: 314.87992 W/m^2-K

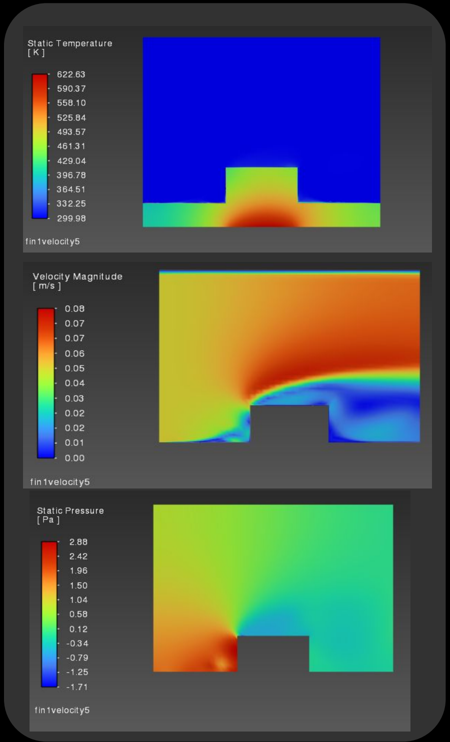


Temperature Distribution



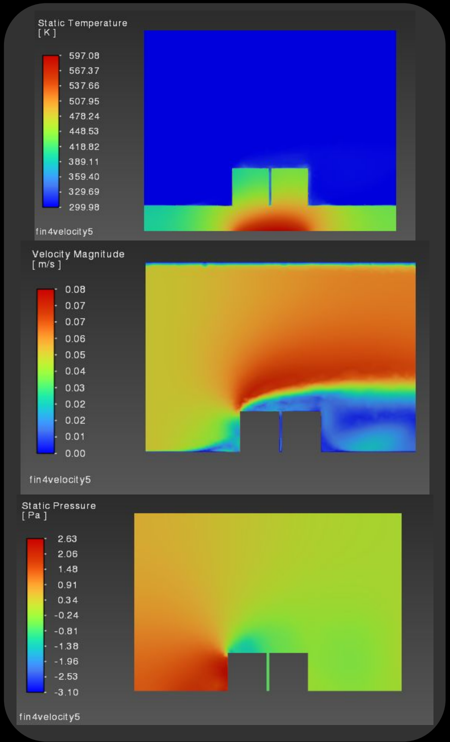
Velocity Distribution

Inlet Velocity : 5 cm/s , T_inlet = 300K



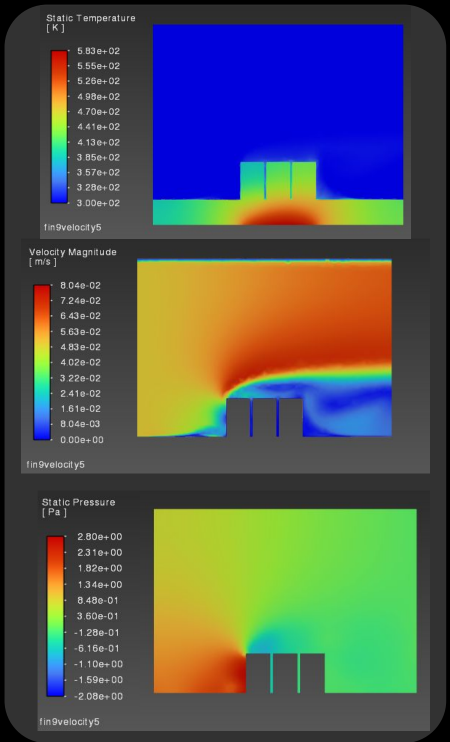
