Comparative Analysis of Solid Pin Fin With Internal Threaded Porous Fin By Using Pin Fin Experimental Set Up

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Abstract- *The present work demonstrates experimental comparative analysis of parameter aimed at enhancement of heat transfer of solid fin and porous fin with internal threaded using pin fin apparatus and investigates the temperature distribution, performance parameters, heat transfer rate, effectiveness and efficiency through different material (Aluminium, Brass & Stainless steel) have a same dimensions pin fin in forced convection condition. This study based on finite-length fin with insulated tip. We observed the temperature at five point on the fin surface along the length for all three material (Brass, Aluminium, Stainless Steel), By which we made calculations for solid and Internal threaded porous fin. We found the variation in parameters like Reynold number, Nusselt number, Fin parameter (m), Efficiency and Effectiveness, for both type of fin, and the result shows that the Fin parameter m increases for the Internal threaded porous fin due to this the Effectiveness of the fin increased. Result shown that the Effectiveness for the solid fin of material Brass, Aluminium, Stainless Steel are 34.58, 39.5, 26.5 respectively .The effectiveness of internal threaded porous fin of material Brass, Aluminium, Stainless Steel are 51, 61.48, 36.56 respectively, which is greater than the Effectiveness of solid fin. We also observed that the Efficiency of the solid fin is greater than the threaded porous fin because in the threaded fin the area of cross section has decreased. The threaded porous fin increases the effectiveness of the fin and reduces the weight of the fin for same heat transfer.*

Keywords- Porous Fin, Internal threading, Heat transfer enhancement, Forced convection, Efficiency, Effectiveness.

I. INTRODUCTION

In many engineering situations, means are often sough to improve heat dissipation from a surface to its surroundings. The Newton Rikhman relation revels that the convective heat flow can be enhanced by increasing the film coefficient the surface area A and the temperature difference. The convective coefficient is a function of the geometry, fluid properties and the flow rate. Control of h through these parameters helps to obtain its optimum value. With regard to the effect of temperature excess difficulties are encountered when the ambient difficulties are encountered when the ambient temperature is too high particularly in hot weather conditions. The surface area exposed to the surroundings is frequently increased by the attachment of protrusions to the surfaces, and the arrangement provides a means by which heat transfer rate can be substantially improved. The protrusions are called fins or spines, and these extensions can take a variety of forms.

Classification of Enhancement Technique

There are applied following technique for enhancement of the heat transfer:-

I. Passive Techniques
II. Active Techniques
III. Compound Techniques.

I. Passive Technique

These techniques may be related to the surface or geometrical modifications to the flow channel by additional devices. They are also pointing higher heat transfer coefficients by disorganized existing flow behavior (except for extended surfaces) which also outshines to rise in the pressure differences. In the case of extended surfaces are dominant heat transfer area on the side of the extended surface is increased. Passive techniques hold the advantage over the active techniques as they do not require any direct input of external power.

II. Active Technique

These techniques are more intricate from the use and design point of view as the method requires some external power input to cause the desired flow modification and improvement in the rate of heat transfer. It finds limited application because of the need of external power in many practical applications. In comparison to the passive techniques, these techniques have not shown much potential as it is difficult to provide external power input in many cases.

III. Compound Technique

A compound augmentation technique is the one where more than one of the above mentioned techniques is used in combination with the purpose of further improving the thermo-hydraulic performance of a heat exchanger.

II. LITERATURE REVIEW

A.I. Ambesange, Prof. S.S. Raut et al This study of heat transfer from Dimple pin fin of circular cross section has been done in this work. In this dissertation work the heat transfer enhancement with circular cross section shaped dimples has been experimentally investigated and results of these investigations are compared with each other. Heat transfer coefficient of fins also increases with increase in Reynold'sno. The maximum Reynolds number in circular fins is 267.85 without dimples and for dimples fin it is 208.05. that with increases in Reynolds number the Nusselt number of the process also gets increased. It shows that Dimpled cross sectional circular fins transfer more heat and has high heat transfer coefficient in each case. It is observed that the maximum increase in efficiency in circular fins with dimples is 99.75% against the efficiency without dimpled fins of 93.51%.So concluded that the Dimpled shape of the fin is more effective to transfer heat than circular shape fins[1].

