

Experimentally Investigate The Heat Transfer Performance Of Annular Fins

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Abstract: *Performance of annular fins of different shapes subject to locally variable heat transfer coefficient is investigated experimentally in this paper. The performance of the fin expressed in terms of fin efficiency, effectiveness and thermal resistance as a function of the ambient temperature and fin geometry parameters has been presented in the literature in the form of curves known as the fin-efficiency curves for different types of fins without use the diamond shape, but in the present work, we study this shape with others. However, for cases in which the heat transfer from the fin is dominated by natural convection, the analysis of fin performance based on locally variable heat transfer coefficient would be of primer importance. The local heat transfer coefficient as a function of the local base temperature has been obtained using the available equations of natural convection for copper pipe. Results have been obtained and presented in a series of fin-efficiency curves for annular fins of circular, diamond and elliptical, at constant heat flow area for a wide range of temperatures from 100 to 220 °C . The dimensionless parameter Biot no. on the locally variable environmental condition is examined for heat transfer rate. The deviation between the overall fin efficiency calculated of elliptical fin shape based on constant heat transfer area is greater than other shapes used reported in the our work, and that presently calculated based on variable heat transfer coefficient, has been estimated and presented for all fin shapes. In this paper the effectiveness and fin shape tube efficiency for diamond , circular and elliptical annular fins were analyzed for different environmental conditions. Experimental results observes that the performance of heat transfer rate to elliptical fin is better than diamond and circular fin for day and night condition with the high range of temperatures used.*

Key Word: (Diamond Fin , Circular Fin , Elliptical Fin, Heat Transfer Performance)

I. INTRODUCTION:

From the study of thermodynamics you have learned that energy can be transferred by interaction of a system with its surroundings. These interactions are called work and heat. However thermodynamics deals with the end states of the process during which an interaction occurs and provides no information concerning the nature of the interaction or the time rate at which it occurs .the objective of this text is to extend thermodynamic analysis through study of the modes of heat transfer and through development of relations to calculate heat transfer rate .A simple yet general definition provides sufficient response to the question .what is heat transfer? heat transfer is thermal energy in transit due to a spatial temperature difference.

Fins can come in a variety of shapes, e.g., rectangular and

circular with constant cross section, and annular and triangular with variable cross section. For a given fin shape, fin material, and convection conditions, there exists an optimized des which transfers the maximum amount of heat for a given mass of the fin . The purpose of extended surfaces (commonly known as fins) is to enhance convective heat transfer from surfaces. The primary mechanism behind the operation of fins is to increase the effective heat transfer area of a surface. They are commonly used in situations in which cooling is attained via free (or natural) convection – for which the heat transfer coefficients h are relatively small. Typically fins are much longer than they are thick. Because of this it is common, and fairly accurate, to assume that the temperature varies only in the lengthwise . The performance of the fins is judged on the basis of .direction the enhancement in heat transfer relative to the no-fin case [1]. In order to evaluate the usage of the fins in this work, it has been calculated both efficiency ,effectiveness of them ,thermal resistance, and overall fin efficiency and fin effectiveness. However, all the calculations proceed from the pattern learnt in the general equations.

The performance of annular fins of different profile subject to locally variable heat transfer coefficient was investigate by Esmail and Mokheimer [2]. The performance of the fin expressed in terms of fin efficiency in the form of curves known as the fin-efficiency curves for different types of fins. These curves, have been obtained based on constant convection heat transfer coefficient. Antonio Acosta-Iborra , Antonio Campo [3]explained the salient feature in the quasi one-dimensional differential equation for annular fins of uniform thickness. It is demonstrated that approximate analytic temperature profiles and heat transfer rates of good quality are easily obtainable without resorting to the exact analytic temperature distribution and heat transfer rate embodying modified Bessel functions. For enhanced visualization, the computed temperature profiles, tip temperatures and fin efficiencies of approximate nature are graphed and tabulated for realistic combinations of the normalized radii ratio and the thermo-geometric fin parameter of interest in thermal engineering applications.

Most of the engineering problems require high performance heat transfer components with progressively less weights , volumes , accommodating shapes and costs .Extended surfaces (fins) are one of the heat exchanging devices that are employed extensively to increase heat transfer rates . The rate of heat depends on the surface area of the fin . Nagarani and Mayilsamy [4] found radial or annular fins are one of the most popular choices for exchanging the heat transfer rate from the primary surface of cylindrical shape .In this paper the heat transfer rate and efficiency for circular and elliptical annular fins were analyzed for different environmental conditions .Elliptical fine efficiency is more than circular fin ,if space restriction is

there a long one particular direction while perpendicular direction is relatively unrestricted elliptical fins could be a good choice .

