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Experimental Investigation of Heat Transfer through Rectangular and Trapezoidal Fins Made of Aluminum 6063 Alloy

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Abstract: *The present work is aimed at fabrication of trapezoidal and rectangular fins made of aluminum 6063 alloy with variable fin cross section. With the help of the experimental setup made under different heat input conditions the temperature variations along the length of the fin is measured. For the experimentation fins are fabricated of dimensions 110*50*10mm for rectangular fin and length of 110x30x10 mm, (length $_X$ base $_X$ width) for trapezoidal fin by using aluminum 6063 alloy. Finally, to find out the heat transfer coefficient of trapezoidal and rectangular fins with the help of numerical and graphical solutions.*

Key words: **heat transfer coefficient, efficiency and effectiveness, extended surface, free convection, force convection.**

I. INTRODUCTION

Heat transfer by convection between a surface and the fluid surrounding can be increased by attaching to the surface thin metallic strips called Fins. The heat conducting through solids, walls or boundaries has to be continuously dissipated to the surrounding or environment to maintain the system in a steady state condition. In many engineering applications large quantities of heat need to be dissipated from small area. The fins increase the effective area of the surface there by increasing the heat transfer by convection.

The fin is generally used when the convection heat transfer coefficient is low, especially under free convection. In the field of industry the fin is used widely, for instance, in cooling of electronic accessories, motorcycle engine and in air cooling of molecules with in a material.

Extended surfaces may exist in many situations but are commonly used as fins to enhance heat transfer by increasing the surface area available for convection. They are particularly beneficial when small, as for a gas and natural convection.

1.1 TYPES OF FINS

The fins are also referred as extended surfaces. Fins are manufactured in different geometries, depending upon the practical applications. The ribs attached along the length of a tube are called longitudinal fins. The concentric macular discs around a tube are termed circumferential fins. Pin fins or spines are rods protruding from a surface. The fins may be of uniform or variable cross-section. They have many different practical applications, via cooling of electronic components, cooling of motor cycle engines, compressors, electric motors transformers, refrigerators, high-efficiency boiler super heater tubes etc. Solid gas turbines blades often act as fins, conducting heat down their length to a cool disc.

(a) Triangular fin
(b) Rectangular fin
(c) Trapezoidal fin
(d) Parabolic fin
(e) Cylindrical fin

1.2 AUMUNUM 6063 ALLOY

Aluminum Alloy 6063 is one of the most popular Alloy in the 6000 series, provides good extrude ability and high quality surface finish. In heat treated condition. Alloy 6063 provides good resistance to general corrosion, including resistance to stress corrosion cracking. AA 6063 is an aluminum alloy, with magnesium and silicon as the alloying elements. The standard controlling its composition is maintained by The Aluminum Association. It has generally good mechanical properties and is heat treatable and weldable. Aluminum 6063 is the most common alloy used for aluminum extrusion. It allows complex shapes to be formed with very smooth surfaces fit for visible architectural and automobile industrial applications.

1.3 Chemical composition of 6063 alloy.

SL:NO	MATERIAL	MAXIMUM (%)	MINIMUM(%)
1	Silicon	0.6	0.2
2	Iron	0.35	0.35
3	Copper	0.10	0.10
4	Manganese	0.10	0.10 <
5	Magnesium	0.9	0.45
6	Chromium	0.10	0.10 <
7	Titanium	0.10	0.10 <
8	Other	0.15	0.05

Saad M. J. Al-Azawi[1] Mechanical Engineering Department University of Anbar. “Effect Orientation on Performance of Longitudinal (Trapezoidal) Fins Heat Sink Subjected to Natural Convection”.A trapezoidal fins heat sink with various orientations tested under a controlled environment. Test results indicate that the sideward horizontal fin orientation yield the lowest heat transfer coefficient. However the sideward vertical fin orientation gave the best performance on the natural cooling. Orientation affected the temperature distribution along the fins, therefore the temperature along the sideward vertical fins have the best performance with uniform distribution, while in sideward and downward the temperature increased in the positions near the base plate surface because of the complication in moving the heated air.