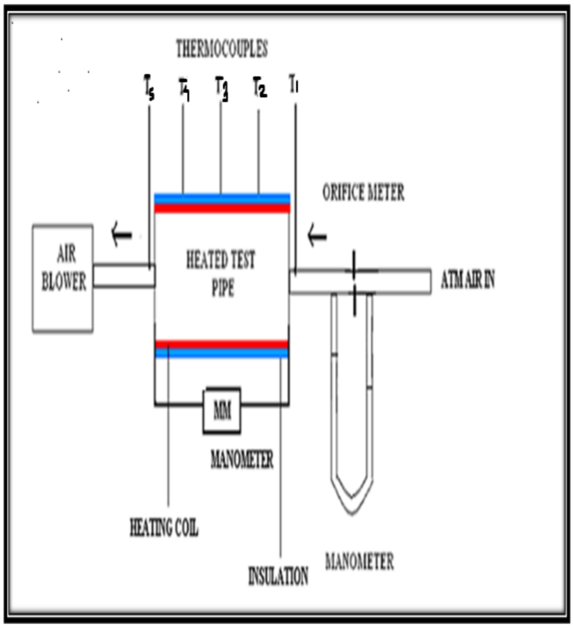
U.S.Gawai, Mathew V K et. alIn this literature they show that heat transfer enhancement use in dimples based on the principal of scrubbing action of cooling fluid taking place inside the dimple and phenomenon of intensifying the delay of flow separation over the surface. Spherical indentation or dimples have shown good heat transfer characteristics when used as surface roughness. The technology using dimples recently attracted interest due to the substantial heat transfer augmentations it induced, with pressure drop penalties smaller than with other type or heat augmentations. The proposed work is concerned with experimental set up for enhancement of the forced convection heat transfer over the dimpled surface and flow structure analysis with in a dimple. The experimental results give heat transfer coefficient and efficiency of aluminium fin is greater than the brass fin[2].

Pankaj N. Shrirao, Dr. Rajeshkumar U. Sambhe, Pradip R. Bodade The present work focuses on Experimental investigation of heat transfer and friction factor characteristics of horizontal circular pipe using internal threads of pitch 100mm, 120mm and 160mm with air as the working fluid. The transitional flow regime is selected for this study with the Reynolds number range 7,000 to 14,000. The horizontal aluminum pipe was subjected to constant and uniform heat flux. The experimental data obtained were compared with those obtained from plain Horizontal pipe. The effects of internal threads of varying depth on heat transfer and friction factor were presented. Based on the same pumping power consumption, the pipe with internal threads possesses the highest performance factors for turbulent flow. The heat transfer coefficient enhancement for internal threads is higher than that for plain pipe for a given Reynolds number. The use of internal threads improved the performance of horizontal circular pipe[3].

Details of experimental set-up

Fig 3.1 shows the schematic diagram of the experimental set up. Test Pipe with Interior Threads show in fig 3.2 the circular channel is used for this investigation and made up of Aluminum (Al) material. The uniform heat flux plate type heater is fabricated from nichrome wire. This heater is connected in series with dimmer stat 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. The Nichrome bend heater get in the test section to a length of 50 cm. Three thermocouples T_2, T_3 and T_4 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 (T_1) and the other at the exit (T_5) 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. The diameter of the orifice is 1.4 cm and coefficient of discharge is 0.64.The orifice meter are connected to a water U-tube manometer to indicate the pressure difference between them. The test tube of 12.7 mm Dia. Solid as well as Internal threaded fin was used for experimentation. Display unit consists of voltmeter, ammeter and temperature indicator. The circuit was designed for a load voltage of 0-220 V; with a maximum current of 10 A. Difference in the levels of manometer fluid represents the variations in the flow rate of air. The airflow velocity Fig 3.1 shows the schematic diagram of the experimental set up. Test Pipe with Interior Threads the circular channel is used for this investigation and made up of Aluminum (al) material. A suction mode blower is used to draw the air from entrance to exit section. The blower send air to heated test section which is 150 mm long and 12.7 mm dia. Through a rectangular duct which is 15 cm width and 10 cm in height. Difference in the levels of manometer fluid represents the variations in the flow rate of air. The velocity of airflow in the tube is measured with the help of orifice plate and the water manometer fitted on board.

In present study, both without interior thread and with interior thread o pitch (p=1mm) are used.



III. OBSERVATIONS & CALCULATIONS

(Aluminium 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 condition reading

T1	T2	T3	T4	T5	T6
105	90	80	65	40	25

Calculations:-

1)Average fin temperature(Tm)

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

2) Mean fin temperature (Tmf)

$$Tmf = \frac{349 + 298}{2} = 323.5K$$

At Tmf in 323.5K properties of air from S.Subramanyan page no. 34

$\rho_a = 1.093$ kg/m^3, $K_a = 0.02826$W/mK , $V_a = 17.95\text{x } 10^{-6}$ m^2/s

3) Air flow rate (Q):-

$$Q = 5.150 \text{ x } 10^{-3} \text{ m}^3\text{/sec}$$

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

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

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

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

6) Reynolds number (R_e) :-

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

7)Nusselt number (N_u) :-

$$N_u = 0.615 \text{ x } (R_e)^{0.466} =$$

8) Heat transfer coefficient (h) :-

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

9) Efficiency of fin (η) :-

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

(10)**Effectiveness(Ɛ) :-**

$$Ɛ = \sqrt{pk/hAc} \times \tanh(ml)$$

OBSERVATIONS & CALCULATIONS

(Aluminum Material)-:

Outer dia. of the fin	12.7mm
Internal mean dia. Of the fin	8.2mm
Length of fin	150mm
Dia. Of the orifice	14mm
Dia. Of the delivery pipe	36mm
Coefficient of discharge	0.65
Pitch of the thread	0.5cm
Input voltage	60V
Input current	0.30A
Manometer reading	0.146

Steady state condition reading (for threaded porous fin):-

T1	T2	T3	T4	T5	T6
105	86	74	62	38	25

Calculations:-

1)Average fin temperature(Tm)

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

2) Mean fin temperature(Tmf)

$$Tmf = \frac{346+298}{2} = 322K$$

At Tmf in 323.5K properties of air from S.Subramanyan page no. 34

$\rho_a = 1.093\ kg/m^3$, $K_a = 0.02826 W/mK$, $V_a = 17.95 \times 10^{-6}\ m^2/s$

3) Air flow rate (Q):-

$$Q = 5.150 \times 10^{-3}\ m^3/sec$$

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

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

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

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

6) Reynolds number (R_e) :-

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

7)Nusselt number (N_u) :-

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

8) Heat transfer coefficient (h):-

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

9) Efficiency of fin (η):-

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

$$m = \sqrt{ph/kAc},$$

Effectiveness(Ɛ) :-

$$Ɛ = \sqrt{pk/hAc} \times \tanh(ml)$$

IV. RESULT & DISCUSSION

The experiments were carried out on the test rig initially without using any interior threads and the different heat transfer characteristics were calculated and then the same is done using interior threads of pitch within duct. The experimentation is divided in following cases.

a) Case I: Experimentation on Circular duct without any interior threads.
b) Case II: Experimentation on porous Circular duct with interior threads of pitch (p=1mm).

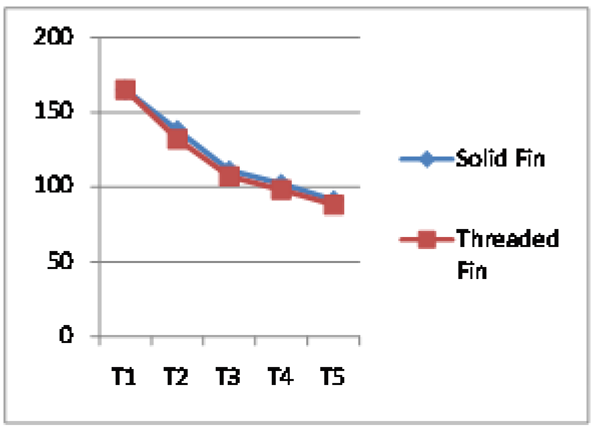
Based on the observations recorded while experimentation, following parameters are calculated for above three cases.

1. Heat transfer coefficient (h)
2. Nusselt number (Nu)
3. Reynold number (Re)
4. Fin parameters (m)
5. Fin efficiency
6. Fin effectiveness

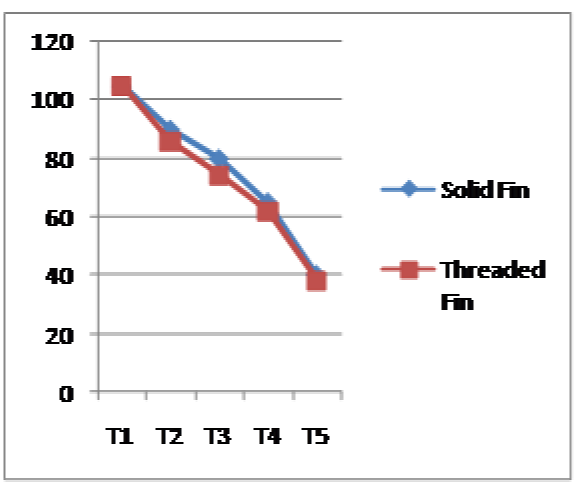
Based on the above calculations following graphs are plotted for interpretation of performance

1) Fin parameter for materials between solid fin and internal threaded fin.
2) Fin efficiency for materials between solid fin and internal threaded fin.
3) Fin effectiveness for materials between solid fin and internal threaded fin.

