Experimental Investigation of Natural Convection for an Annular Composite Fin by Using Matlab Programming

[I]Padma Lochan Nayak, [II]Suvendu Mohanty, [III]Jagdish Pradhan
[I,II]Research Scholar, Dept. of Mechanical Engg., National Institute of Tech. Patna, Bihar, India
[III]Research Scholar, Dept. of Mechanical Engg., Center For Mechanics, BPUT, Odisha, India

Abstract

An experimental investigation of natural convection heat transfer in a heated an annular composite fin dissipating heat in a radial direction. The aim of this project is analysis the efficiency in both (with and without coating)an annular fin and physical dimensionless number such as (Nusselt's number, Grashoff's number and Prandtl's number) of the natural convention heat transfer process by the variation of heat transfer coefficient for any surface condition.By using MATLAB software to calculate the base fin efficiency and the coated fin efficiency by the variation of heat transfer coefficient at constant radius in both the fins. From the experimental result it has been found that the efficiency of zinc coating fin is higher than the efficiency of steel(base) fin and by using without coating fin the experimental efficiency is increasing 2.5% as compare with the Matlab efficiency but by using zinc coating fin the experimental efficiency is increasing 14.2% as compare with the Matlab efficiency.

Keywords

Annular composite fin, Efficiency ratio, MATLAB simulation, Experimental data of composite fin (only zinc coating).

I. Introduction

Now days, most of the engineering processes require better dNow most of the engineering and industrial field require better design of fin configuration to capture the heat and transfer that heat in proper ways with progressively less weight, volume and accommodates shape. To adopted the new manufacturing technology for design the fin and cost as well as the thermal behaviour. The rate of heat transfer depends on the surface area of the fin. The annular composite fin is one of the most popular choices for exchanging the heat from the primary surface to surrounding fluid. Through the free or force convection heat transfer takes place between the extended surface to atmosphere fluid, so that heat transfer rate can be increased by the connection of an extended surface (fin) of thin strips metal. An extended surface geometry is divided in two types such as a straight fin and annular fin. The heat transfer takes place by an extended surface through the conduction mode within the boundary condition as well as convection heat transfer from boundary condition of the conduction to the surrounding fluids, but in present report using an annular composite fin has been investigated the experimental efficiency and MATLAB efficiency (i.e calculated by MATLAB coding) for both the fins (i.e with and without coating) and compare it. Generally the fins are attached, where the heat transfer coefficient is much lower than the other fluid side. Generally the composite fins may be used under the high temperatures condition and also corrosion atmosphere. If we use the fins in high temperature side the life of the fin can be reduced, so increase the life of the fins or protected the base material under the high temperature. We have use an anti-hostile coating material is coated over the base material by the galvanization process. When used an extended surface is made of two or more different materials it is called composite fin. The construction of the composite fins either the galvanization process or electrochemical process. The coating of different materials and their alloys are used to protect the base material for the different environmental conditions such as more highly polluted air in industrial regions, moisturescontent of the air, water contains chemical pollutants and marine water those are effects on the coating materials. Due to those effects the coating materials are destroyed by corrosion but the base material is protected, so that the life of the fin is increase..

II. Literature Review

K.Balaji and B.N.V Srinivas discussed the effect of coating on the efficiency of annular fin. He has observed that high thermal conductivity coating materials are reducing the temperature variation from base to tip [1].

B. kundu& P.K. Dasreported the performance of elliptic fin has been analysed using a semi analytical technique. He has also shown the efficiency of elliptic fin by using sector method [2].

S.Lalot, C.Tournier and M.Jensen discussed the fin efficiency of annular fin made of two materials by using the arithmetic special mean approximate method [3].

Chi-Yuan Laireported the thermal performance of singular annular fin with variable thermal properties such as heat transfer coefficient and thermal conductivity. He has also describe the singular annular fin can be divided into several circular sections and each section is taken its variable thermal properties. The results obtained from each section have been combined each section and calculated by using recursive formula [4]. Mokheimer Esmail M.A.investigated the performance of annular fins of different profiles subject to locally variable heat transfer coefficient. 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 [5].

Akihiko Horibe, Zhongmin Li and Naoto Harukidiscussed the composite fin are made of coating layer over a core metal then calculation efficiency of the fins by an analytical process. He has also investigated the theoretical results show that fin efficiency of a coated fin decreases with an increase of the coating layer thickness if the thermal conductivity of coating layer is much less than that of the substrate metallic fin and vice versa [6]..