Single Fin

T_outlet = 301.08 K



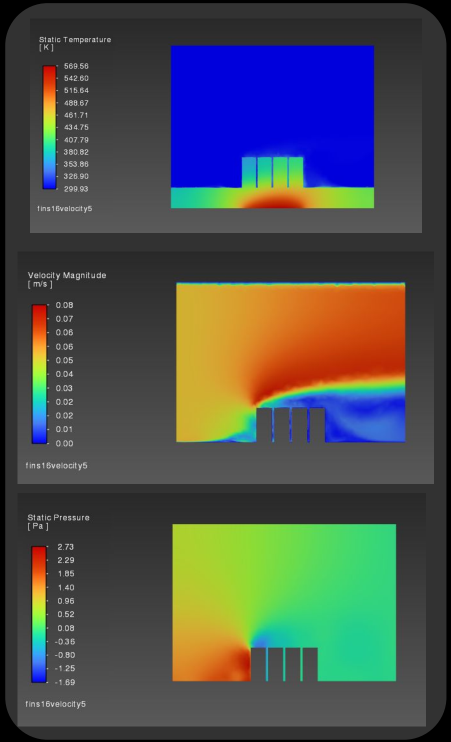
4 Fins

T_outlet = 301.085 K



9 Fins

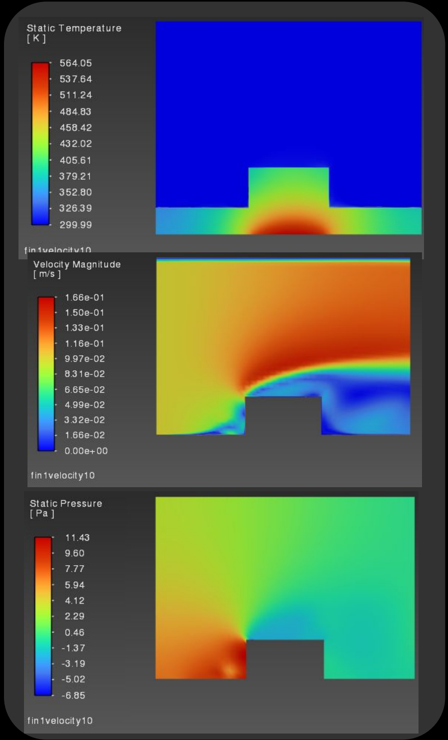
T_outlet = 301.16



16 Fins

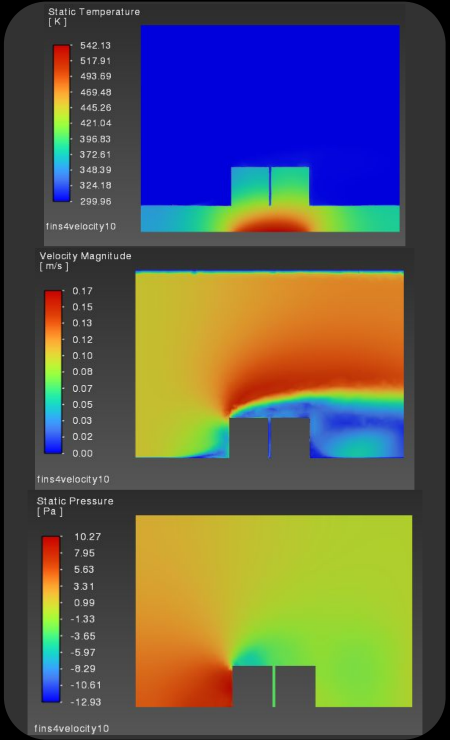
