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Thermal performance of different types of fins using convective heat transfer

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Abstract **- This research examines the efficiency of various fin forms and includes heat transfer rate analysis. For analysis, four distinct fins are employed. Fins come in a variety of shapes, including round, square, hexagonal, and rectangular. The goal is to figure out how much heat is exchanged and how efficient a similar region with a different shape is. The goal of the research is to determine the maximum heat transfer from the fin surface as well as the efficiency of different fin shapes. The steady-state thermal analysis using ANSYS 14.5 is utilized for this investigation. Heat is transferred from a solid rod to a solid fin. Convection occurs with air flowing through a duct at the same time. The fin is used to mount a nichrome (band type) heater for heat delivery. The fins on the heater are composed of aluminum, which has a higher thermal conductivity than other materials. The solid work programme generates fin models, which are then loaded into ANSYS 14.5. The investigation is carried out in a systematic manner. Lay out the experimental setup first, then obtain individual readings from various shaped fins. The heat transfer rate and efficiency are estimated from the recorded readings for various Reynolds' Numbers, and the results are then compared to other fins.**

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Keywords- Heat transfer, fins, thermal conductivity, steady-state thermal analysis, ANSYS 14.

I. Introduction

Heat exchangers are utilized in a variety of activities, including thermal energy conversion, usage, and recovery in industrial, commercial, and residential settings. Increased heat exchanger performance can lead to more cost-effective heat exchanger design, allowing for energy, material, and cost savings in the heat exchange process. The requirement to improve the thermal performance of heat exchangers, resulting in energy, material, and cost savings, has led to the invention and application of a variety of heat transfer augmentation techniques. Heat transfer enhancement or intensification are terms used to describe these procedures. By lowering the thermal resistance of a heat exchanger, augmentation techniques improve convective heat transfer. Heat transfer enhancement strategies result in a higher heat transfer coefficient but at the expense of a higher pressure drop. As a result, when constructing a heat exchanger employing any of these approaches, a heat transfer rate and pressure drop study must be performed. Aside from that, long-term performance and a full economic study of the heat exchanger must be investigated. Several strategies have been presented in recent years to obtain high heat transfer rates in an existing or new heat exchanger while taking into account increasing pumping power. Finned surfaces with extensions are utilized to enhance the fin's surface area in contact with the fluid flowing around it. As the surface area of the fin increases, the more fluid contact it has with the base surface, increasing the rate of heat transfer from the base surface. The necessity to improve the thermal performance of heat exchangers in order to save energy,

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material, and money has led to the creation and application of a variety of heat transfer augmentation techniques. To boost the convective heat transfer rate of pin fins, we are advised to employ four varieties of aluminum fins, one of which is conventional and the other three of spiral surface with varied pitch. Fins are thin metal strips added to the heat transfer surface to enhance the area available for heat transmission. Because there is a relationship between pressure and heat transfer rate, the rate of heat transfer in a low-density condition is not the same as at atmospheric pressure. It is vital to study the heat transmission properties of fins in low density situations when using fins for heat rejection. Furthermore, to avoid high waste heat, the radiator's heat transfer area must be increased.

For various input parameters, Saroj Yadava et al. [1] suggested the thermal analysis performance of different shapes of fins. Mehran Ahmadi et al. [2] investigated the addition of vertically-mounted rectangular interrupted fins to increase heat transfer numerically and experimentally. R. The results of two common pin fin heat immersion with and without splitters in circular and square form pin-fins were compared by Sajedi et al. [3]. Pradeep Singh et al. [4] examined the heat transfer performance of fins with and without extensions with the same shape. S. Kushwaha et al. [5] studied heat transmission in electronic components of heat sinks with different profiles of fins, such as Rectangular, Trapezoidal, and Parabolic fins. L.Prabhu et al. [6] used the ANSYS workbench to study heat transfer for the design of fins with different design configurations such as cylindrical, square, and rectangular. By altering the shape and material utilised, Arun Eldhose et al. [7] were able to determine the Fin efficiency, Heat transfer rate, Temperature distribution, and Heat transfer coefficient of a Pin fin. The temperature distribution and heat flux through various fin surfaces were investigated by Muhammad Ferdous Raiyan et al. [8]. Flared and rectangular fin arrays were used in this experiment, and Mukesh Didwania et al. [9] calculated the maximum heat transfer rate of fin surface in duct due to changes in fine shape. ANSYS 12.0, a three-dimensional finite volume based steady-state thermal analysis tool, was utilized for the analysis.