III. Methodology

A. Material selection

In the present experimental investigation, we have taken the base fin material will be selected is steel and the coating fin material are use zinc over the base fin metal and to see the table no. 3.1.

B. Modeling of annular fin using MATLAB

Using the MATLAB software to compare the efficiency and physical dimensionless number for heat transfer by the natural

ISSN : 2394-2975 (Online)
ISSN : 2394-6814 (Print)

convection process of the experimental results and the efficiency calculated through the MATLAB programming for both the fins.

C. Physical model

The sketch of an annular composite fin with rectangular profile is shown in the fig. 1. (a)& (b) with the coordinate system.

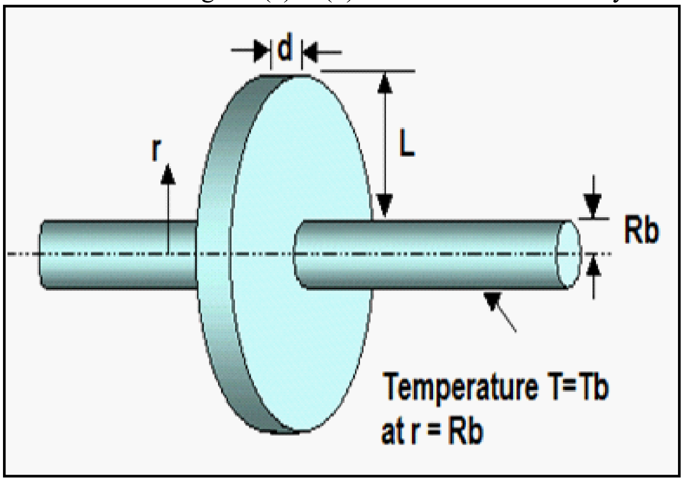

Fig. 1.(a)Circular fins without coating

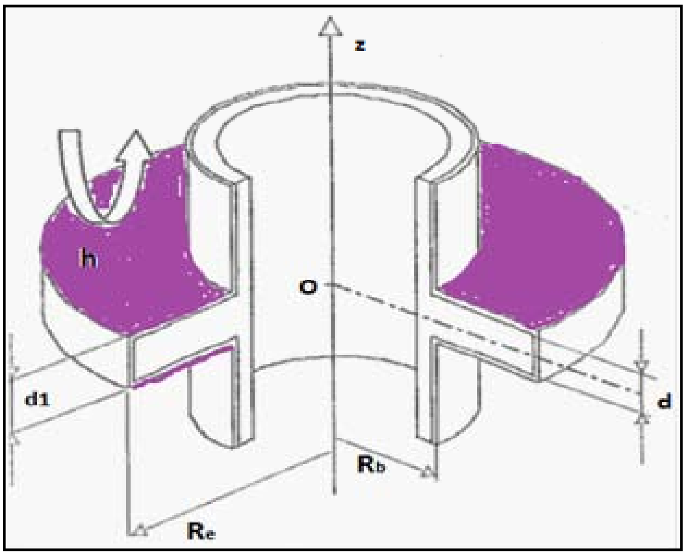

Fig. 1. (b) Circular fins with coating

The mathematical formulation is based upon the following assumption:-

1. The fin materials of each zone are considered as homogeneous.
2. The fin materials of each zone are isotropic.
3. Neglected the heat transfer at the fin end.
4. Neglected the physical contact resistance between the cylindrical tube and fin base.
5. Neglected the physical contact resistance between the base fin (steel) and coated fin (zinc).

Solve the equations (partial differential form) of heat propagation in the core material (region-1) of the fin and the coated material (region-2) of the fin.