T_outlet = 301.177 K

Inlet Velocity : 10 cm/s



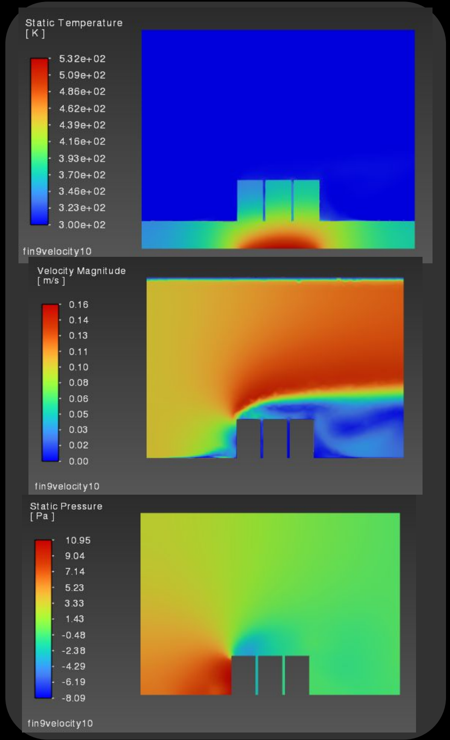
Single Fin

T_outlet = 300.54 K



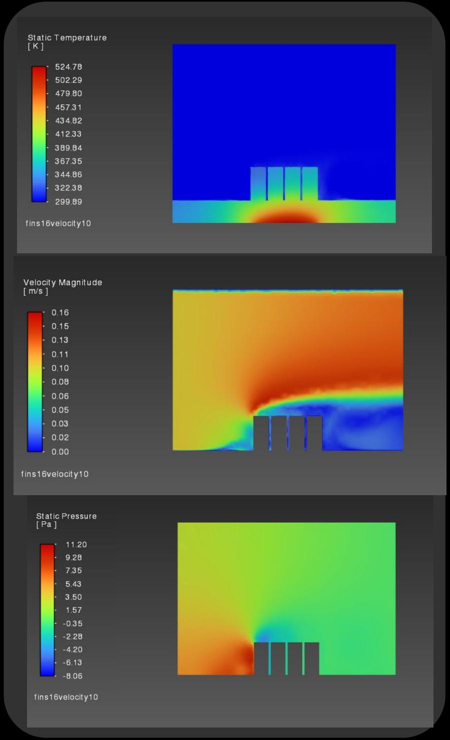
4 Fins

T_outlet = 300.57 K



9 Fins

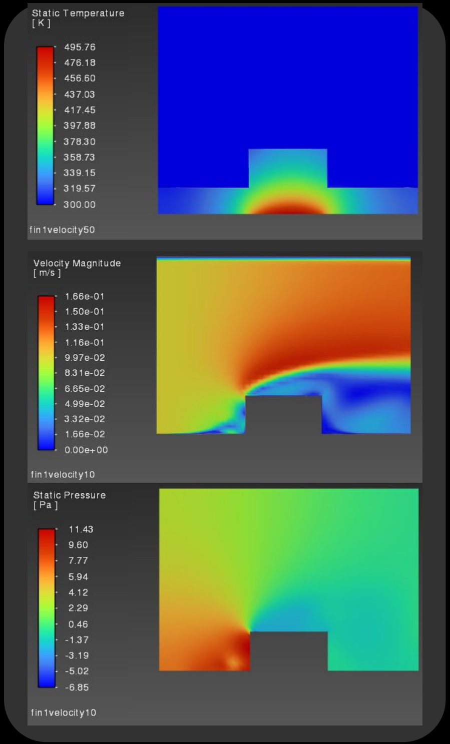