TABLE I

EXPERIMENTAL SETUP SPECIFICATIONS

Sr. No.	Parameters	Dimensions
1	Duct size	150 x 100 mm
2	Coefficient of discharge Cd	0.65
3	Number of thermocouples on fin	5
4	Centrifugal blower with motor	
5	Digital temperature indicator-range	0-200 C
6	Digital Voltmeter-range	0 -200V AC
7	Digital Ammeter-range	0-2 Amp., AC
8	Dimmer stat: open type	0-2 Amp., 0-230V
9	Nichrome wire-Band type heater capacity	250 Watt

II. METHODOLOGY

In this paper, the methodology is used as problem identification, Section of notches, creating a 3D model, analyzing the model in steady-state thermal analysis, comparing results and implementation to collect all relevant information about heat transfer and fins before conducting a literature review.

The fins are constructed using CREO 2.0 once all of the relevant data has been collected. Following the creation of the model, the analysis is carried out using ANSYS 14.5 (steady-state thermal analysis). The outcomes of each analysis are then compared, and the best fins are chosen. The analytic result is compared to the theoretical calculation.

III. MATERIAL CHARACTERISTICS

Fins are a means to increase the heat transfer surface area, but their efficiency is determined on the fin materials and design. The optimum material is one with a high thermal conductivity, and as heat is removed from the fin through convection, the surface area must be as large as possible. To ensure heat transmission rates, the ideal material to use is one with the maximum thermal conductivity. The material is also thermally resistant; corrosion resistance and material weight are important factors, particularly at high temperatures. When compared to other materials, pure aluminium and copper are the best. This is owing to their particular weight and excellent heat conductivity. In this example, we chose aluminium as the primary material.

For Aluminium Fin:

1. Aluminum having the thermal conductivity value of 160 w/m-k.
2. Aluminum is mechanically soft material.
3. Good resistance to corrosion.
4. It has excellent thermal conductivity.

IV. Fins Size, Geometry and Cad Model

There are four types of fins geometry is used here as follows

1. Circular
2. Hexagonal
3. Square
4. Rectangular

Because the goal of the project is to compute heat transfer coefficient and efficiency under various climatic situations, the equivalence diameter and dimensions in mm are determined as follows, taking into account the blower capacity and construction of the air conditioning system.