Recently at 2012 , Nagarani and et.al. presents a paper have an numerical and experimental comparative study of elliptical and circular fins which are made up of same kind of metal with same surface area and fed with constant heat inputs under free convection. The numerical result show more distribution of isotherms and elevated rate of temperature distribution along the major axis of elliptical fin than those of circular fin. The experimental result proved that the surface temperature of elliptical fin decreased with increase in fin length along major axis. [5].

II. Experimental work

The experimental apparatus used in the present study for the estimation of heat transfer on annular fin at one tube is illustrated in figure (1) . The various dimensions required for the setup are taken from the reference [4]. The annular circular ,diamond and elliptical fin made of aluminum is vertically mounted on the circular tube. The circular fins have the outer diameter of 118.2mm ,thickness 1mm and the space between the fin is 15mm . The horizontal circular tube is placed on three supports which is 73 mm above the experimental table to avoid ground effect. Length, diameter and thickness on the horizontal circular pipe made of copper are 900mm,25mm and 4mm. Electrical heating coil with 0.4 kW capacity is kept inside the tube. Size of the box is 800x400x50mm . Thermal conductivity of aluminum is 233 W/mK.



Fig. 1.The schematic diagram of the experimental setup

The process is done with free convection .The temperature of air measured as the ambient temperature entering test specimen is and test fin temperatures are measured using J type the base and fin tip. The thermocouples at the base and fin tip. temperatures of the circular tube at inlet and outlet are measured using a thermocouple. For elliptical fin the major and minor axis ratio are 1.8 with same circular tube dimension. The diameter for diamond shape is 113mm. Surface area of three fin shapes are equal . The readings are taken for three month at different environmental condition like morning, afternoon and evening and reading for both fins are tabulated. For circular,

diamond and elliptical fin the following formulas are used for calculating heat transfer coefficient and shaped tube efficiency. The heat transfer coefficient (h, w\m2 .K)) can be estimated from the following equation: [6,7]

$$h = \frac{Q_{fin}}{A_t * (T_s - T_{\infty})} \quad (1)$$

$$\text{Actual heat input} \quad Q = I V \quad (2)$$

$$\text{Shaped tube efficiency} \quad \eta_{fin} = \frac{Q_{fin}}{Q_{max}} = \frac{(T_s - T_{\infty})}{(T_b - T_{\infty})} \quad (3)$$

The fin efficiency of a any fin , η_{fin} , is defined as:

$$\eta_{fin} = \frac{q_{fin}}{q_{fin max}} = \frac{\text{Actual heat ftrnsfer rate from the fin}}{\text{Ideal heat transfer rate from the fin}} \quad (4)$$

. This relation enables us to determine the heat transfer from a fin when its efficiency is known.

The performance of the fins judged on the basis of the enhancement in heat transfer relative to the no-fin case . the performance of fins expressed in term of the fin effectiveness ϵ_{fin} is defined as :

$$\epsilon_{fin} = \frac{Q_{fin}}{Q_{no fin}} = \frac{Q_{fin}}{hA_B(T_B - T_{\infty})} \quad (5)$$

The behavior of a circular fin was used to experimental work an equivalent elliptical and diamond shaped fin which closely approximates the actual behavior of a continuous fin.

$$\eta_o = 1 - \left(\frac{A_{fin}}{A_t} \right) (1 - \eta_{fin}) \quad (6)$$

The heat transfer performance of heat sinks is usually expressed in terms of their thermal resistances R_o in $^{\circ}\text{C}/\text{W}$, which is defined as:

$$R_o = \frac{1}{(h)(A_t)(\eta_o)} \quad (7)$$

This equation may be used to expression for the thermal resistance of a fin array. A small value of thermal resistance indicates a small temperature drop across the heat sink, and thus a high fin efficiency. The governing equation for one dimensional conduction with convection is applicable to systems in which the lateral conduction resistance is small relative to the convection resistance. Under these conditions the temperature profile is one dimensional. The conditions for which Eq. (5.13) is valid are determined from the following criterion:[7]

$$Bi = \frac{hlc}{K} < 0.1 \dots\dots\dots(8)$$

Where Bi is the Biot number based upon the maximum half thickness of the fin profile.