T_outlet = 300.58 K



16 Fins

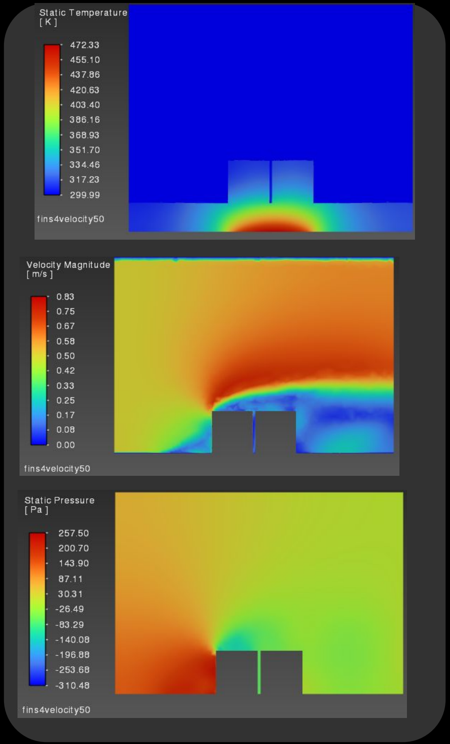
T_outlet = 300.59 K

Inlet Velocity : 50 cm/s



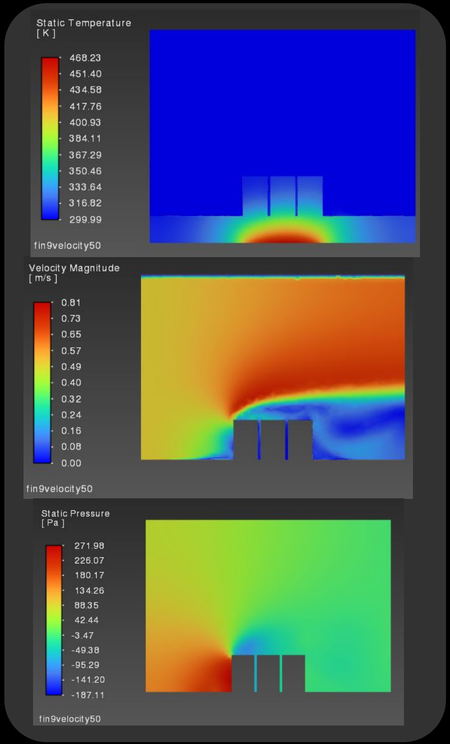
Single Fin

T_outlet = 300.09 K



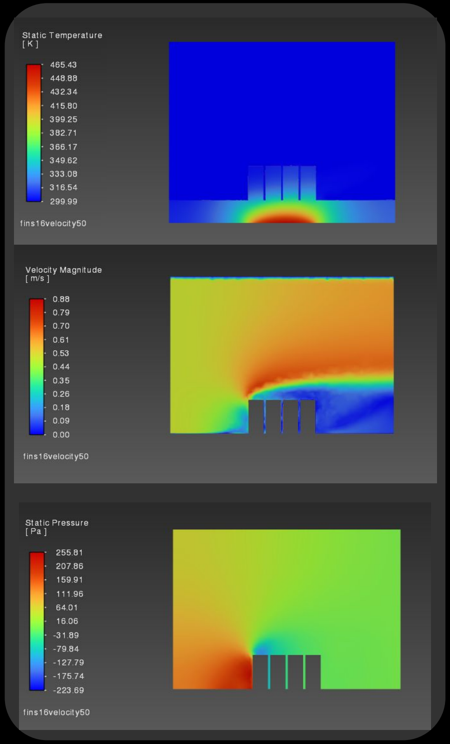