1. Circular – 100*24
2. Hexagonal - 100*24.9
3. Square – 100*20
4. Rectangular – 100*20

A. *CAD Model of Different Fins*

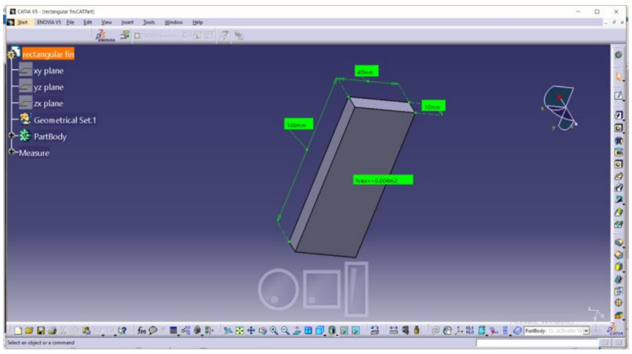

Fig 1: Rectangular Fin

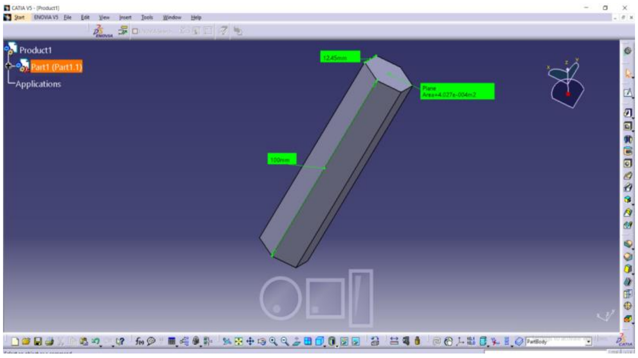

Fig 2: Hexagonal Fin

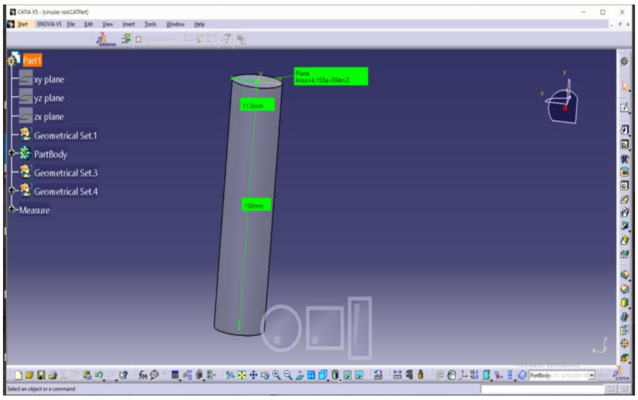

Fig 3: Circular Fin

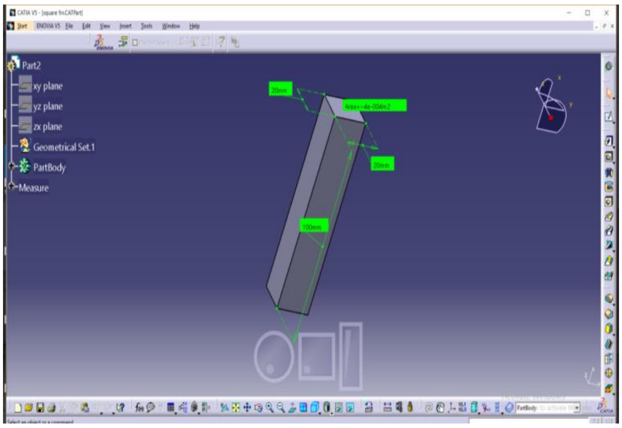

Fig 4: Square Fin

B. *Duct Sizing*

The fin assembly must remain contained within a rectangular duct. The air conditioning unit's duct dimensions are 250 x 250 mm. Because the a/c unit has two compressors and a blower capacity of 600 cubic feet per minute, the fin duct is connected to the a/c duct by a diffuser. As a result, the duct dimensions are determined as follows:

Dimensions of the duct are 150 mm x 100 mm. Inside the circular tube, a finned type air heater with a capacity of 150 W is fitted.

V. Test Performance

The first blower and heater are turned on at the same time. The pressure variations caused by the fins used in the blower are measured using a manometer once it has been started. The temperature of the atmosphere is also measured. For 4 fins, a reading is taken. Using a differential pressure transducer, the pressure decrease in the test portion is also monitored. The voltage, current, and temperature at various thermocouple attachment locations are recorded. Figure 1-4 shows the cad model.

TABLE 2.

TEMPERATURE READINGS FOR ALL TYPE OF FINS

Trial No	FIN TYPE	Voltmeter Reading V (Volts)	Ammeter Reading I (Amps)	Manometer Reading Hw (mm)	Thermocouple Reading					
					T1	T2	T3	T4	T5	T6= Ta
1	Circular	96	0.46	215	185	140	130	105	90	40
2	Rectangular	95	0.48	220	187	140	150	123	95	40
3	Square	95	0.47	220	176	143	138	126	90	40
4	Hexagonal	96	0.48	205	180	114	103	105	93	40

Based on the reading obtained the various paramenter for the performance of fins are calculated by using following equations and the results are shown in figure 5.