Rigan Jain, M.M. Sahu.[2] “Comparative Study of Performance of Trapezoidal and Rectangular Fins on a Vertical Base Under Free Convection Heat Transfer”.This paper concerned with Computational fluid dynamics (CFD) study of the steady-state natural convection heat transfer from vertical trapezoidal fins extending perpendicularly from vertical rectangular base. The effect of heat loads on base-to-ambient temperature difference and on the heat transfer performance of trapezoidal fin arrays for the optimum fin separation values has been studied with the help of simulation models.

Ambeprasad. S.Kushwaha, Prof.RavindraKirar [3] (Mechanical, P.C.S.T, Bhopal/ R.G.P.V, India) “Heat transfer through fins “Fluent incorporation [flow lab 1.2]” April 12, 2007”.This paper deals with the comparative study of heat sink having fins of various profiles namely Rectangular, Trapezoidal and Parabolic as heat sinks are the commonly used devices for enhancing heat transfer in electronic components. For the purpose of study heat sink is modeled by using the optimal geometric parameter such as fin height, fin thickness, base height, fin pitches 48 mm, 1.6 mm, 8mm, 2mm and after that simulation is done at different heat load of 50W, 75W, 100W and with a air flow at 15CFM and air inlet temperature is taken as 295 K. The simulation is carried out with a commercial package provided by fluent incorporation. The result obtained taking into consideration only the thermal performance. As per the current era of the technologicaldevelopment everything is needed to be compact; whether it is a normal computer or laptop or the rack server we need everything that can be placed in a small space, so here the space constraint plays an major role as you cannot install a large heat sink for your device as it increases the size and the cost. So in this paper the pitch of fin is kept 2mm.

E. M. Sparrow, B. R. Baliga and S. V. Patankar[4] Author and Article Information“Forced Convection Heat Transfer from a Shrouded Fin Array with and without Tip Clearance”.The analysis involves the solution of the velocity field in the inter-fin space and in the shroud clearance gap beyond the tips, after which the governing energy equations for the fluid and the fins are solved simultaneously. For the fin, the results show that the heat loss is a minimum adjacent to the base and increases along the fin in the direction of the tip. The maximum fin heat loss occurs either at the tip or intermediate between the base and the tip, depending on whether or not there is clearance between the fin tips and the shroud. The calculated heat transfer coefficients vary along the fin and, in some cases, take on negative values. The results demonstrate that the conventional uniform heat transfer coefficient model is inapplicable to shrouded fin arrays.

E. M. Sparrow and S. Acharya[5] Author and Article Information “A Natural Convection Fin with a Solution-Determined Nonmonotonically Varying Heat Transfer Coefficient” .In this paper a conjugate conduction-convection analysis has been made for a vertical plate fin which exchanges heat with its fluid environment by natural convection. The analysis is based on a first-principles approach whereby the heat conduction equation for the fin is solved simultaneously with the conservation equations for mass, momentum, and energy in the fluid boundary layer adjacent to the fin. The natural convection heat transfer coefficient is not specified in advance but is one of the results of the numerical solutions. For a wide range of operating conditions, the local heat transfer coefficients were found not to decrease monotonically in the flow direction, as is usual. Rather, the coefficient decreased at first, attained a minimum, and then increased with increasing downstream distance. This behavior was attributed to an enhanced buoyancy resulting from an increase in the wall-to-fluid temperature difference along the streamwise direction. To supplement the first-principles analysis, results were also obtained from a simple adaptation of the conventional fin model.

