EXPERIMENTAL AND THEORETICAL ANALYSIS OF PARAMETER OF POROUS FIN FOR ENHANCEMENT OF HEAT TRANSFER

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Abstract: The present paper demonstrates experimental and theoretical analysis of parameter aimed at enhancement of heat transfer of a porous fin using pin fin apparatus. The present work investigates the temperature distribution, performance parameters, heat transfer rate and efficiency through different material (Aluminum, Brass Stainless steel & Copper) have a same dimensions pin fin in natural convection condition. This study based on finite-length fin with insulated tip. As we know that fins are basically an extended surface which is use to increase the heat transfer rate, this is basically a secondary surface mounted on primary surface to augment heat transfer from it. To dissipate heat a faster rate, different heat transfer enhancement methods have been suggested in literature. Active and passive heat transfer enhancement techniques are commonly employed for heat transfer for heat transfer augmentation in fluids. Recent development in technology has led to demand for high performance lightweight, and compact heat transfer equipment. The excessive heat must be dissipated to the surrounding for smooth functioning of system. This is more important in cooling of gas turbine blade, thermal power plants, air-conditioning equipment and electrical and electronics component. This component is getting more compacting size, which generates heat continuously. This excessive heat will reduce the life of component. To overcome this problem there is need of effective cooling system. This experimental work is an extension in this direction to analyze the heat augmentation capacity of porous fin of different material.
Keywords: Fin, Extended surface, Heat exchangers, Heat transfer enhancement, free and force convection.

Nomenclature

D	Dia. Of duct in m
L	Length of duct in m
Tm	Average fin temperature in K
Tmf	Mean fin temperature in K
Q	Air flow rate in m3/sec
V	Velocity of air at ambient temperature in m/s
Vmf	Velocity of air at mean temperature in m/s
Re	Reynolds number
Nu	Nusselt number
h	Heat transfer coefficient in W/m2K
Kair	Thermal conductivity of air in W/m2k
m	Physical significance