1) Room pressure Pa = 700mm Hg or

Pa = 93325.65 N/m^2

2) Density of air at RTP = ρa = $\frac{Pa}{RTa}$

= 1.055 Kg/m^3

3) Temp at base of fin

T_b= T_1+2 = 185+2 =187°C

Fins Calculation

Air head causing flow of air through orifice

$$ha= \frac{Pw\ x\ hw}{Pa}$$

Volume flow rate of air through orifice

$$Q = Cd\times ao\times\sqrt{2g\ \times h_a}$$

Velocity of air flow through the duct

$$V = \frac{Q}{Area\ of\ duct}$$

Average temp of fin surface

$$Ts = \frac{T1+T2+T3+T4+T5}{5}$$

Mean flim temp of fluid

$$Tf = \frac{Ts+Ta}{2}$$

Properties of air at mean film temp Tf= 80°C

From Heat and mass transfer data hand book

Kinematic viscosity of air ϑ = 21.09 x 10^{-6}m^2/sec

Prantl's no. Pr =0.692

Thermal conductivity K = 0.03047 w/mk

Reynold's Number

$$Re = \frac{VD}{\vartheta}$$

Nusselt Number

Corresponding to this Reynolds number, lead the values of C,m and n in the equation

$$Nu = Nu = C\ x\ Re^{m}\times Pr^{n}$$

Heat transfer Coefficient

$$\mathbf{h} = \frac{Nuxkair}{D}$$

m Parameter,

$$m = \sqrt{\frac{hP}{KA}}$$

Q_{fin} = m x K_{fin} x Ao x (T_b – Ta) x tan h mL

Efficiency of the fin

$$nf = \frac{\tan h\ mL}{mL}$$

Effectiveness of fin

$$€ = \frac{Qfin}{hA\ (Tb-Ta}$$

2) Temp at base of fin

T_b= T_1+2

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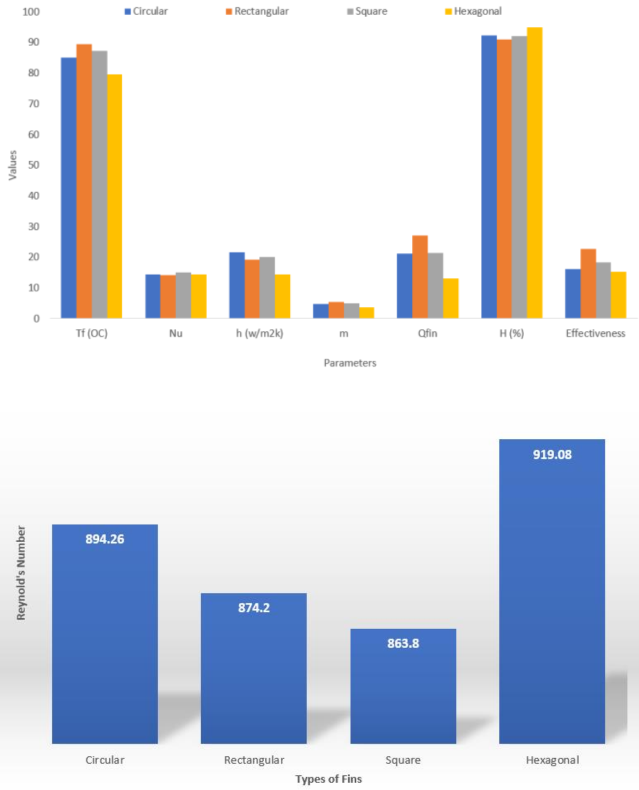

Figure 5. Parameter for the performance of types of fins

VI. Thermal Analysis of Fin

A. Steady State Thermal Analysis

Stable thermal analysis assesses the thermal balance of a system that has a continuous temperature over time. In other words, thermal analysis in a constant state involves the evaluation of the balancing state of a system subject to constant thermal charges and environmental conditions. Linear static analysis is the easiest way to analyse stationary conditions in which independent variables are prescribed input parameters such as material properties.