EmreOzturk and Ilker[6] Tari "Forced Air Cooling of CPUs with Heat Sinks: A Numerical Study" IEEE transactions on components and packaging technologies, Vol. 31, NO. 3, Sep 2008. In this paper the flow and temperature fields inside the chassis are numerically investigated as a conjugate heat transfer problem. The computational effort is concentrated on the forced air cooling of the CPU using a heat sink. Three different commercial heat sink designs are analyzed by using commercial computational fluid dynamics software packages Icepack and Fluent. The grid independent, well converged, and well posed simulations are performed, and the results are compared with the experimental data. It is observed that flow obstructions in the chassis and the resulting air recirculation affect the heat sink temperature distribution. The specific thermal resistance values for the heat sinks are compared. It is observed that although they have different geometries, all of the three heat sinks have similar specific thermal resistances. The best heat sink is selected and modified in order to have a lower maximum temperature distribution in the heat sink by changing the geometry and the material. Especially, replacing aluminum with copper as the heat sink material improved the performance. The importance of modeling the entire chassis is demonstrated by comparing the simulation results with the results from a model of only the CPU-heat-sink-fan assembly.

Adomian, G. [7]: Stochastic Systems. Academic Press Inc. New York. "Semilinear stochastic systems: Analysis with the method of the stochastic Green's function and application in mechanics".This work deals with the analysis of a class of semilinear vector stochastic operator equations. The method of the stochastic Green's function due to Adomian is extended to the certain class of equations. Some perturbation techniques are also developed and a pertinent application in nonlinear mechanics is considered.

Ganji, D.D, Sadighi, A[8]: Application of homotopy- perturbation and variational iteration methods to nonlinear heat transfer and porous media equations, J. Comput. Appl.Math,207: 24-34. "Heat Distribution in Rectangular Fins Using Efficient Finite Element and Differential Quadrature Methods".Finite element method (FEM) and differential quadrature method (DQM) are among important numerical techniques used in engineering analyses. Usually elements are sub-divided uniformly in FEM (conventional FEM, CFEM) to obtain temperature distribution behavior in a fin or plate. Hence, extra computational complexity is needed to obtain a fair solution with required accuracy. In this paper, non-uniform sub-elements are considered for FEM (efficient FEM, EFEM) solution to reduce the computational complexity. Then this EFEM is applied for the solution of one-dimensional heat transfer problem in a rectangular thin fin. The ob-tained results are compared with CFEM and efficient DQM (EDQM), with non-uniform mesh generation). It is found that the EFEM exhibit more accurate results than CFEM and EDQM showing its potentiality.

Ganji, D.D, Sadighi, A[9]: Application of homotopy- perturbation and variational iteration methods to nonlinear heat transfer and porous media equations, J. Comput. Appl.Math,207: 24-34. "Estimation of Heat Dissipation from Plate with Multiple Tapered and Rectangular Fins".The current work determines the rate of heat flow from a heating element. Extended tapered surfaces are provided on the element in order to enhance better convection. Overall heat transfer during this process is determined by modeling and meshing using finite element software and its validation is done using the governing equations. The heat dissipation from the element is also compared with the rectangular fins provided around it. The study is conducted by considering various materials to obtain optimum material selection to enhance the better flow of heat from the system.

II. EXPERIMENTAL SET-UP AND METHODOLOGY

2.1 MANUFACTURING OF FINS

Two aluminum 6063 alloy rectangular blocks of 20*5*5cm are taken first and marking is done according to required dimensions. Aluminum6063 alloy rectangular blocks are made into cylinder up to 4cm (base) to insert in heater. Then the remaining blocks are machined into the trapezoidal and rectangular shapes by using shaping machine. The fin edge should be 10mm.

The Trapezoidal fin should have 3cm at base and 1cm at tip and the Rectangular fin should have 1cm throughout the fin. After finishing the fin, the cylindrical part of the either rectangular or trapezoidal fin (4cm long) inserted in a MS knob of diameter 4cm. After inserting it a band heater is put around it and is placed in an asbestos shell. The specimen of Al rod is fitted in a rectangular duct in horizontal position. Heater side of the fin is inserted in duct. Other side of the fin is cooled by natural convection.

