THERMAL AND PARAMETRIC ANALYSIS OF PIN-FIN: VOL 1

Karan Sangaj[1], Sudarshan Shinde[2], Aditya Suryawanshi[3], Rameez Shanediwan[4], Apurva Potdar[5]

[1,2,3,4,5] UG , Department of Mechanical Engineering , KIT's College of Engineering , Kolhapur , India.

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Abstract - *The purpose of this study is firstly to give an overview of the Fins and description of recent improvement of fin geometries that increase the heat transfer rate. The objective or main purpose of this project is to improve the performance of the fins using different geometry and material. In recent years, advance devices generate and dissipate tremendous amount of heat and power. For many cooling applications these devices has become a major challenge. Older style heat sinks were often insufficient for cooling newer, hotter running components. So for determining optimum fin geometry, we have considered different shapes (rectangular, circular, tapered, conical, parabolic etc.) and different materials (copper, aluminum, mild steel, brass, stainless steel). Through analysis of different pin-fin geometries (combination of one of the shapes with different material), we have calculated heat transfer rate and optimized with all aspects to get higher heat transfer rate. In the present work, Experiments have been conducted to find the temperature distribution within the pin fin made of different material and geometries and steady state heat transfer analysis has been carried using a finite element software ANSYS to test and validate results. The temperature distribution at different regions of pin fin are evaluated by FEM and compared with the results obtained by experimental and analytical work. The principle implemented in this project is to increase the heat dissipation rate by using the invisible working fluid, nothing but air. We know that, by increasing the surface area we can increase the heat dissipation rate. The main aim of the project is to optimize the thermal properties by varying geometry, material and thickness of fins.*

***Key Words*: Thermal Analysis, Pin-Fin, Optimization, Parametric Analysis, Heat Transfer, ANSYS, Material Selection.**

1. INTRODUCTION

Extended surface heat transfer is the study of high performance heat transfer components with respect to parameters and their behaviour in a variety of thermal environments [1]. An extended surface is a solid within which heat transfer by conduction is assumed to be one dimensional, while heat is also transferred by convection from the surface in a direction transverse to that of conduction. Fins are used to increase the heat transfer rate from surface to the surrounding fluid. Familiar examples are the circumferential fins around the cylinder of motor cycle engine & pin fins attached to the condenser tubes at the back of domestic refrigerator. In present pin-fins are normally used in different shapes & sizes depending upon its applications. It is obvious that a fin surface sticks out from the primary heat transfer surface. The temperature difference with surrounding fluid will steadily diminish as one move out along the fin. The design of the fins therefore required knowledge of the temperature distribution in the fin .Fins are quite often found in industry, especially in heat exchanger industry as in finned tubes of double-pipe, shell and-tube and compact heat exchangers [2]. As an example, fins are used in air cooled finned tube heat exchangers like car radiators and heat rejection devices. Moreover, fins are also utilized in cooling of large heat flux electronic devices as well as in cooling of gas turbine blades. Fins are also used in thermal storage heat exchanger systems including phase change materials. To the best knowledge of the, fins as passive elements for enhancing heat transfer rates.

2. OBJECTIVES

1. To Increase in Heat transfer rate by varying pin-fin geometry and material for analytical investigation.

2. To vary the air flow rate over the pin-fin surface for increasing the efficiency.

3. To select best Suitable pin-fin from various materials and geometry of pin-fin experimented.

3. DESIGN PARAMETERS

Once the system constraints are determined, design parameters are to be considered. In order to obtain the minimum thermal resistance and pressure drop, parameters must be designed well.

3.1 MATERIAL SELECTION

Metals with high thermal conductivity and relatively low cost are preferred, like aluminum and steel. Combinations of different materials are possible like the use of aluminum fins bonded to a copper base. Research shows, thermal Resistance of the pin-fin is decreased when base plate material was copper as compare to aluminum. This is due to higher thermal conductivity of copper. However, this makes the pin-fin more expensive and heavy. Generally material which are good conductor of heat are used for pin fin such as copper (k= 398w/mk) but sometimes aluminum (k= 238 w/mk) is preferred due to its low cost &weight. Thermal performance is better in case of copper but it has high cost compared with aluminum so copper is used when temp is reduced in large amount otherwise aluminum fins are used. Another material used for fin is mild steel. The thermal conductivity of mild steel is 54 W/m ^{o}C. The melting and boiling point of mild steel is 1427 ^{o}C. Mild steel has silvery colour and it has greater resistance to corrosion. It is used to deoxidizing molten irons and steel. It is used to prepare the metals from their oxides by heating a mixture of powdered aluminium and the oxides of the metal to be reduced. Its electrical resistivity is 2.669 micro ohms/cm.