Real systems display non-linear static state conduct. In these cases, a solver has to retrieve a permanent solution that meets the parameters input to the governing equations. Steady state thermal analysis can be used for many simulations, even during the final stages of the design process. It facilitates decisions on the design of typical operating conditions and acts as a basis for transient control analysis and analysis of failures.

B. Methodology

There are three key steps in STEADY-STATE THERMAL ANALYSIS calculations:

Pre-Processing, Solver Execution, and Post-Processing are the three stages of the process (As shown in figure 5-10).

The modelling goals are determined and a computational grid is created during the pre-processing stage. The solver is started in the second phase by setting numerical models and boundary conditions. The solver continues to run until convergence is achieved. The findings are analysed once the solver has finished, which is the post-processing phase. Procedure.

Step 1: In ANSYS Workbench or Space Claim 3D Modellers, draw the cylindrical fin, rectangular fin, hexagonal fin, and square fin.

Step 2: Run more simulations with the produced fins in ANSYS software.

Step 3: Analyse the data and calculate efficiency and other parameters using it.

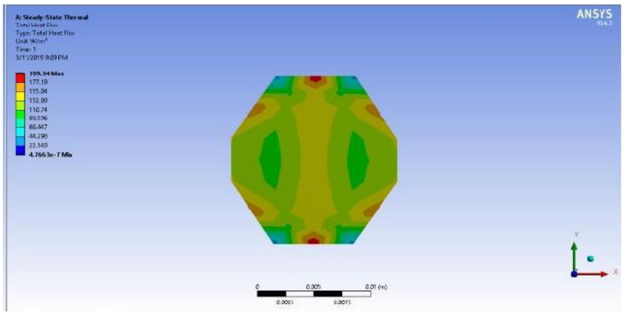

Fig 5: Analysis of Hexagonal Fin

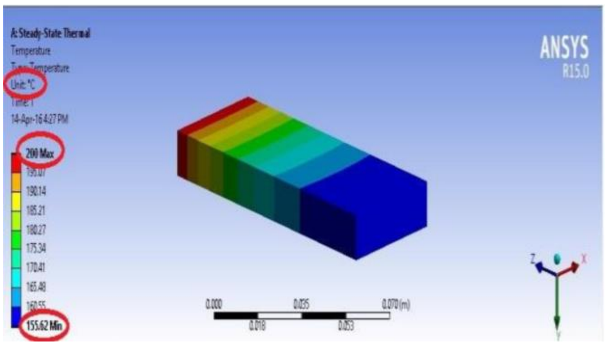

Fig 6: Analysis of Rectangular Fin

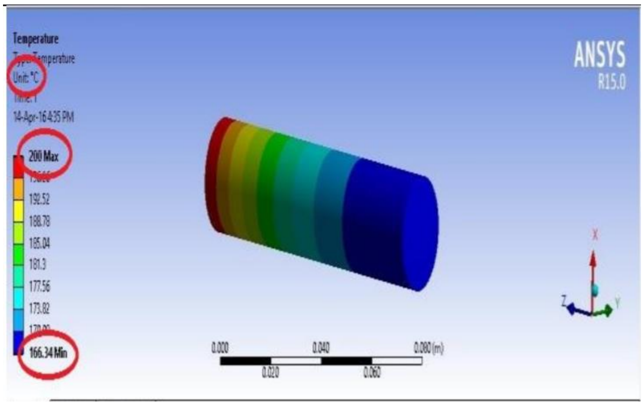

Fig 7: Analysis Of Circular Fin

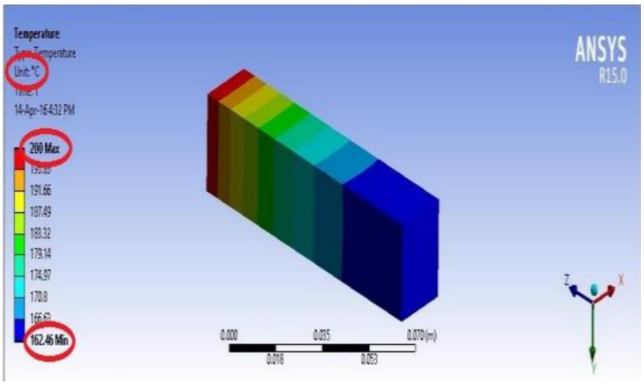

Fig 8: Analysis of Square Fin

TABLE III

FINS STEADY-STATE THERMAL ANALYSIS ANALYSIS TEMP COMPARISON

Fin Configuration	Maximum Temperature	Minimum Temperature