I. INTRODUCTION

Fins are one of the most problems in the heat transfer to increase rate of heat transfer on a solid surface. For the cases of constant heat transfer coefficient, the analytical solution of temperature profile and rate of heat transfer can be easily obtained [1]. However in some problem such as boiling liquid, the heat transfer coefficient of fin no constant and varies with temperature difference between surface and the adjacent fluid in a nonlinear manner. The dependence of heat transfer coefficient on the local temperature difference can be governed by a power–law type form. Numerous studies have devoted to the analysis of fin performance of this type of problems due to its important application in engineering. Chang [2] solved a decomposition solution for temperature dependent surface heat flux. ADM results used for compared with results of the present study. Joneidi and Ganji [3] solved differential transformation method to determined fin efficiency of convective straight fins with temperature dependent thermal conductivity. Later Unal [4-7] made a series studies on an extended surface with no uniform heat transfer coefficient and showed that the equation can be integrated analytically in a closed form for a limited number of cases. Liaw and Yeh [8] used the same model and further studies all possible type of heat transfer including the cases of film and transition boiling with and without heat transfer at fin tip. They also conducted an analytical and experimental study for a fin with a various type of boiling occurring simultaneously at adjacent location on its surface [9]. Abbasbandy and shivanian [10] made exact analytical solution of a nonlinear equation arising in heat transfer that nonlinear equation same with equation that solved in this study with DTM. Of course, in the present study solution represented by an infinite series, but in the paper solved equation pure analytically. Sen Kou, Lee and Lai [11] made thermal analysis of a longitudinal fin with variable thermal properties by recursive formulation. Khani and abdul Aziz [12] made thermal analysis of a longitudinal trapezoidal fin with temperature dependent thermal conductivity and heat transfer coefficient, in this paper used of HAM for solved equation. In the present study for the comparison, problem solved numerically by Rang-Kutta fourth order method for N=1 and several assigned value of n. The concept of differential transformation method was first introduced by Zhou [13] in 1986 and it was used to solve both linear and nonlinear initial value problem in electric circuit analysis. One of most Advantages of this method reducing the size of computational work while the Taylor series method is computationally taken long time for large orders. Aziz and Hug [14] used the regular perturbation method and a numerical solution to compute a closed form solution for a straight convective fin with temperature-dependent thermal conductivity. The HAM was used by Domairry and Fazeli to solve rectangular purely convective fin with temperature dependent thermal conductivity [15]. Khani, ahmadzadeRaji, and HamidiNejad [16] used HAM to evaluate the analytical approximate solution and efficiency of the nonlinear fin problem with temperature dependent thermal conductivity and heat transfer coefficient. Mustafa Inc [17] used HAM to evaluate the efficiency of straight fin with temperature dependent thermal conductivity and to determine temperature distribution within the fin. Arslanturk [18] and Rajabi [19] used the ADM and HPM to evaluate the efficiency of straight fins with temperature dependent thermal conductivity and to determine the temperature distribution within the fin. Lesnic and Heggs [20] applied the ADM to determine the temperature distribution within a single fin with a temperature dependent heat transfer coefficient. Ching-Huang and Chen [21] used to adomain decomposition method to evaluate fin efficiency and the optimal length of convective rectangular fin with variable thermal conductivity, and to determine the temperature distribution within the fin. Kundu and Das [22] made the thermal analysis and optimization of straight taper fins has been addressed. In this paper has been observed that the variable heat transfer coefficient has a strong influence over the fin efficiency. Mokheimer [23] investigated performance of annular fins of different subject to locally variable heat transfer coefficient, in this paper performance of fin expressed in terms of fin efficiency as a function of the ambient and fin geometry parameters. Recently, differential transformation method has been used to solve a wide range of physical problem. This method provides a direct scheme for solving linear and nonlinear deterministic and stochastic equation without the need for linearization and yield rapidly convergent series solution. Rashidi and Erfani [24] used DTM for solved fin efficiency of convective straight fins with temperature dependent thermal conductivity and comparison results with HAM. Chiam [25] used of perturbation method for solve heat transfer in a fluid with variable thermal conductivity over a linearly stretching sheet. Their results of this study showed that the differential transformation method has many merits including fast convergence and high accuracy. In this study is to apply differential transformation method to investigate a straight fin governed by power-law type temperature dependent heat transfer coefficient. Base of DTM, temperature on the fin surface can be expressed explicitly as a function of position along the fin. The effect of exponent value and fin parameter on temperature profile as well as fin tip temperature can also be obtained quickly. In addition to, heat transfer rate and fin efficiency are presented in detail. In the present study results are compared with [2, 10].

II. EXPERIMENTAL INVESTIGATION

2.1 Specifications of circular duct used in the analysis

The experimental study is done internal threads into the circular duct. Specifications as listed below:-
Specifications of Circular Duct:
Material of construction= Aluminum
Inner Diameter, ID= 10 cm
Outer Diameter, OD=11 cm
Length of duct = 50 cm
Air at atmospheric temperature was allowed to flow through the inner diameter of channel.

2.2 Details of experimental set-up

Figure shows the schematic diagram of the experimental set up. Test Pipe show in figure, thecircular channel is used for this investigation and made up of Aluminum, Brass, Copper& Stainless steel material. All the geometrical dimensions are in term of channel height while the heat transfer coefficient are presented in term of channel hydraulic diameter (Dh=0.1m) A suction mode blower is used to draw the air from entrance to exit section. The heated test section is 500mm long and 100mm dia. The uniform heat flux plate type heater is fabricated from nicrome wire. This heater is connected in series with dimmerstat in order to supply the same amount of heat to heater. The heater is wounded on the surface of channel. Commercial fiber glass insulation is used on external surface to prevent the heat leakage due to convection and radiation. Nichrome bend heater encloses the test section to a length of 50 cm. Three thermocouples T2, T3 and T4 at a distance of 15 cm, 30 cm and 45 cm from the origin of the heating zone are embedded on the walls of the pipe and two thermocouples are placed in the air stream, one at the entrance (T1) and the other at the exit (T5) of the test section to measure the temperature of flowing air as shown in Fig. 3 The pipe system consists of a valve, which controls the airflow rate through it and an orifice meter to find the volume flow rate of air through the system.

