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EXPERIMENTAL AND NUMERICAL ANALYSIS OF HEAT TRANSFER THROUGH FINS

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Abstract: Employing extended surfaces, or 'fins', are, undoubtedly the most widely used method for dissipation of excess heat generated in reciprocating and rotary machine components. Moreover the amount of heat extracted by a fin from the machine surface depends, to a great extend, on the cross sectional shape. This research (project), titled "Experimental and Numerical Analysis of Heat Transfer Through Fins" aims at studying the said dependence of a fins thermal dissipation capacity on its geometry. For simplicity, the most commonly used cylindrical pin fin, or spine was used as a standard and the characteristics' of three alternative shapes were compared against those of the former. Furthermore, to prove the consistency of the trend, experiments were carried out on two materials aluminum and copper. The investigation helps understand how fin shapes affect their behavior and could lend an insight into realizing the utility of each fin from a designers perspective.

Keywords: Experimentation, Problem Analysis, Design Apparatus, Procedure, Observation Table, Conclusion

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INTRODUCTION

In the study of heat transfer, a fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases

the heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to an object, however, increases the surface area and can sometimes be an economical solution to heat transfer problems. Typically fin material has high thermal conductivity and so they are made up of materials like copper, aluminum and iron. The fin is exposed to flowing fluid which cools or heats with high thermal conductivity allowing the heat being conducted from the wall through surface. Thus fins are used to enhance convective heat transfer in a wide range of engineering applications, and offer a practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface area. Fins are commonly applied for heat management in electrical appliances such as computer power supplies or substation transformers. Other applications include IC engine cooling, such as fins in a car radiator and compressors. Fins are also used in newer technology such as hydrogen fuel cells. Fins improve heat transfer in two ways as follows: i. Creating turbulent flow through fin geometry which reduces thermal resistance (inverse of convective heat transfer co-efficient) through the nearly stagnant filmthat forms when a fluid flows parallel to a solid surface. ii. Increasing fin density which increases the heat transfer area that comes in contact with the fluid. Fins come in varying shapes and sizes. Different types of fins available are cylindrical, parabolic, conical, trapezoidal, annular, step fin, rectangular etc. The project investigates the behavior of fins of uniform and varying cross sections and aims to determine which of the four used fins is the most effective in dissipating heat to its surroundings. to a solid surface. ii. Increasing fin density which increases the heat transfer area that comes in contact with the fluid. Fins come in varying shapes and sizes. Different types of fins available are cylindrical, parabolic, conical, trapezoidal, annular, step fin, rectangular etc. The project investigates the behavior of fins of uniform and varying cross sections and aims to determine which of the four used fins is the most effective in dissipating heat to its surroundings.

MATERIALS AND METHOD

NATURAL CONVECTION: Natural convection is a mechanism, or type of heat transport, in which the fluid motion is not generated by any external source but only by density differences in the fluid occurring due to temperature gradients.

FORCED CONVECTION: Forced convection is a mechanism, or type of transport in which fluid motion is generated by an external source.

EXPERIMENTATION AND PROBLEM ANALYSIS: The experiment is carried out to find out the actual temperature profile for each fin and subsequently, compare them for their effectiveness. For this, the setup is constructed as explained in the following section. Four fins of different cross-sections are attached to a base plate of the same material.

DESIGN OF APPARATUS : The experimental setup consists of the following components:

2 nos. Single Phase 230V AC supply, 2 nos. Heating apparatus (350W, 230V, 1.515A), 27 nos. Thermocouples (PT-100), Electrical Panel, Galvanized Iron Duct, Base plate and fin assembly, Bosch SKIL Blower. Details of apparatus are as follows:

BASE - FIN ASSEMBLY: For the study of heat transfer through fins using different surfaces and cross section four 3D shapes have been taken and are manufactured.