3.1.1 SPECIFICATIONS OF MATERIALS

Sr. No.	Material	Thermal Conductivity (K)	Temperature Expansion Coefficient (α) 10^{-6}	Density (ρ)
		(W/m-k)	(m/m°C)	(kg/m3)
1.	Copper	385	16 - 16.7	8940
2.	Aluminium	205	21 - 24	2700
3.	Brass	109	18 - 19	8553
4.	Steel	50.2	11 - 12.5	7850
5.	Iron	79.5	10.4 - 11	7850

TABLE 1: Specifications of Materials

3.2 FIN SHAPES

Different kinds of pin-fin geometries are possible. Straight fins, fluted fins, wavy fins and fins with non-standard geometry are possible. The most common ones are pin-fins whose cross section can be round, square, hexagonal, elliptical, or any other suitable geometry. There are mainly two types of fin profiles used in conventional pin-fin design–rectangular fins and circular pin-fin. Results show that total heat transfer rate of rectangular plate fins is greater than cylindrical pin-fins with same dimensions and other control parameters. Rectangular fins are 40% more effective than cylindrical pin-fins for same dimensions.

3.3 AIR FLOW DIRECTIONS

There are two ways in which air can flow over pin-fin, by pushing air over pin-fin or by pulling out the air from pin-fin. For pin-fin that was investigated (rectangular fin), pushing air gives better performance when fin density is low and Pulling air gives better performance when the fin density is high.

3.4 FLOW CROSS SECTIONAL AREA

Designing a pin-fin with a smaller cross sectional area, the flow area creates the by-pass of air. Since some of the air delivered by the blower will not participate in the heat transfer, efficiency is reduced.

4. FACTORS AFFECTING THE PERFORMANCE OF HEAT TRANSFER

1) Shape of pin fin (cross-section of fin).

2) Geometric parameters (diameter, length, aspect ratio, void fraction).

3) Number of fins.

4) Material of pin fin.

5) Shroud clearance (bypass factor).

6) Nature of fluid flow (natural or forced).

7) Location of fan/Blower in case of forced convection i.e. velocity of flowing fluid.

8) Type of flowing fluid.

9) Surface finish of the fins.

10) Inclination of fins.

5. INSTRUMENTATION

In instrumentation section we are discussing the main parts used for experimental setup. Various parts like ammeter, voltmeter, temperature indicator, thermocouple an anemometer. Each one of this part is discussed in detail below.

5.1 TEMPERATURE INDICATOR

FIG 1: Temperature Indicator

Digital Temperature Indicator with range: 0- 300 ^{0}C and Resolution 0.1^{0}C is used for measurement. Eight different thermocouple readings can be measured.

5.2 AMMETER

An ammeter of 0 to 2 A with resolution 0.01A is used for measurement. They are connected in the series with the circuit whose current is to be measured. The power loss in an ammeter is (I^2.Ra) where I is the current to be measured Ra is the resistance of the ammeter therefore ammeter should have low electrical resistance so that they cause a small voltage drop and consequently absorb small power.

FIG 2: Ammeter

5.3 VOLTMETER

A digital voltmeter of 0 to 750 Volts A.C. with resolution 0.1 Volt is used. They are connected in parallel with the circuit whose voltage is to be measured .the power loss in voltmeter is (V^2/Rv), where V is the voltage to be measured and Rv is the resistance of the voltmeter. Therefore voltmeters should have a high electrical resistance, in order that the current drawn by them is small and consequently the power consumed is small.

FIG 3: Voltmeter

5.4 THERMOCOUPLE

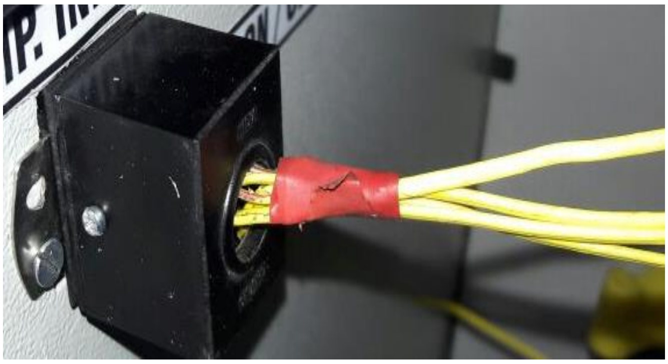


FIG 4: Thermocouple

A thermocouple is a device used extensively for measuring temperature. A thermocouple is comprised of at least two metals joined together to form two junctions. One is connected to the body whose temperature is to be measured; this is the hot or measuring junction. The other junction is connected to a body of known temperature; this is the cold or reference junction. Therefore the thermocouple measures unknown temperature of the body with reference to the known temperature of the other body.

