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A Comparative Experimental Analysis of Different Geometry Fins

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Abstract
The fins are generally used to increase the heat transfer rate by increasing the surface area which is to be in contact with surrounding fluid. It is necessary to study the effect of fin geometry on heat transfer rate. In this paper an experimental study was done to explore the effect of fin geometry on the performance of the fin. Uniform cross sectional fins such as circular, rectangular, square and a non-uniform cross section cone made of aluminium were used for the study. Same surface area is maintained for all fins (except cone) by maintaining same perimeter and length. Along length of the fin the temperature distribution, the rate of heat transfer, effectiveness and efficiency were studied under free and forced convection conditions. Different velocities of the air were considered for the study of forced convection condition. Experimental results obtained were compared with that of theoretical values. The results revealed that the rectangular cross sectional fin exhibits comparatively better performance in all aspects including quantity of material requirement.

Keywords:*Fins, Temperature distribution, Heat transfer, Effectiveness and Efficiency.*

I. Introduction

The heat transfer from the surface plays very important role in many of engineering applications especially in the field of mechanical. The heat transfer rate from the surface by convection depends on the surface area exposed to surrounding environment and the temperature difference between surface and surrounding environment. In many of cooling of surface applications especially in electronic equipment, the heat dissipation from the surface can be increased by increasing surface area by attaching some kind of extended surfaces called fins.

The rate of heat dissipation also depends on the material of the fin, dimensions and geometry. The material requirement of fin also dependent on geometrical shape of the fin. The performance of the fins depends on profile distribution of temperature on the surface along the length, heat transfer coefficient, effectiveness and efficiency. The effectiveness of the fin is defined as the ratio of heat dissipation rate with fin to that of without fin and the efficiency may be defines as the ratio of actual heat dissipation rate of fin to that of maximum heat dissipation rate with fin. Maximum heat dissipation rate with fin is obtained when entire fin were at base temperature. Keeping all these in view the different geometrical fins made of aluminium are studied in this paper and the performance of these fins are estimated by using all the said parameters and compared. The volumetric material analysis is also described in this study.

II. LITERATURE REVIEW

Hameed, V.M. and Khaleel, M.A [1]investigated experimentally and numericallyunder natural convection conditions for seven different Aluminium fins. They obtained better performance for the fins when the perforations are added. Saurabh Pathak et.al. [2] experimented with various geometries in order to enhance the heat dissipation. Three different shapes such as circular, square, tapper had been taken, modelled and analyzed in SOLID WORKS 2015. The analysis was done on heat transfer of material with different geometry. After analysis, they came to know that both alloy steel and aluminium alloy 1060show different minimum temperature with different geometry. They concluded from their study that the Tapper fin of alloy steel given better heat transfer.W. A. Khan et.al. [3] described in their study, the overall thermal performance with different geometrical shapes of fins. For entropy generation rate a dimensionless expression was considered in their study. They indicated in their results that the preferred fin profile exhibits the better. Sayed Zaidshah and Viveksheel [4], presented fins with various designs shapes and materials that cause the heat transfer rate to an increasing factor in many operations for both experimental and computational analysis. The notches in varieties of shapes that helped to raise heat transfer coefficient are determined. They also done by experimental setup and finite element analysis also and the results implies the thermal behaviour of the different fins with various materials. Results represented that the implementing notches in the design of fins leads to the dissipation of heat from surface.