RECTANGULAR	200	155.62
SQUARE	200	162.46
CIRCULAR	200	166.34
HEXAGONAL	200	150.21

VII. RESULTS, DISCUSSION AND CONCLUSION

The experimental examination of fin efficacy is included in the first phase of this study. We utilised four fins of the same material with varied geometries: round, rectangular, square, and hexagonal. Aluminum has been chosen above the other materials because of its superior heat conductivity. We discovered the convective heat transfer coefficient, heat transfer rate, Reynolds' number, Nusselt number, Efficiency, and Effectiveness values.

The design and analysis of the fin utilizing ANSYS, CATIA software are included in the second portion of the project. From the experimental examination through the pressure drop, temperature drop, density difference, and velocity difference for all four fins, various input boundary conditions such as air velocity, temperature, and pressure are presented at the duct entrance.

According to the output result of experimental calculation and analysis, hexagonal fins have a higher efficiency than the other three fins, and according to ANSYS analysis, temperature at the end of fins with hexagonal configurations is the lowest, as compared to fins with other configurations. As a result, the experimental and analytical results for hexagonal fins are exactly the same.

Due to the highest area of contact, the hexagonal fin is determined to be the best for maximal heat transfer rate and efficiency based on the aforementioned statistics.

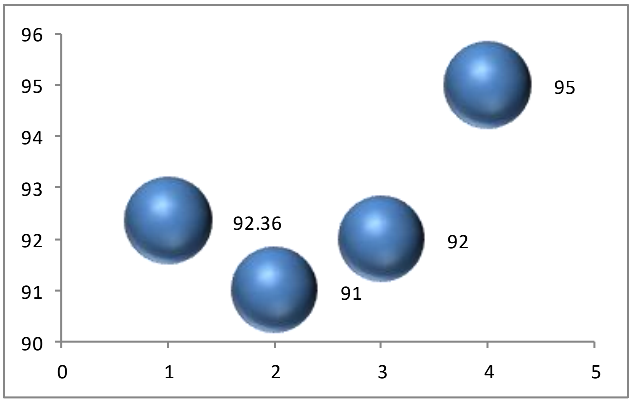

Fig. 9: Fins Efficiency

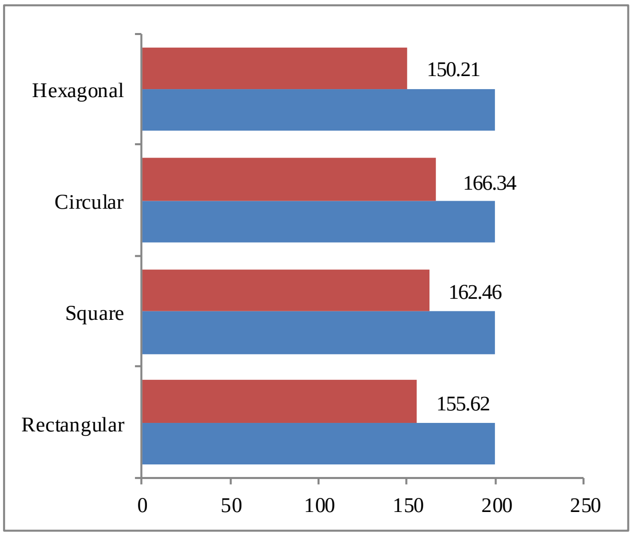

Figure 10: Fins Temperature Difference in °C

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