WORKING PRINCIPLE

The working principle of thermocouple is based on three effects, discovered by Seebeck, Peltier and Thomson. They are as follows:

1) Seebeck effect: A thermocouple is a device for the measurement of temperature. Its operation is based upon the findings of seeback (1821) [3]. The Seebeck effect states that when two different or unlike metals are joined together at two junctions, an electromotive force (EMF) is generated at the two junctions. The amount of EMF generated is different for different combinations of the metals.

2) Peltier effect: As per the Peltier effect, when two dissimilar metals are joined together to form two junctions, EMF is generated within the circuit due to the different temperatures of the two junctions of the circuit. When an electric current flows across a junction of two dissimilar conductors, heat is liberated or absorbed [4].

3) Thomson effect: The Thomson effect is defined as the change in the heat content of a single conductor of unit cross section when a unit quantity of electricity flows along it through a temperature gradient of 1 K [5].

5.5 ANEMOMETER

An anemometer is a device used for measuring wind speed, and is a common weather station instrument. The maximum measuring capacity of Anemometer is 30m/s. this is mainly used for measuring velocity of air for forced convection setup.

FIG 5: Anemometer

6. MANUFACTURING PROCESS OVERVIEW

FIG 6: Manufacturing Process

7. EXPERIMENTAL SETUP

A fin of circular cross section in fitted across a long rectangular duct. The side end of the duct is connected to the suction side of a blower and the air flows past the fin perpendicular to the axis. One end of the fin is projected to the square plate mica heater. Temperature measured at four points along the length of the fin. The air flow rate is measured by an anemometer. Current and voltage is measured by ammeter and voltmeter respectively which is fitted on the control panel. Dimmer stat is also mounted on control panel which is used to vary the heat input to the base of fin. A block of 40 mm diameter and 20 mm length is provided to mount the fin. Loose running fit is provided to mount the fin to the aluminium base plate. Mica square plate heater is fitted on the block.

7.1 MAIN PARTS OF SETUP

Sr. No.	PART NAME	QUANTITY
1	Frame	1
2	Blower	1
3	Ammeter	1
4	Voltmeter	1
5	Dimmer stat	1
6	Temperature Indicator	1
7	Fins	1
8	Thermocouple	8
9	Electrical Material	10 m
10	Acrylic glass	1
11	Switches	2
12	Valve	1
13	Dimmer for fan	1

TABLE 2: Main Parts of Setup

7.2 BALL VALVE

A ball valve is a form of quarter-turn valve which uses a hollow, perforated and pivoting ball to control flow through it. It is open when the ball's hole is in line with the flow and closed when it is pivoted 90-degrees by the valve handle. The handle lies flat in alignment with the flow when open, and is perpendicular to it when closed, making for easy visual confirmation of the valve's status.

FIG 7: Ball Valve

7.3 BLOWER

The blower used, operates on 1HP motor. Dual function blower with blowing and extracting functions.

FIG 8: Blower

7.4 DIMMER (FOR BLOWER)

The fan regulator is equipped with silver coated brass terminals and is compliant with IP20 specification.

FIG 9: Dimmer (For Blower)

7.5 DUCT

The duct is rectangular shaped of dimension 200mm x250mm cross section. Length duct is 200 mm. The material used for duct manufacturing is Mild Steel.

FIG 10: Duct

7.6 HEATER PLATE

The heater plate is a square plate mica heater of 35 mm x 35 mm.

FIG 11: Heater Plate

7.7 FUSE

A fuse is a type of low resistance resistor that acts as a sacrificial device to provide over current protection, of either the load or source circuit. Its essential component is a metal wire or strip that melts when too much current flows through it, interrupting the circuit that it connects.

FIG 12: Fuse

7.8 FIN

Material of Fins are mild steel, copper or aluminium used with variable dimension. Four thermocouples of K type are fitted on the length of fin for temperature measurement at equal interval respectively from base plate.

FIG 13: Fin

7.9 FRAME

Material of frame is mild steel. Frame has dimension of 55 inch height, 20 inch width and 28 inch length.