G. Agwu Nnanna et. al.,[5] developed a generalized analytical solution for computation of heat transfer from fin surface. A study was performed on the fin efficiency for various conditions. The variation of temperature distribution, efficiency and effectiveness of fins were studied TrushitPatela and RamakantaMehera [6]. They considered porous rectangular fin and is simulated by using Darcy's model. They also performed thermal analysis on a finite-length extended surface with tip insulated. The low efficiency flat plate air collector is investigated in Ali Daliran and Yahya Ajabshirchi [7] study to improve thermal performance. Thermal efficiency of solar collector for two models C1 (without fins) and C2 (with fins) both of 1 m^2 surface area with forced convection flow is studied theoretically and experimentally. Thermal efficiency was respectively calculated 30% and 51% for experimental types with and without fins and 33% and 55% for those of theoretical work which generally seem reasonable. From the past few decades number of efforts were made by researchers to enhance the rate of heat transfer with the use of pin fins by varying number of parameters [8]. The parameters like fin spacing, fin geometries, temperature distribution, height, length have been reviewed and some brief reviews about the ways of improving the rate heat transfer by use pin fins are discussed. It was found that in materials of fins, aluminium proved to be more efficient than others. Adding spacing and interruptions can also enhance the efficiency. Introduction to notches and slots can also be useful to improve the efficiency of pin fins. By increasing Reynolds number, heat transfer by pin fins can be increased. Also pin fins of elliptical geometry can also improve the rate of heat transfer as compared to other geometries like annular and eccentric fins. Adding coating to fins can also improve heat transfer. A pin fin array with dimples is another case of enhancing heat transfer through pin fins.

III. MATERIALS, METHODOLOGY AND EXPERIMENTATION

Different geometry fins made of aluminium are used for the study. Aluminium, a light weight material, having high conductivity (225 W/m K) is used in many of cooling applications. The following four different cross sections of fins are considered in this study:

1. Circular cross section
2. Rectangular cross section
3. Square cross section
4. Circular non uniform cross section (cone)

The constant perimeter is maintained for all the three circular, rectangular, square cross sections and same perimeter is maintained at the base fourth type of fin i.e. for conecross section. This constant perimeter is maintained throughout the length of the fin to maintain same surface area. To maintain constant perimeter and surface area, the dimensions for the fins shown in table-1 are considered. Equal length of 70mm is taken to maintain same surface area for all fins.

Table-1: Fin dimensions

S. No.	Fin Type	Dimension	Perimeter in mm	Surface area in mm^2	Cross section area in mm^2
1	Circular	Diameter D=12.75mm	40	2800	127.67
2	Rectangular	Width w=15mm, Thickness t=5mm	40	2800	75
3	Square	Side a=10mm	40	2800	100
4	Cone	Base Diameter D=12.75mm	40 at base	2800	Non uniform

A base plate with dimension 150X100X10 mm^3 is taken to fix all the fins to test and compare the performance. Uniform heat is supplied to the base plate by using electric heating element to maintain steady constant temperature at the base of the fin. Regulator to control the heat input, ammeter, voltmeter, thermocouples to measure temperature and digital temperature indicator to record the fin temperature at different positions are used. The thermocouples are attached to the fins to measure the temperature at fixed positions such as x_1(x=0 i.e. base), x_2(x=23.33mm), x_3(x=46.66mm) and x_4(x=70mm) to study the distribution of temperature on the finsurface. The experimental set up fabricated to record all required data is shown in figure-1

Fig-1. Experimental set up

The free and forced convection conditions are applied for evaluating the performance of the fins. In free convection the atmosphere air with $25^{O}C$ is considered as surrounded fluid. In forced convection the same air with different velocities such as U_1=1.5, U_2=1.8 and U_3=2.1m/s produced by blower is used. All the test readings are recorded when the system is in steady state conditions. The results of the experimentation of all fins are discussed in results and discussion section.

IV. RESULTS AND DISCUSSIONS

The experimental results obtained from tests are summarised and comparative performance analysis of distribution of temperature along fin length, heat transfer coefficient, heat transfer rates, effectiveness and efficiency of all the fins under free and forced convection are discussed below. Finally the volumetric analysis for quantity of material requirement is also given.

4.1 Temperature distribution on the surface along the length of the fin

The steady state temperature distribution for all the fins along the length for the same base temperature and same heat input in forced and free convection conditions are shown in figure 2 to figure 5. The length of the fin is very large compared to base dimension and the heat transfer rate depends on surface area. Since the same surface area is maintained for all fins, the geometry plays an important role in heat transfer rate and temperature on the surface as well. Experimentally it was observed more or less same temperature prevails on the surface except cone, because for the cone the conduction heat from base to tip reduces as area decreases. The temperature on the surface is the measure of convection heat transfer; higher convection heat transfer was obtained with all fins except cone. In forced convection as velocity of air increases the surface temperature and tip temperature reduces greatly as shown in figures.