Fig.1 Rectangular fins

2.2 EXPERIMENTAL SET-UP FABRICATION.

The experimental setup consists of two aluminum rods of 25cm long and 5*5 cm area, voltmeter of 0-400v, ammeter of 0-20amps, temperature indicator 0-400 degree centigrade, 2 pole 6 way selector switch, 6 way peri connector, k-type thermocouples of 1m length, electronic dimmer 1.5kw or 1kw, band heater 250w, heating test specimen. An Al rod of 15*5*5 cm long is taken and design into required trapezoidal fin and the other into rectangular fin of 110*50*10mm.

Table:1 Specifications of experimental set-up

SL.NO	EQUIPMENT	QUANTITY
1	Aluminum 6063 alloy circular rods	25cm length
2	Voltmeter	0-400v
3	Ammeter	0-20amps
4	Temperature Indicator	0-400^{o} C
5	Switch	2-pole 6waysector switch
6	k-type thermocouple	1m
7	Heater	250w

Fig.2 Experimental test rig

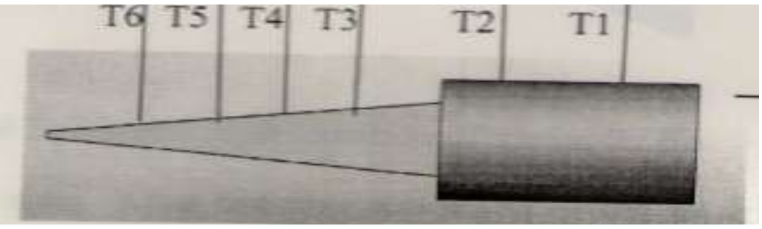

Fig.3 Fin with nodes

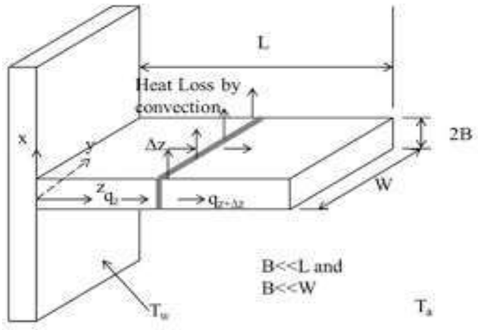

Fig.4 Rectangular fin profile

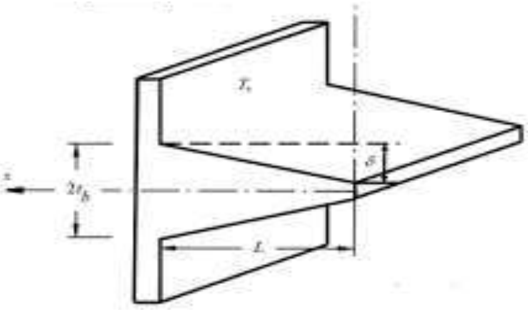

Fig.5 Trapezoidal fin profile

2.3 EXPERIMENTAL PROCEDURE.

Ensure that all on/off switches given on the panel are at off position. Ensure that the variac knob is in zero position are not, otherwise set into zero position. Now switch on the main power supply (220volts A.C., 50Hz). Switch on the main panel with the help of main on/off switch given on the panel. Ensure Leave the experiment for some time until attains stable condition. Take thermocouple readings, voltmeter, and ammeter readings when steady state is reached. Take another reading of temperature at different voltage after 15mintues. In the same way take the reading of temperature and voltage at different time. When the experiment is over switch off the heater first. Adjust the variac to zero position. Switch the power supply to pane.