FIG 14: Frame

7.10 FINAL SETUP

FIG 15: Final Setup

8. EXPERIMENTATION

8.1 SCHEMATIC DIAGRAM OF PIN FIN SETUP

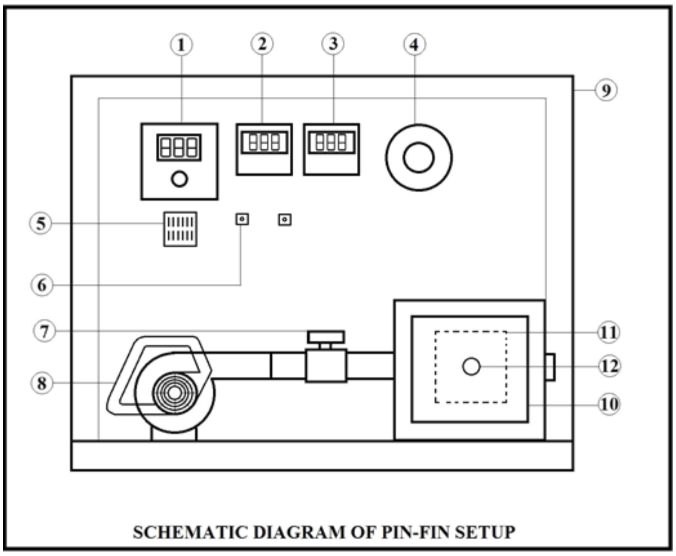


FIG 16: Schematic Diagram of Pin Fin Setup

SR NO	PART NAME
1	TEMP INDICATOR
2	VOLTMETER
3	AMMETER
4	DIMMERSTAT
5	12 WAY SWITCH
6	ON/OFF SWITCH
7	BALL VALVE

8	BLOWER
9	MAIN FRAME
10	DUCT
11	HEATER PLATE
12	PIN-FIN

TABLE 3: Parts Specifications

8.2 WORKING OF EXPERIMENTAL SETUP

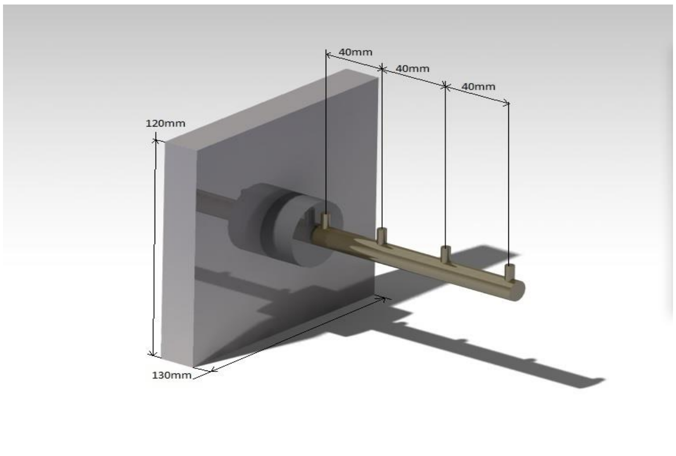
To study the temperature distribution along the length of a pin fin with forced convection, the procedure is as follows:

1. Insert the required fin and make proper connections.
2. Switch on the main supply
3. Start heating the fin by switching ON the heater
4. Adjust dimmer stat voltage equal to 80 volts.
5. Wait for 20 minutes and adjust the voltage to 60 volts.
6. Wait to obtain the steady state condition.
7. Start the blower and measure air flow by anemometer.
8. Note down the thermocouple readings (1) to (4) at a time interval of 5-10 minutes.
9. When the steady state is reached, record the final reading (1) to (4).
10. Repeat the same experiment with different air flow readings.
11. Remove the fin when it is cooled.

8.3 PRECAUTIONS

1. See that the dimmer stat is at zero position before Switching ON the heater.
2. Operate the changeover switch of temperature indicator, gently.
3. be sure that the steady state is reached before taking the final reading.

8.4 LINE DIAGRAM OF PIN-FIN



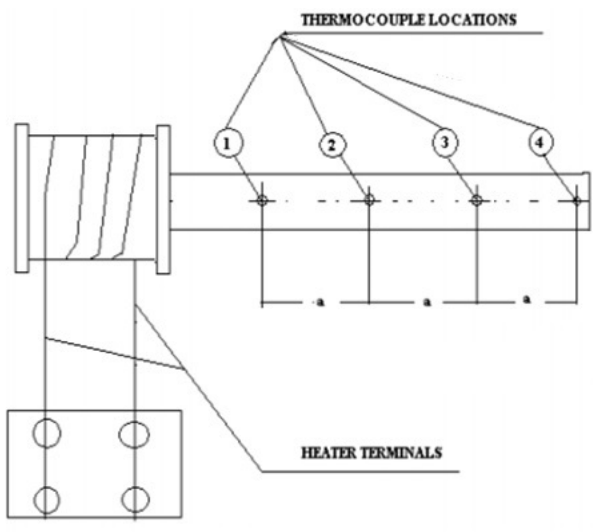


FIG 17: Line Diagram of Pin-Fin

9. CONCLUSION

In this volume we have discussed the objectives, design parameters and factors affecting the performance of heat transfer. We have also discussed the manufacturing process, instrumentation and working of experimental setup. Design parameters such as material selection, fin shapes, air flow directions and flow cross section area are discussed above.

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