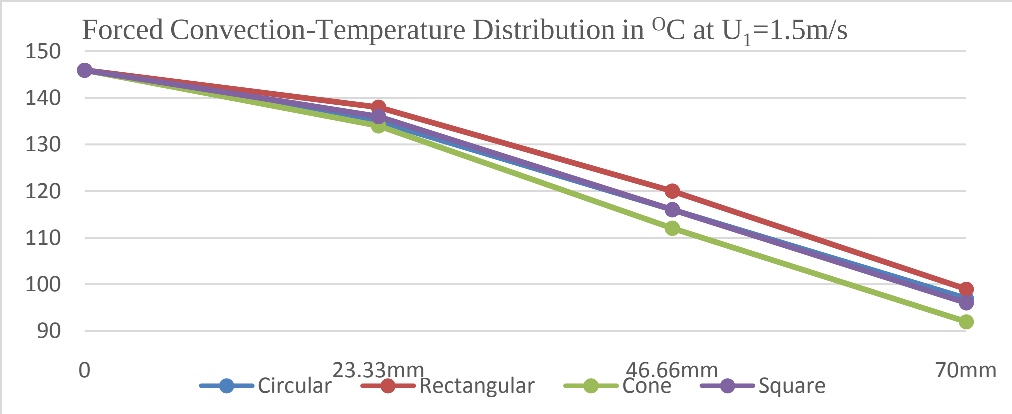

Fig-2. Forced Convection-Temperature Distribution at U_1=1.5m/s

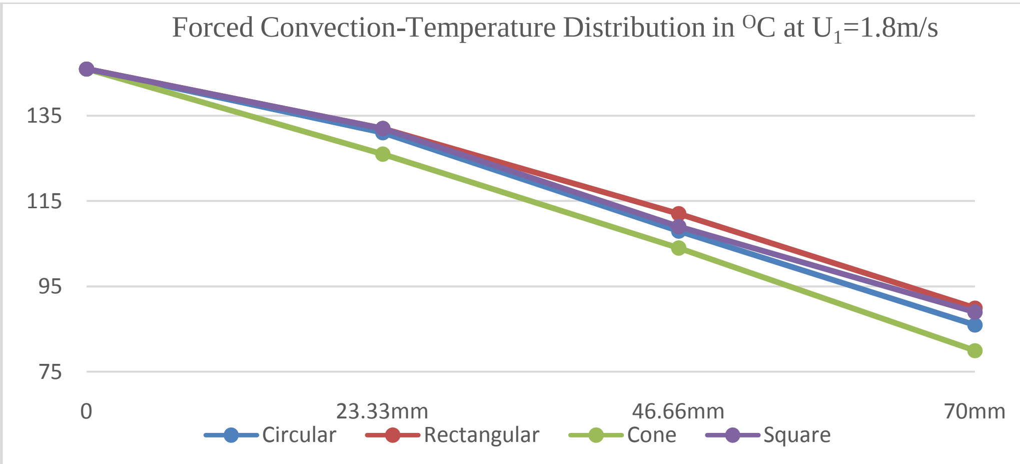

Fig-3. Forced Convection-Temperature Distribution at U_1=1.8m/s

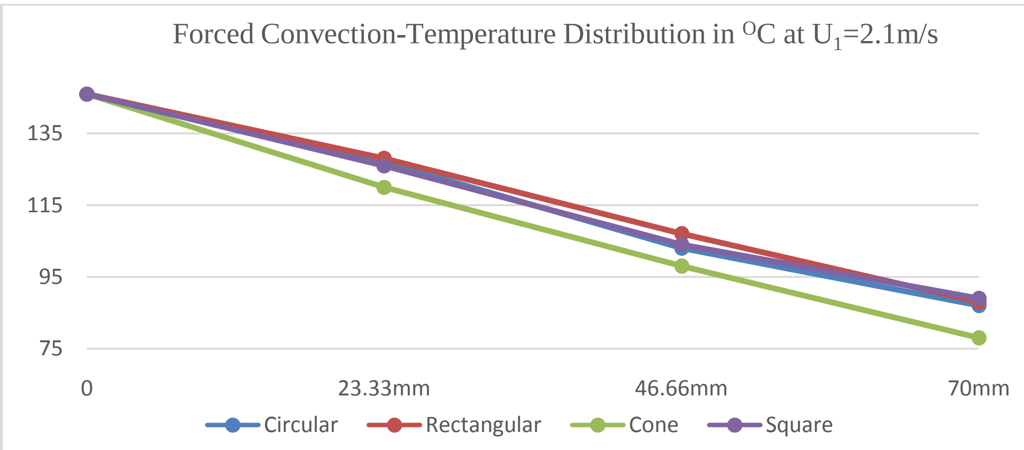

Fig-4. Forced Convection-Temperature Distribution at U_1=1.8m/s

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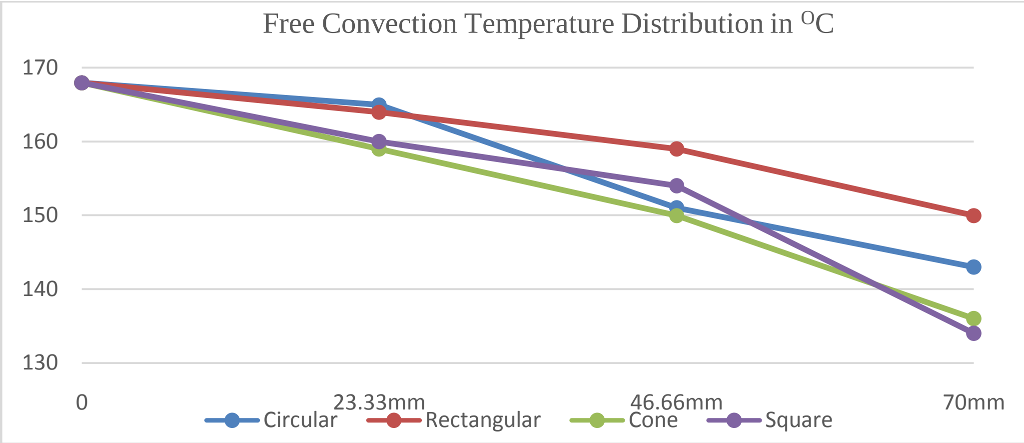

Fig-5. Free Convection-Temperature Distribution

4.2 Convective Heat Transfer Coefficient (h)

The variation of convective heat transfer coefficient for all the fins for different air stream velocities is shown in figure-6 and for free convection heat transfer coefficient is shown in figure-7. The convective heat transfer coefficient mainly depends on fin temperature, material, fluid surrounded and its velocity. Experimentally it was observed that higher convective heat transfer coefficients are obtained with higher air stream velocity. The rectangular fin heat transfer coefficient was higher compared to other due to higher surface temperature. The cone type fin has comparatively lower convective heat transfer coefficient and lower heat dissipation rate. The sharp edges on surface also have impact on heat transfer coefficients. The rectangular and square fins have higher heat transfer coefficient and heat transfer rate compared to other.