4 Fins

T_outlet = 300.116 K



9 Fins

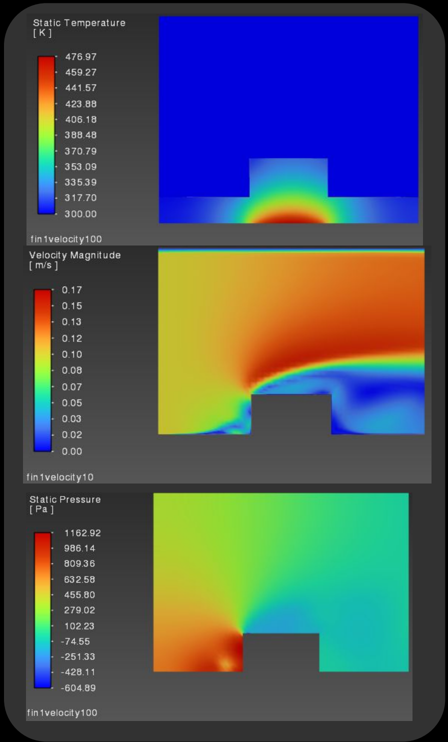
T_outlet = 300.117 K



16 Fins

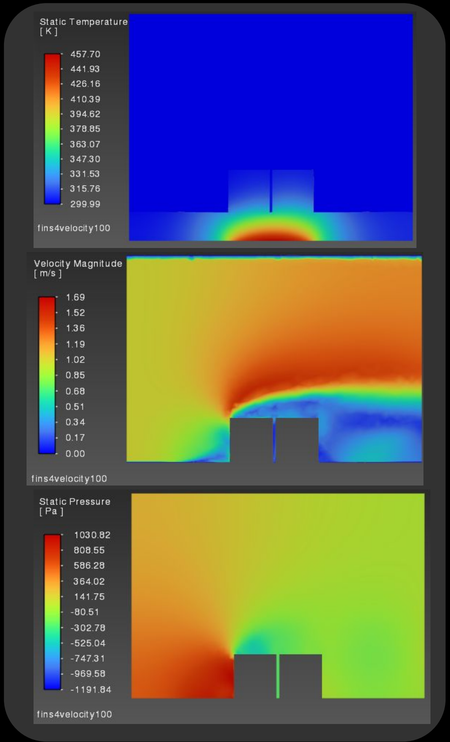
T_outlet = 300.123 K

Inlet Velocity : 100 cm/s



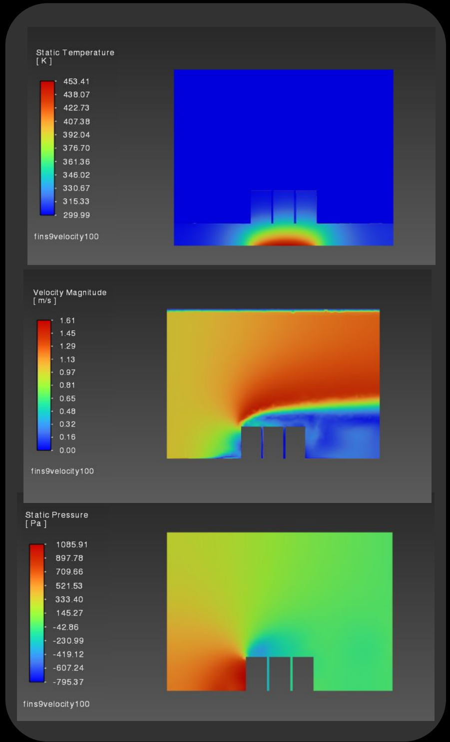