III. Results and Discussions:

One objective of the present experiments was to demonstrate that an enhancement of the heat transfer rate by used three shapes of aluminum fin . These shapes are circular, diamond and elliptical.

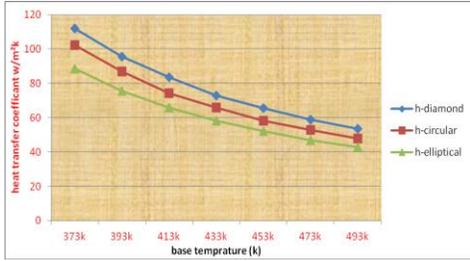


Figure 2. Heat transfer coefficient with respect to base temperature at Pm condition.

The Above figure is explain the comparison between of base temperature , and heat transfer co-efficient for circular, diamond and elliptical fins along the tube profile using experimental setup reading taken for different environmental condition. Base temperature goes on increases, heat transfer co-efficient goes on decreases .Heat transfer co-efficient of elliptical fin is lower than circular and diamond fins at all temperature range (from 373 to 493 K) and different environmental condition. Variation in heat transfer coefficient is less at morning when compared to afternoon and evening. Change in heat transfer coefficient for all fins are the same in the morning and evening. In evening variation for three type of fins are between the two curves .For same surface area, heat transfer coefficient for diamond fin is higher than elliptical fin and circular fin. It is obvious that's the heat transfer coefficient of diamond fin is higher than 20% than circular fin and 9% for elliptical fin for different environmental condition.

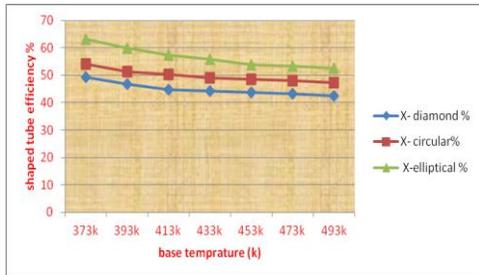


Figure.3. Shaped tube efficiency with respect to base temperature for morning time (Am, T∞ = 286K).

Fig.3.represents the shaped tube efficiency for elliptical fin, circular fin and diamond fin to the circular tube plotted against base temperature number for the same heat input and kind of metal. The shape tube efficiency of elliptical fin is

higher than other fins shape used about 20.2% for diamond shape and 12.3% for circular shape.

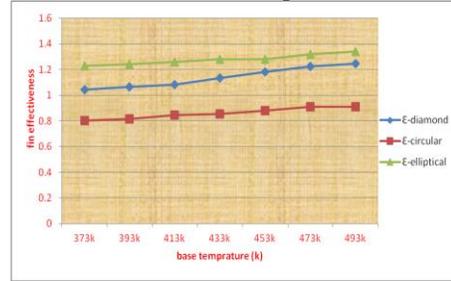


Figure.4. Fin effectiveness with respect to base temperature at Pm.

The effectiveness of circular fin is less than 1 indicates that the fin actually acts like as insulation fin at the heights' temperature range from 100 to 220°C, that's mean low performance of heat transfer rate in this range. While the others fin shape had effectiveness more than one.

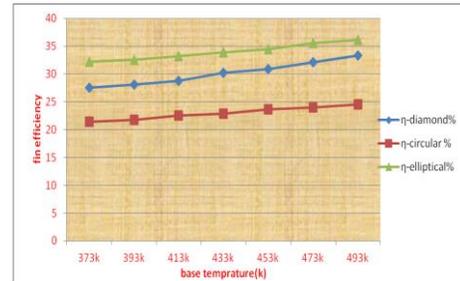
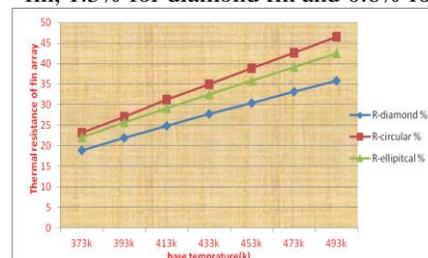


Figure .5 The fin efficiency with base temperature at Pm.