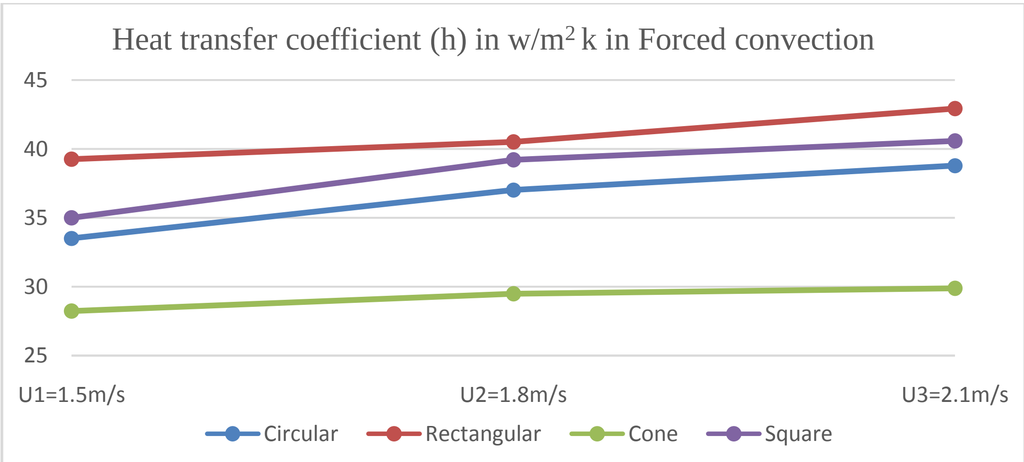

Fig-6. Heat transfer coefficient (h) in w/m^2 k in Forced convection

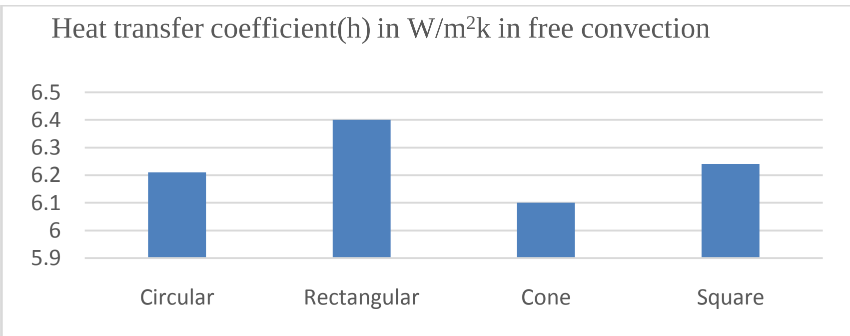

Fig-7.Heat transfer coefficient(h) in W/m^{2}k in free convection

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4.3 Heat Transfer Rate (Q)

For the same heat input supplied at the base, the actual heat dissipation by different fins to the surroundings in forced convection and free convection are shown in figure-8 and figure-9 respectively. The higher heat transfer rates were observed in forced convection due higher heat transfer coefficients. The rectangular and square fins dissipate comparatively more heat to the surroundings. The sharp edges on the surfaces provide necessary turbulence on the fin surface, thereby heat transfer coefficient and heat dissipation. Heat dissipation is almost same for all fins except cone in natural convection. The lower surface area of the cone is the reason for lower heat dissipation in free convection.