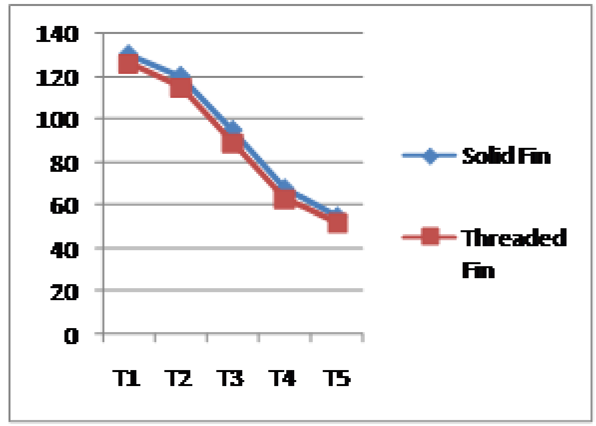
Temperature distribution curve for the brass fin



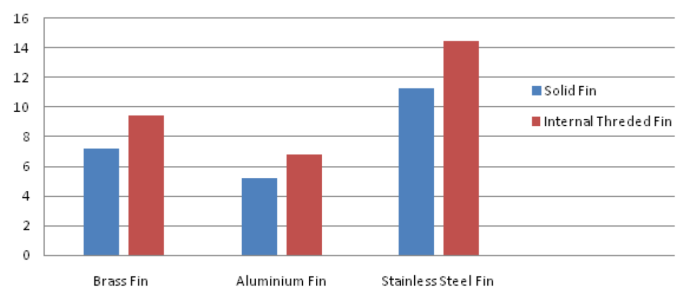
Temperature distribution curve for the Aluminium fin



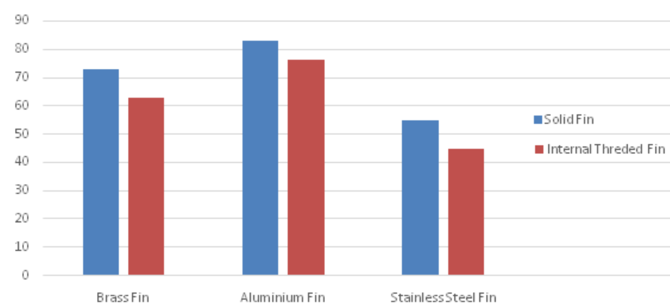
Temperature distribution curve for the Stainless steel fin



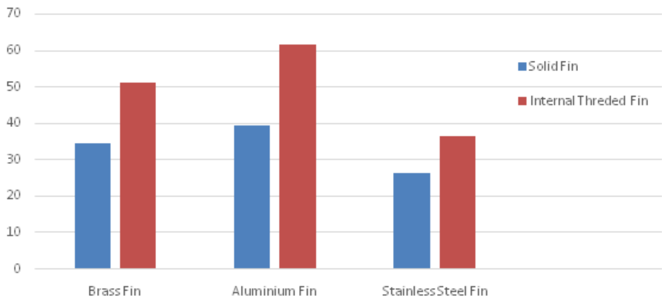
Fin parameter (m) for different material



Efficiency comparison graph for different material of fin



Effectiveness comparison graph for different material of fin



Comparison to all materials fin (without thread)

	Brass Fin	Aluminum Fin	Stainless Steel
Re	234.71	240.55	227.6
Nu	7.82	7.91	7.71
m	7.2	5.21	11.25
h	18.28 W/m^2K	17.60 W/m^2K	17.60 W/m^2K
η	73%	83%	55%
ε	34.58	39.5	26.5

Comparison to all materials fin (with threaded porous fin of 1 mm pitch)

	Brass Fin	Aluminum Fin	Stainless Steel
Re	233.7	238	223
Nu	7.81	7.87	7.64
m	9.40	6.75	14.38
h	18 W/m2K	17.20 W/m2K	17.24 W/m2K
η	63%	76%	45%
ε	51	61.48	36.56

V. CONCLUSIONS

Experimental investigations have been carried out to study the effects of the interior threads of pitch (p= 1mm) on the performance Circular duct. Heat transfer coefficient and fin efficiency are analyzed with using mentioned passive heat transfer enhancement methods. From the graph plotted above following conclusions are made.

1. The heat transfer in the Circular duct could be promoted by using interior threads. The heat transfer rate increases in the Circular duct with a significant rate as compared to without interior threads. This increase in the heat transfer is depending on the many factors but heat transfer coefficient plays important role in it. The results show that the effectiveness for the interior threaded with porous fin is more as compare to the without using any interior threads(solid fin) in duct. The result shows that the efficiency of the threaded fin is decreased as the cross sectional area is decreased but the effectiveness of the threaded fin is increased. This increases in the heat transfer rate occurred due to the turbulence.

2. The interior threads fin causes the maximum turbulence in the duct due to which maximum heat transfer to occur.

3. As the interior threaded fin increases the effectiveness which is major parameter behind using fins. In comparison to solid fin and threaded porous fin, the threaded porous fin will save material due to high effectiveness and our object weight will decrease.

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