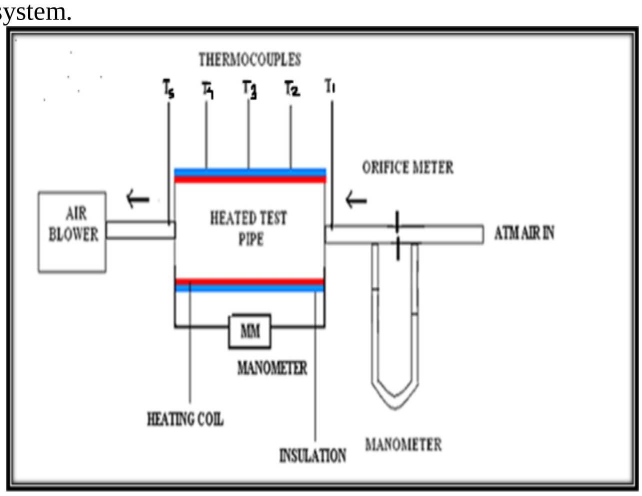

Fig. 1 Schematic diagram of the experimental set up

2.3 Design Parameters

2.3.1Duct and Thread dimensions

- Diameter of Duct (D)= 10 cm
- Length of Duct (L)= 50 cm
- Heating Coil Length = 50 cm
- Thickness of channel (t1) = 0.5 cm
- Pitch of thread (P) = 1cm & 0.5 cm
- Material used for fin = Aluminum,Brass, Copper, Stainless steel

2.3.2 Constructional Features

The material selected for the duct is Aluminum because it is light in weight, have high conductivity, easily available and

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cheaper in comparison to copper.
The experimental setup consists of following components:-

The "J.P.T.I."unit consist of a experimental setup of different materials		
Sr.no.	Components	Technical Description
1	Centrifugal Blower	Specifications speed N = 2800 rpm.
2	Control Valve	Mass flow rate kg/sec
3	Thermocouples	Eight copper-constantan thermocouples having range of –50 to 1200 degree celcius.
4	Heater	Plate type heater is used & length of heater is 500mm.
5	Circular channel	Circular duct made from aluminum sheet of thickness 0.5 cm, length 50 cm and Diameter 10 cm.
6	Digital Temperature Indicator	Digital temperature indicator is used in order to get the temperature readings from different place of duct.
7	Ammeter and Voltmeter	Ammeter and voltmeter are used to get the readings of current and voltage supplied to the heater.

Fig.2:- Pin Fin Apparatus(J.P.T.I)

Fig.3:-Test fin

OBSERVATIONS & CALCULATIONS (Brass Material)

Dia. Of the fin	12.7mm
Length of fin	150mm
Dia. Of the orifice	14mm
Dia. Of the delivery pipe	36mm
Coefficient of discharge	0.65
Input voltage	60V
Input current	0.30A
Manometer reading	0.146

Steady state conditionreading:-

T1	T2	T3	T4	T5	T6
165	138	111	102	91	25

Calculations:-

1)Average fin temperature(Tm)

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

$$Tm = \frac{165 + 138 + 111 + 102 + 91}{5}$$

Tm = 121+273 = 394K

2)Mean fin temperature(Tmf)

$$Tmf = \frac{394 + 298}{2} = 346K$$

At Tmf in 346K properties of air from S.Subramanyan page no. 34

$\rho_a = 1.029$ kg/m^3, $K_a = 0.0297$ W/mK , $V_a = 20.02 \times 10^{-6}$ m^2/s

3)Air flow rate (Q):-

Q = 5.308×10^{-3} m^3/sec

4)Velocity of air at ambient temp.(T6)