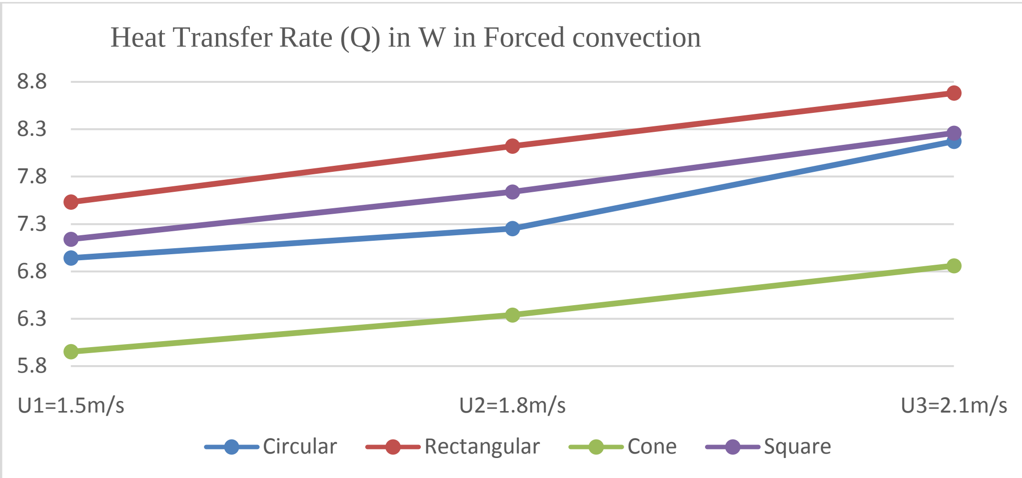

Fig-8.Heat Transfer Rate (Q) in W in Forced convection

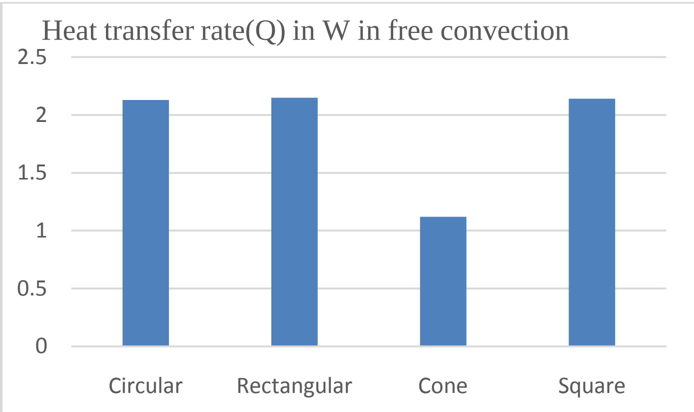

Fig-9. Heat Transfer Rate (Q) in W in free convection

4.4 Effectiveness and Efficiency

The effectiveness and efficiency of all the fins in forced and free convections are described in figure-10 to figure-13. The better effectiveness and efficiencies were obtained with rectangular fin in both free and forced convection conditions. The higher effectiveness and efficiencies of rectangular fin was due to higher heat transfer coefficient and heat transfer rates.

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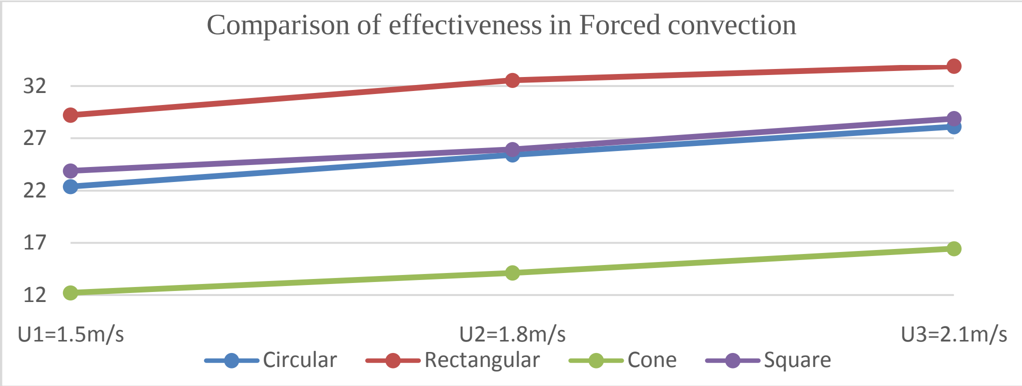

