Indian Institute of Technology, Gandhinagar

Determination of Fin Shape with High-Efficiency

Group 8

Group Project Report
CL 204 Heat Transfer

Under the guidance of
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Team Members

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Introduction

In the modern world, heat transfer in devices and machines is crucial, particularly when it comes to surfaces with fixed temperatures. Newton's law of cooling helps us understand the rate of heat transfer, with the convection heat transfer coefficient (h), conduction coefficient (k), length (l), and the surface area (As) playing vital roles.

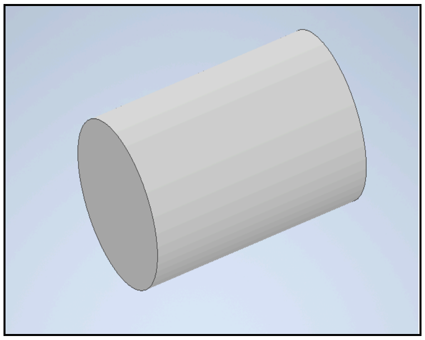
Fins are the surface that extend from an object that are mainly used to enhance heat transfer (HT) to or from the surrounding environment by convection. Fins are used in many different industries to control the heat in the industry. Fins are also mainly used in electrical appliances such as power stations, computers, and substation transformers. They are also used in cooling systems in IC engines such as car radiators.

This report explores the optimization of heat transfer by implementing fins and extended surfaces onto a base material, typically made of highly conductive materials like aluminum. Fins have the ability to significantly boost the heat transfer rate by expanding the surface area exposed to convection and radiation . These fins have been widely adopted, with different designs varying from traditional to groundbreaking, all with the ultimate goal of maximizing thermal efficiency.

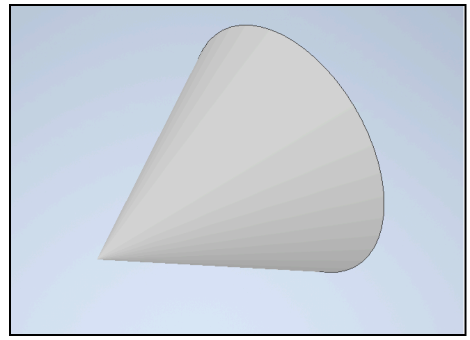
Understanding the temperature distribution along the fin or pin is crucial for determining the heat transfer from the surface to its surroundings. Since conduction and natural convection occur simultaneously from the surface, both of these effects must be considered in the analysis. We are neglecting the radiation because the value of the radiation factor would be much less from the other two factors.

Types of fins on which we will work are:

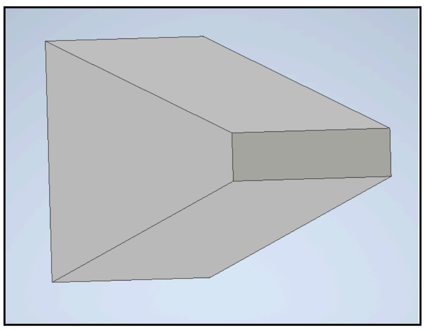
- Cylindrical pin fin
- Tapered profile pin fin
- Concave parabolic pin fin
- Variable area straight fin
- Annular fin
- Perforated fin (if time permits)



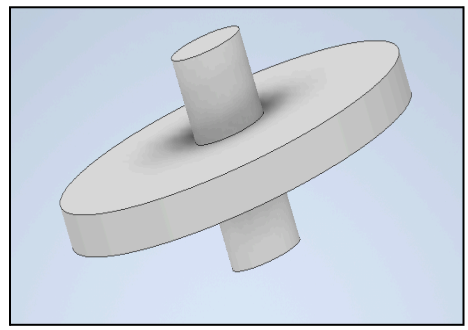
1.1 Cylindrical fin



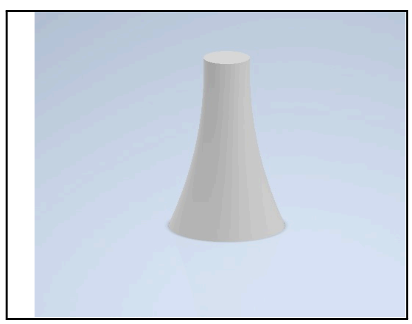
1.2 Tappered Pin Fin



1.3 Varying Cross Section



1.4 Annular fin



1.5 Concave Pin Fin

Project Statement

The objective of our project is to determine the optimal shape of fins that would yield the highest efficiency in heat transfer. We aim to analyze temperature profiles and identify the most efficient shape among three variations: cylindrical pin fin, tapered profile pin fin, and concave parabolic pin fin, Variable area straight fin. The aim of this project is to find a balance between convection heat transfer coefficient and surface area, considering the practical constraints associated with fluid motion and the potential drawbacks of excessive fin density.