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

$$= \frac{0.005308}{0.0165}$$

= 0.32m/s

5)Velocity of air at mean temp.(Tmf):-

$$Vmf = V \times \frac{Tmf}{T6} \ in\ K$$

$$Vmf = 0.32 \times \frac{346}{298} \ in\ K$$

Vmf = 0.37 m/s

6)Reynolds number (R_e) :-

$$Reynolds\ number = \frac{Vmf \times d}{kinematic\ viscosity\ of\ air}$$

$$Reynolds\ number = \frac{0.37 \times 0.0127}{20.02 \times 10\hat{} - 6}$$

R_e = 234.71

7)Nusselt number (N_u) :-

$N_u = 0.615 \times (R_e)^{0.466} = 7.82$

8) Heat transfer coefficient (h) :-

$$h = \frac{Nu \times Kair}{d}$$

$$h = \frac{7.82 \times 0.0297}{0.0127}$$

h = 18.28W/m^2K

9) Efficiency of fin (η) :-

$$\eta = \frac{\tanh(ml)}{ml}$$

m =7.22

$$\eta = 73\%$$

Comparison Differenttype Material of Fin:-

	Brass Fin	Aluminum Fin	Stainless Steel	Copper
Re	234.71	240.55	240.15	242.83
m	7.2	5.21	11.25	3.85
η	73%	83%	55%	89.99%

III. RESULTS

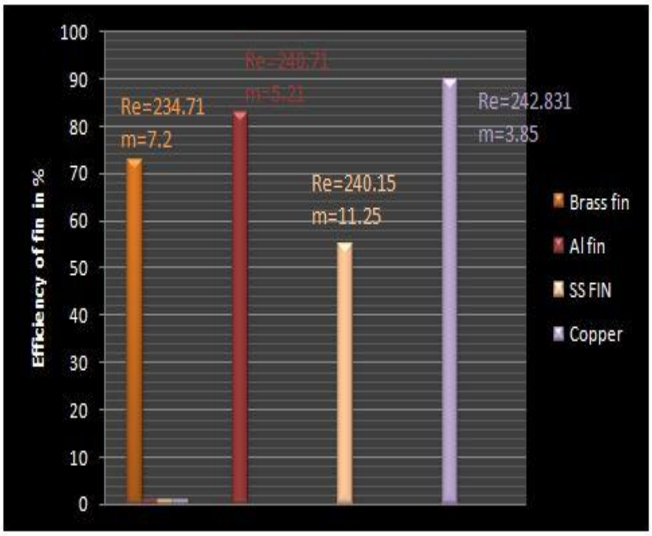
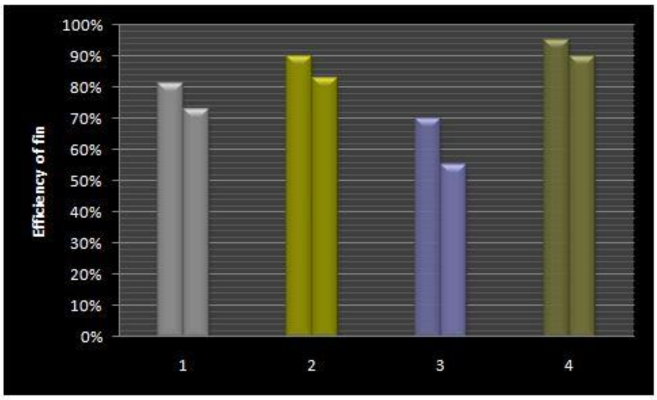


Figure1: Fin efficiency with different material

The performance of copper material fin is better as compare to other material because thermal conductivity is very high for same dimensions of extended surfaces, high Reynolds's number and low value of physical significance.



1.Brass	2.Al	3.SS	4.Copper

Figure2: Theoretical & Actual Fin efficiency for Different material

Note:-Theoretical data are collected with the reference{3}Laxmikant Chavan and Niranjan Purane "Analysis of pin fin using different material and Forms"Index values 2013,ISSN(ONLINE):2319-7064.

IV. CONCLUSIONS

The experimental work has been used to solution of the heat conduction problem for fin with temperature dependent heat transfer coefficient. In this paper Reynolds number and physical significance parameter (m) varying with experiments of different material porous fin. The performance of fin is depended on ability to conductance of heat; better thermal conductivity to perform of fin is very fast.This experimental work is an extension in this direction to analyze the heat augmentation capacity of porous finof different materials.

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