Single Fin

T_outlet = 300.049 K



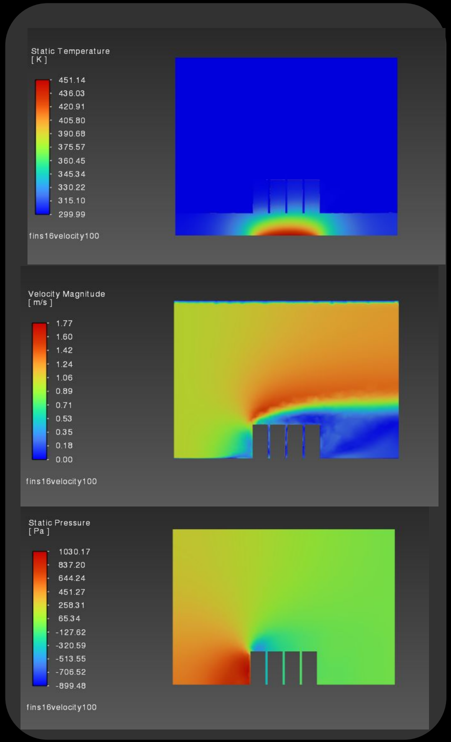
4 Fins

T_outlet = 300.063 K



9 Fins

T_outlet = 300.0749 K



16 Fins

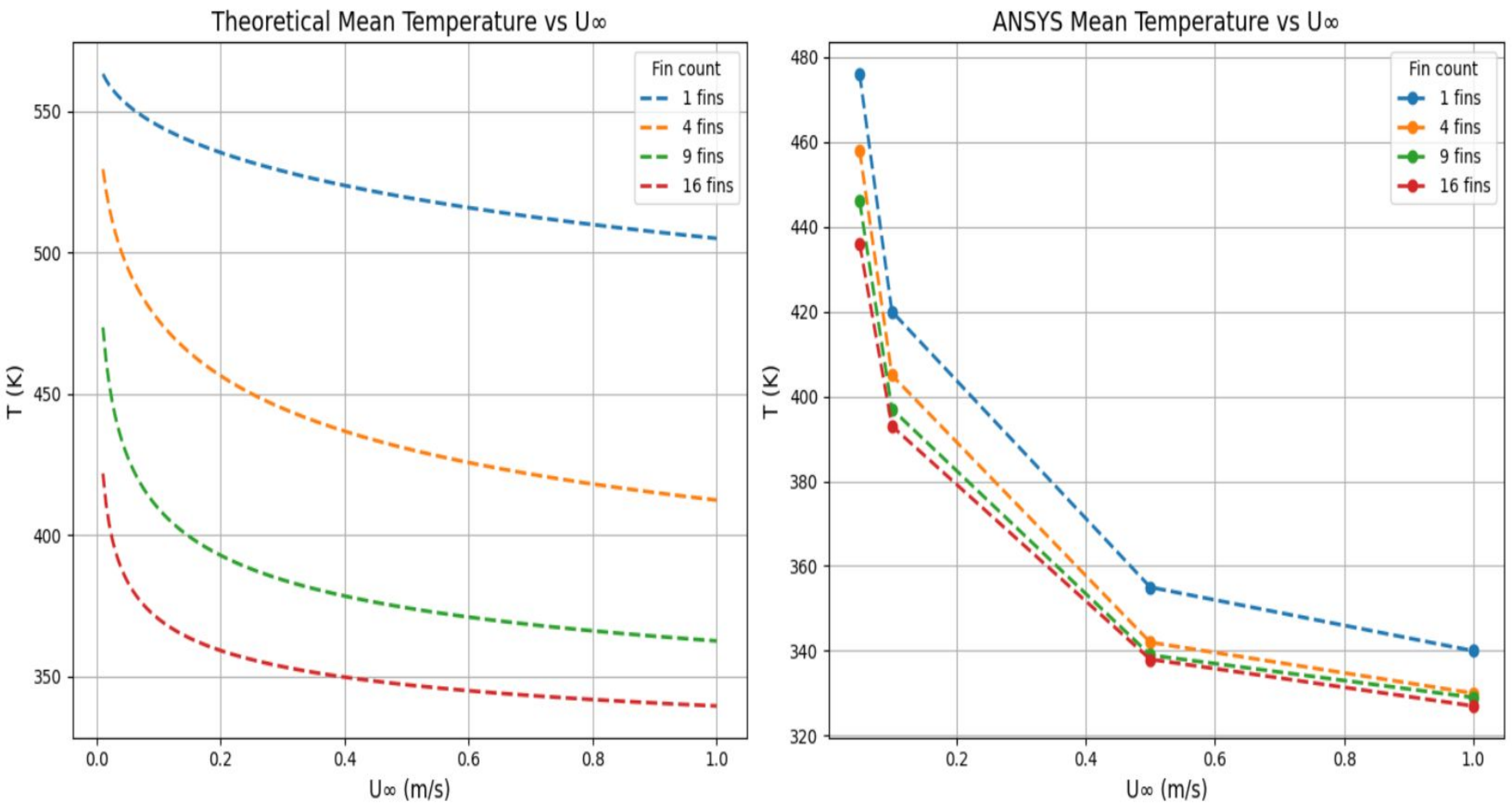
T_outlet = 300.08 K

ANSYS Data T_mean (K)