Background Theory

Temperature Profile

If we consider a volume element of fin at location x having a length delta x, having a cross-section area A_c, and a perimeter of *p*. Under the steady state, the energy balance expressions as:

$$\begin{pmatrix} \text{Rate of } \textit{heat} \\ \textit{conduction} \text{ into} \\ \text{the element at } x \end{pmatrix} = \begin{pmatrix} \text{Rate of } \textit{heat} \\ \textit{conduction} \text{ from the} \\ \text{element at } x + \Delta x \end{pmatrix} + \begin{pmatrix} \text{Rate of } \textit{heat} \\ \textit{convection} \text{ from} \\ \text{the element} \end{pmatrix}$$

On evaluation we get the temperature profile equation for:

- **Infinitely Long Fin**

$$\frac{T(x) - T_\infty}{T_b - T_\infty} = e^{-ax} = e^{-x\sqrt{hp/kA_c}}$$

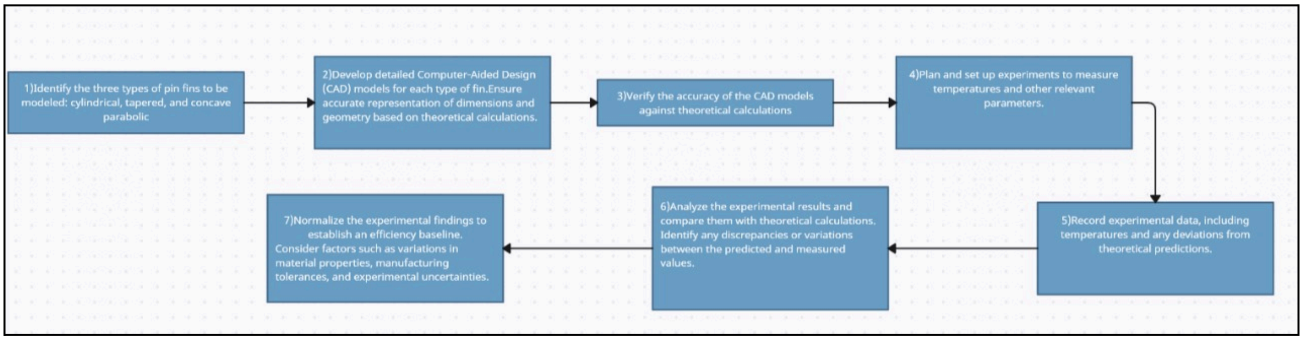
- **Adiabatic Tip**

$$\frac{T(x) - T_\infty}{T_b - T_\infty} = \frac{\cosh a(L - x)}{\cosh aL}$$

Fin Effeciency

$$\eta_{\text{fin}} = \frac{\dot{Q}_{\text{fin}}}{Q_{\text{fin, max}}} = \frac{\text{Actual heat transfer rate from the fin}}{\begin{array}{c}\text{Ideal heat transfer rate from the fin} \\ \text{if the entire fin were at base temperature}\end{array}}$$

Work Plan



1. First we identified different shapes of fins
2. Then we developed the CAD models for each type of fin.
3. We made sure that there is accurate representation of dimensions and geometry based on the theoretical calculations.
4. We verified the accuracy of the CAD models against theoretical calculations.
5. We then planned the experimental setup to measure the temperature and other measurements.
6. We will then record experimental data including temperatures and any deviations from theoretical predictions.
7. We will then analyze the experimental results and compare them with the theoretical calculations.
8. We will then identify the discrepancies.
9. After getting all the data, we will then normalize the readings and establish the efficiency relation.