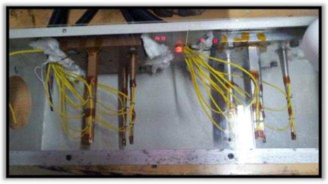

Figure 1 : Base - Fin Assembly

The shapes are: Cylindrical, Conical, Concave parabolic, Trapezoidal For the consideration of change of heat transfer due to conductivity two materials are used. The materials are: Aluminum (Lower conductivity), Copper (Higher conductivity)

ELECTRICAL PANEL: The electrical panel consists of the display of the Thermocouple Temperatures (PT100). The temperatures can be viewed by using two displays each with 12 channel selector switch as shown in figure below.

Figure 2 : Electric Panel

Heating element 1 is attached to the base plate made of copper and element 2 is attached to the base plate made of aluminium. The panel is provided with three display screens to view temperatures of the ambient air and of the two base plates. A predetermined temperature can be set in these controllers. There are two ammeters and a voltmeter to display the voltage across the heating element and the current through the element.

BLOWER: A blower, used to emulate forced convection conditions is connected to the right end of the duct. It is a variable speed blower with seven different speeds. Its Specifications are: 600W, 230V AC 0-1800 rpm in seven steps 3.3 C.M.M.

Figure 3: Blower and Duct

DUCT: Fins are mounted inside a duct with the help of bolts. Blower is connected to the right end of the duct, while the left end carries a hole, open to the atmosphere, for exhaust of air.Front and top faces of the duct are covered using acrylic sheets for protection and visibility. The duct dimensions are: 200 mm x 200 mm x 800 mm The material of duct is Galvanized Iron.

HEATING APPARATUS: A flat plate heating element is used to heat the base plates. The heating plate is connected between the base plate and duct. To insulate the duct ceramic wool is used. The thermocouple numbers on the electrical panel for each fin at distances, 50mm, 100mm and 150mm from the fin base, respectively.

PROCEDURE (Natural Convection): Switch on the mains and the power supply to the heating elements and set the desired base plate temperatures, Note down the voltage and current readings for each channel from the voltmeter and ammeters, After both the base plates attain the set temperatures, start noting down the temperatures recorded by the thermocouples along the lengths of the fins at regular time intervals, Find the heat transfer rate at the base of each fin using the formula: *Qcond = k Ac/s***,** Find out the value of the surface heat transfer coefficient for the base plate, Calculate the fin effectiveness for each fin.

OBSERVATION TABLE: Ambient temperature (K), T∞ =-----,Blower speed (m/s) =------

Table 1

Sr. No.	Temperature along the Fins (K)											
	1	2	3	4	5	6	7	8	9	10	11	12

Forced Convection: Switch on the mains and the power supply to the heating elements and set the desired base plate temperatures, Note down the voltage and current readings for each channel from the voltmeter and ammeters, Switch on the blower and set it to Speed 1 i.e. 11.2m/s Once at least two subsequent readings agree, it can be assumed that the steady state, Fill out the observation tables and

carry out the relevant calculations, Plot the temperature distribution of each fin along its length, Estimate the slope of each graph at the fin base.

RESULTS: (NATURAL CONVECTION)

OBSERVATION TABLE: Experiment Temperature (^{0}k) Readings - Natural Convection

Table 2

	Copper			Aluminium		
	50 mm	100 mm	150 mm	50 mm	100 mm	150 mm
Trapezoidal	364	359	358	363	356	355
Cylindrical	362	358	354	367	354	352
Conical	358	354	351	366	353	349
Parabolic	362	353	345	357	348	340

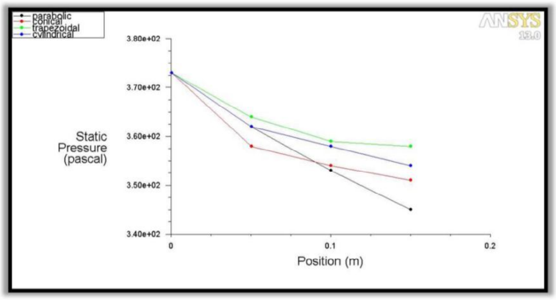

Figure 4**:** Experiments Temp. Plot – Copper

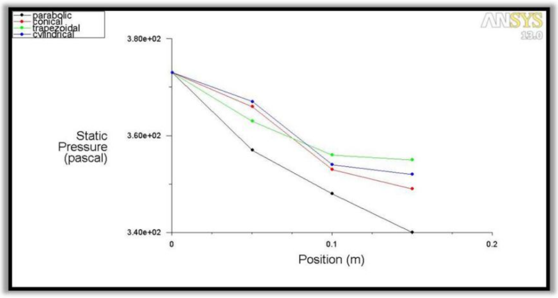

Figure 5: Experiment Temp. Plot – Aluminum

FORCED CONVECTION (Speed: 11.2 m/s)