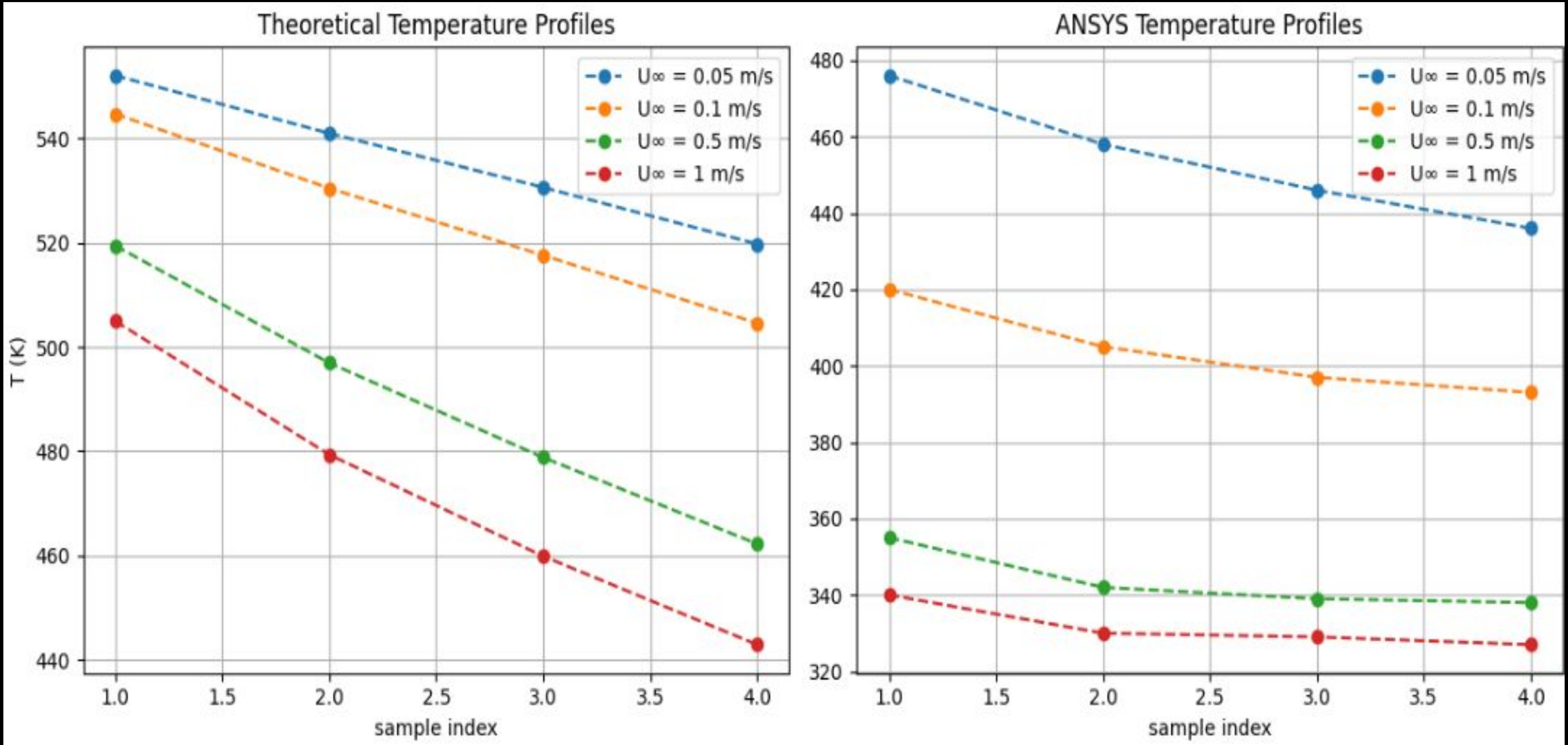
Fins →	1 fin	4 fins	9 fins	16 fins
U∞ = 0.05 m/s	476	458	446	436
U∞ = 0.10 m/s	420	405	397	393
U∞ = 0.50 m/s	355	342	339	338
U∞ = 1.00 m/s	340	330	329	327

Theoretical Data T_mean (K)

Fins →	1 fin	4 fins	9 fins	16 fins
U∞ = 0.05 m/s	512	503	494	485
U∞ = 0.10 m/s	506	494	483	472
U∞ = 0.50 m/s	485	466	451	437
U∞ = 1.00 m/s	473	451	435	420



Theoretical Mean Temperature vs U∞
ANSYS Mean Temperature vs U∞
Fin count
1 fins
4 fins
9 fins
16 fins
T (K)
U∞ (m/s)



NOTE :: Sample Index 1, 2, 3, 4 correspond to number fins 1, 4, 9 and 16 respectively