Fig-10.Effectiveness in Forced convection

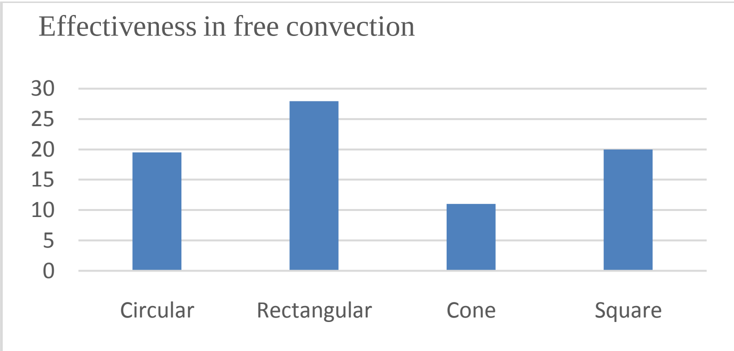

Fig-11.Effectiveness in free convection

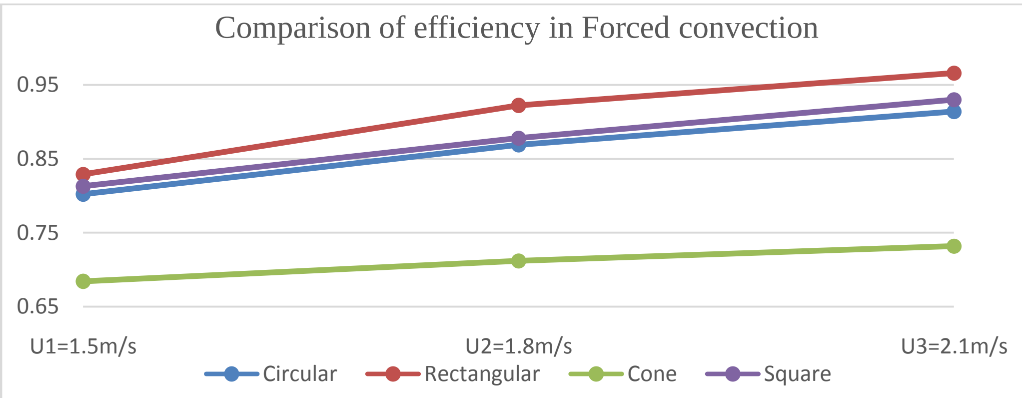

Fig-12.Efficiency in Forced convection

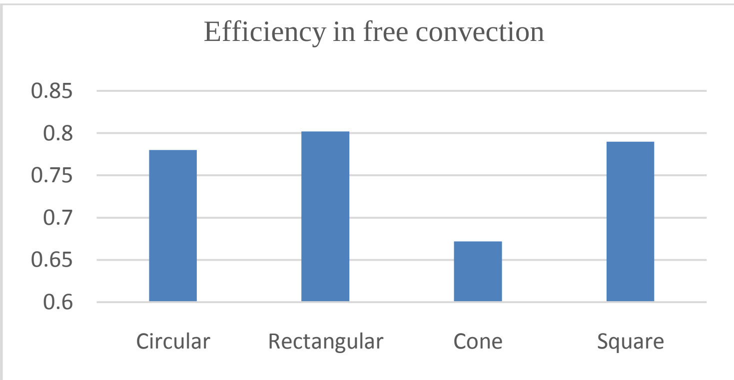

Fig-13.Efficiency in free convection

4.5 Volumetric analysis

The quantity of material required and number of fins can be produced per m^3 of volume for these fins for the given specifications on volume basis are as follows. The material saving is observed with cone and rectangular fins compared to other.

FIN TYPE	Volume in m^3	No. of Fins per m^3 of material
Circular	8.937×10^{-06}	111894
Rectangular	5.25×10^{-06}	190476
Cone	2.97×10^{-06}	336700
Square	7×10^{-06}	142857

V. CONCLUSIONS

The conclusions of the present experimental study are as follows

- Higher convective heat transfer coefficient and heat transfer rate were obtained with rectangular fin in both forced and free convection conditions. The heat transfer rate order for all fins are Rectangular >Square >Circular >Cone. The sharp edges on the surface increases heat transfer coefficient and heat transfer rate for rectangular and square fin.
- Better effectiveness and efficiency were observed for rectangular fin compared to other. The more uniform temperature on the surface of rectangular fin results in the higher effectiveness and efficiency.
- The quantity of material required and number of fins can be produced per m^3 of volume for these fins for the given specifications also proves better material saving with rectangular fin.

Hence it is concluded that, the rectangular fin exhibits very good performance and better material saving compared to other.

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