III. RESULTSAND DESCUSSION

Table:2 Forced convection rectangular fin

S.NO	V	Q	A	T_1	T_2	T_3	T_4	T_5	T_6
1	100	55	0.55	31	100	98	90	91	88.5
2	110	65	0.61	31	170	160	60	161	156
3	120	80	0.67	31	190	180	180	180	175
4	130	90	0.73	31	200	195	190	190	185

Table:3 Forced Convection Trapezoidal fin

S.NO	V	Q	A	T_1	T_2	T_3	T_4	T_5	T_6
1	100	55	0.55	31	90	80	80	65	55
2	110	65	0.61	31	100	90	86	68	60
3	120	80	0.67	31	105	100	95	71	71
4	130	90	0.73	31	120	114	114	85	80

Table:4 Result table for rectangular fin forced convection

S.NO	V	Qi	A	V_0	V_a	Re	h	Ɛ	Ƞ(%)
1	100	55	0.55	31.12	0.857	5116.4	12.36	0.060	99.34
2	110	65	0.61	35.31	0.97	5112.35	14.01	0.527	85.42
3	120	80	0.67	35.76	0.985	5102.8	14.65	0.530	85.2
4	130	90	0.72	35.93	0.99	5006.32	15.02	0.54	85.0

Table:5 Result table for trapezoidal fin forced convection

S.NO	V	Qi	A	V_0	V_a	Re	h	Ɛ	Ƞ(%)
1	100	55	0.57	31.1	0.881	5134.5	12.56	0.2430	93.82
2	110	65	0.64	35.5	0.9904	5637.9	15.60	0.241	94.2
3	120	80	0.67	35.9	1.069	5972.0	14.60	0.250	93.54
4	130	90	0.72	35.93	0.9905	5434.8	14.10	0.026	90

V-Volts, Qi- Heat input, A-Amps, Re- Reynolds number, h- Heat transfer coefficient, Ɛ-Fin effectiveness, V_0- Velocity of orifice, Va-Velocity of air in duct.

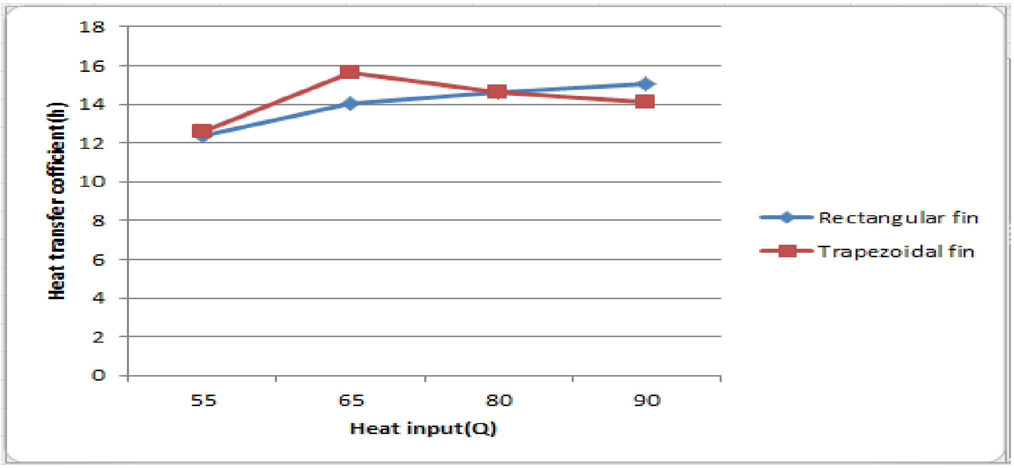

Fig.6 Heat input (Q) vs Heat transfer coefficient(h)