Assumptions

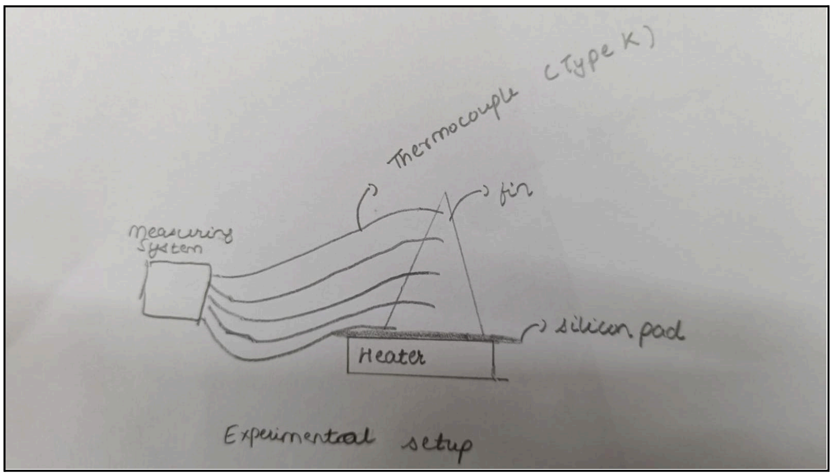
To create a tractable equation for the heat transfer of a fin, many assumptions need to be made:

1. Constant material properties (independent of temperature)
2. No internal heat generation
3. One-dimensional conduction
4. Steady State
5. Radiation is neglected
6. Adiabatic tip (for theoretical calculations)

Experimental Setup

Approach 1

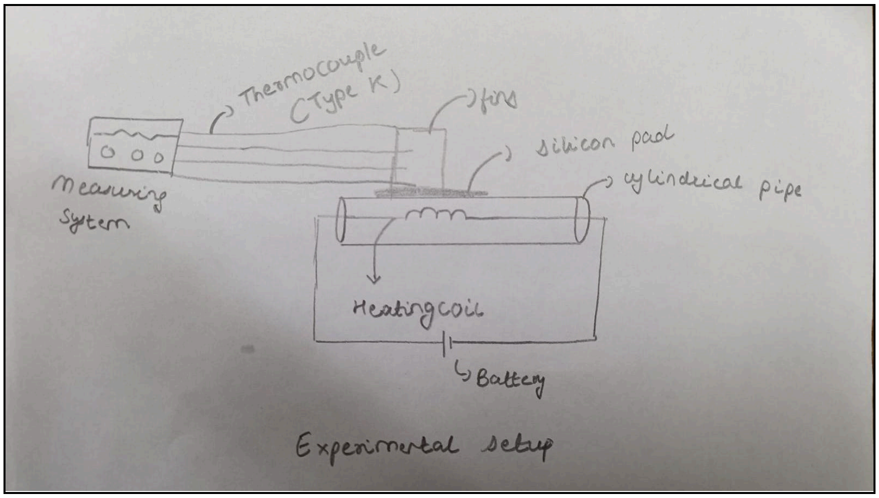
We plan to use a hollow aluminum pipe as the base for our experiment. Inside the pipe, we will place a coiled heater to ensure a consistent heat supply. To enhance the surface area for heat dissipation, we intend to weld aluminum fins of various shapes, such as cylindrical, parabolic, tapered, etc., at different positions along the pipe. These fins will be exposed to the surrounding air. To measure the temperature distribution on the surface of these fins, we will attach thermocouples at regular intervals, both at the base and along the extended parts of the aluminum fins. This setup will allow us to analyze and visualize the temperature profiles associated with different fin shapes. By plotting these profiles, we can determine the efficiency of each fin design.



Approach 1

Approach 2

In this method, we will utilize heating silicon pads as the foundation for heat sink beds. The heater will be linked to these pads, generating heat that will serve as the heat source. Aluminum fins will be directly affixed to these pads. Subsequently, thermocouples can be attached to both the pads and the extended aluminum fins to gauge temperature. The temperature profiles of distinct fin shapes can then be analyzed. By comparing the efficiency of various fins, we can identify the fin design that exhibits the highest efficiency.



Approach 2

BUDGET:

Material	Cost
Heater	(Available from sett lab)
Aluminum Rods	(Available from machine shop) + 1000 (tentative)
Perforated aluminum sheet	(not known)
Polyimide tape	200
Machine shop equipments	(Available from machine shop)
Thermocouple type K	150*5 = 750
Aluminum foil	70
Connecting Wires	210
Pipe	350
Heating rod	1X249=249/-
Miscellaneous	1000

Total cost : Rs 3900 (approximately)

REFERENCES:

[1]“Fin (extended surface),” *Wikipedia*, Nov. 14, 2022. https://en.wikipedia.org/wiki/Fin_(extended_surface)#:~:text=In%20the%20study%20of%20heat

[2]APA. Cengel, Y. A., & Ghajar, A. J. (2014). Heat and mass transfer: Fundamentals and applications (5th ed.). McGraw-Hill Professional.