Efficiency curve illustrated ,that's elliptical fin shape is greater than others two fin shape. This because the heat transfer coefficient increases with increasing efficiency and the elliptical fins have the advantage ,its surface area can be increased in one direction when space is restricted in perpendicular direction which is not possible in diamond and circular fin. . In morning heat transfer coefficient is lesser than in the evening and efficiency will change according to this parameter. Efficiency of elliptical fin is 11.31% greater than diamond fin and 48% circular fin shapes in the morning ,but the difference are less 10.8% for diamond fin and 32.6% for circular fin in the evening . It shows that the efficiency of the fins is changed according to the environmental condition.

The overall efficiency of three fin shapes used during the night are higher than morning as followed: 1% for elliptical fin, 1.3% for diamond fin and 0.6% for circular fin.



Figur6 .Thermal Resistance of fin array with respect to base temperature at Pm ($T_{\infty} = 286K$).

The thermal resistance for all shapes fin increase linearly with the base temperatures. There is a nearly conform results of thermal resistance between the circular and elliptical fin at ranges of temperatures from 373 to 413K as shown in figure 6.

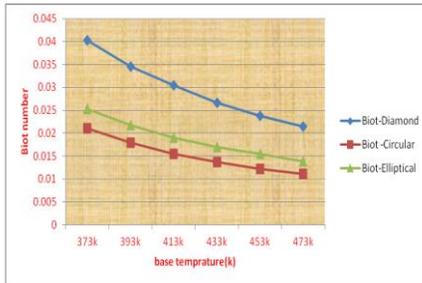


Fig. 7.Biot number with respect to base temperature at Pm Biot number and air humidity in the view of improving the performance and concluded that the fin heat transfer rate and efficiency get increased with increase in the axis ratio. The range of Biot no. is less than 0.1, for three shapes of fins ,that's mean an excellent distribution of temperatures on the fins surface. The Biot no. decreasing with increasing the base temperatures for different environmental condition used due to increasing the efficiency and effectiveness' (performance of heat transfer) of three shaped fins as shown in figure 7.

IV. Conclusion:

- 1- It is found from the empirical study that the variation of surface temperature depends on the shape factor.
- 2- If the length of the fin along major axis is increased, the shape factor also gets decreased, which in turn reduces the temperature near the tip.
- 3-The shaped tube efficiency decrease with increasing the base temperature for all fin shaped used in this work.
- 4-Heat transfer coefficient for diamond fin shape better and transfer more amount of heat than other shapes.
- 5-The effectiveness of diamond and elliptical fins are larger than one $\epsilon > 1$ indicating that fins are *increasing* heat transfer from the surface, as they should. So we recommended to use these fin shapes in the industries for next real application in the futures.
- 6- Elliptical fin efficiency is greater than other fin shapes for different environmental condition.
- 7-The thermal resistance of circular is higher than elliptical and diamond fins. This mean the total heat transfer of elliptical array fins is bigger than other fins used in our present work.
- 8-The metals with high thermal conductivity enhance the heat transfer rate and increase the shaped tube efficiency but reduce the Biot number.
- 9-The aforementioned limit of Biot number for the shaped tube efficiency and the effectiveness of elliptical fins is an optimized range beyond which there will be a reduction in heat transfer rate in spite of adding metal to the base tube.

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Nomenclature

A_{fin}	Area of the elliptical and diamond and circular fins	(m ²)
A_f	The total area of fin surface	(m ²)
A_b	Area of array of fins on the tube	(m ²)
q_{fin}	Semi minor axis of the elliptical fins	(m)
Bi	Biot number	
h	Heat transfer coefficient	(W/m ² K)
k	Thermal conductivity	(W/mK)
L_c	The critical length of fin	(m)
r_o	Outer radius of the circular tube	(m)
r_i	Linear radius of the circular tube	(m)
T_b	Base temperature	(K)
T_s	Surface fin temperature	(K)
T_{∞}	Ambient temperature	(K)
I	Actual current of the heater	(A)
V	Supplied voltages to the heater	(v)
Q_{ms}	Average temperature of the surface of the shaped Tube equal to the temperature of the base of the fin	(W)
Q_{fs}	Heat transfer with fin	(W)
Q_{fs}	Heat transfer without fin	(W)
R_f	Thermal Resistance of fin array	(k/W)
Greek symbols		
η	Shaped tube efficiency	
η_f	fin efficiency	
ϵ	fin effectiveness	