OBSERVATION TABLE : Experiment Temp. Readings - Forced Convection - 11.2m/s

Table 3

	Copper			Aluminium		
	50 mm	100 mm	150 mm	50 mm	100 mm	150 mm
Trapezoidal	345	340	334	343	327	319
Cylindrical	345	335	331	339	323	321
Conical	343	333	326	341	324	317
Parabolic	346	329	321	341	321	312

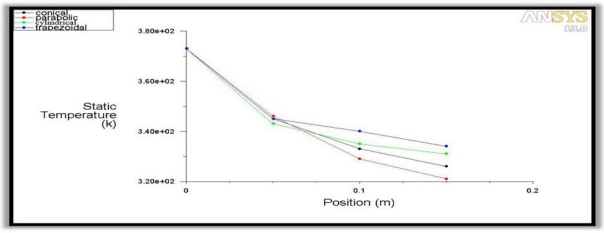

Figure 6: Experiment Temp. Plot – Copper

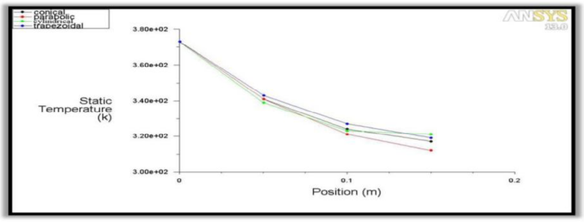

Figure 7: Experiment Temp. Plot – Aluminum

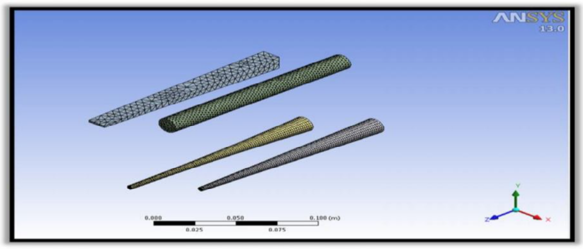

Figure 8: Meshed model of Fins

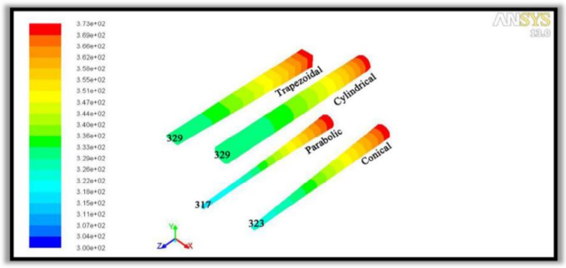

Figure 9: Analysis Temp. Contour Forced Con.

CONCLUSION: The experimental and numerical analysis of heat transfer through fins of four cross-sections was carried out and the results from both the approaches were obtained and compared, From the results, it is observed that for the same fin material, the trapezoidal fin experienced the least temperature drop over its length, while the parabolic pin fin consistently had the largest temperature drop, Also as heat flux entering each fin is same owing to their equal base area, parabolic fins are able to achieve least tip temperature for the same material. Hence, the parabolic fin is the most efficient in dissipating heat to its surroundings, Due to their greater thermal conductivity, copper fins are, in general, more efficient than aluminium fins, However, a designer must consider the trade-off between the greater conductivity and the larger density of copper before selecting it to fabricate fins.

FUTURE PROSPECTS: Pin fins are, in general, more efficient than straight fins at dissipating heat. Yet, the latter are more preferred owing to the ease in manufacturing and the ease in clustering them over small areas. However, a recent paradigm shift indicates that designers are turning towards the greater heat dissipation potential offered by pin fins. Pin fins have found applications in fields where thermal dissipation plays a very crucial role.

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