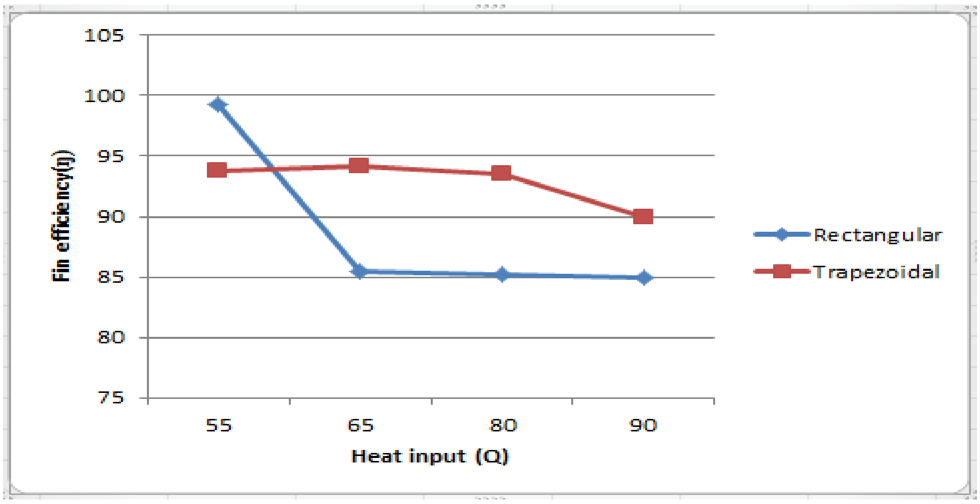

Fig.7 Heat input (Q) vs Fin efficiency(ŋ)

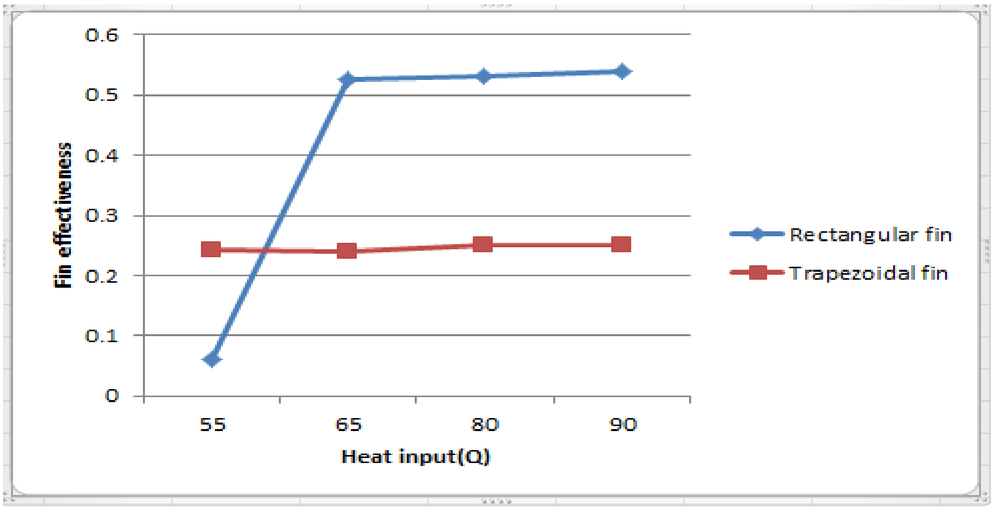

Fig.8 Heat input(Q) vs Fin effectiveness(ε)

IV. CONCLUSION

The experimental investigation was carried out with the help of rectangular and trapezoidal fins of dimensions 110*50*10mm for rectangular fin and length of 110x30x10 mm under the different heat input conditions Fin with extensions Provide near about 5% to 13% more enhancement of heat transfer as compare to fin without extension. Choosing the minimum value of ambient fluid temperature provide the greater heat transfer rate enhancement. Temperature variation at the nodes near the base is more when compared to the distant nodes.

A most significant finding of the experimentation is that at heat inputs of 55W, 65W, 80W and 90W heat transfer is enhanced by 38%, 49%, 38%, and 23% for trapezoidal fins in forced convection. The average efficiency of the trapezoidal fin has enhanced by 8.2% in forced convection. The average effectiveness of a trapezoidal fin has increased by 53.5% in forced convection.

Heat transfer coefficient is more in forced convection compared to the natural convection in the case of both the fins. When compared to both the fins, the heat transfer coefficient is twice in trapezoidal fin then the heat transfer coefficient in the rectangular fin in both the natural and forced convections.

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