D. Range of investigation of the annular composite fin

Table no.3.1

Experimental setup specification data for an annular composite fin are given below

Tube material	Steel
Tube inside diameter	0.9cm
Tube outside diameter	1.3cm
Base fin material	Steel
Coating material	Zinc
Thermal conductivity of zinc	111W/mK
Base fin thickness	2mm
Coating thickness in each sides	2mm
Fin base radius	0.65cm
Extremity radius	5.05cm
Circular steel fin diameter	10.1cm
Circular iron piece diameter	4cm
Band type heater power capacity	200 W

Table no. 3.2

1. Setup spanner	2. Setup screw driver
3. Band type heater	4. Circular iron piece
5. Digital Voltmeter (0 to 199 V)	6. Digital watch
7. Digital Ammeter (0 to 1.999 A)	8. Digital Temperature (0 to 3000 C)

IV. Procedure for Experimental

To study the temperature variation along the radial length of the annular fin in natural convection only, the following procedure are given below the natural convection

A. Natural Convection

1. Switch on the system the electric current pass to the heater and start heating the heater at that time to adjust the voltage on the voltmeter in our requirement. In the present report taken voltage range from 90V to 115V.
2. During heating the energy (heat) is transfer to the steel tube through the mode of conduction. A circular fin is placed at distant 6.6 cm from the heater base and through the conduction the heat is flow in radial direction of the circular fin.
3. After steady state has been reached, the thermocouples reading were noted down at four different points on the radial direction of the circular fin and also measure the ambient temperature at a particular voltage. Similar ways the reading of the thermocouples were noted down by the variation of voltage and ambient temperature and then calculate the average surface temperature of the each voltage.
4. Similar procedures are taken the reading for both the fins like with coating and without coating fin.

B. Calculation data obtain from the experiment

Data obtained using zinc coated over the base (steel) fin in average surrounding temperature is 22.40 c on date 19/05/2014 at NIT Patna.

Table no. 4.1

Input Voltage(V)	Input Current (I)	Heat input through heater (Q) =VI (W)	Thermocouple reading			
			T_{t1}(⁰C)	T_{t2}(⁰C)	T_{t3}(⁰C)	T_{t4}(⁰C)
90	0.317	28.53	34.5	33.2	31.6	30.3
95	0.337	31.63	34.6	33.3	31.8	30.5
100	0.352	35.10	34.8	33.4	31.9	30.6
105	0.373	39.48	35.0	33.5	31.4	30.7
110	0.387	42.79	35.1	33.0	32.0	30.8
115	0.406	46.57	35.3	33.2	32.1	30.7

Average surface temperature $(T_s) = \frac{T_{t1}+T_{t2}+T_{t3}+T_{t4}}{4}$ (⁰C)	Base temperature $(T_b = T_{t1})$ (⁰C)	Experimental efficiency (η)
32.4	34.5	82.6
32.5	34.6	82.3
32.6	34.8	82.2
32.65	35.0	81.3
32.72	35.1	81.2
32.85	35.3	81.0

Mean film temperature (T_f) (⁰C)	Thermal conductivity of air (K_{air}) (W/m K)	Kinematic viscosity (ϑ) x 10^{-6} (m^2/s)	Prandtl's number (Pr)
27.40	0.02620	15.79	0.71226
27.43	0.02622	15.80	0.71225
27.50	0.026225	15.8075	0.71225
27.52	0.026226	15.8098	0.71224
27.56	0.026229	15.8130	0.71224
27.61	0.026232	15.8177	0.71223

Nusselt's number (Nu)	Grashoff's number (Gr)	Heat transfer coefficient (h) (W/m^2 K)	Heat losses through fin (Q_{Fin}) (W)	Efficiency (η_M) calculate through MATLAB
14.3025	7.4456 x10^5	7.9729	1.412	95.37
14.3216	7.4856 x10^5	7.9896	1.425	95.36
14.3563	7.5584 x10^5	8.0105	1.447	95.34
14.3698	7.5870 10^5	8.0186	1.456	95.30
14.3878	7.6251 x10^5	8.0294	1.467	95.33
14.4124	7.6775 x10^5	8.0442	1.489	95.32

Table no. 4.2

Similar way we have proceed the experimental procedure, we obtained data by using base (steel) fin metal without coating in an average surrounding temperature is 22.40 c on date 20/05/2014 at NIT Patna.

Input Voltage (V)	Input Current (I)	Heat input through heater(Q) = VI (W)	Thermocouple reading			
			T_{t1} (⁰C)	T_{t2}(⁰C)	T_{t3}(⁰C)	T_{t4} (⁰C)
90	0.317	28.53	34.2	33.1	31.1	29.6
95	0.337	31.63	34.5	33.3	31.3	29.8
100	0.352	35.10	34.7	33.2	31.4	30.1
105	0.373	39.48	34.9	33.4	31.3	29.8
110	0.387	42.79	35	33.6	31.2	29.9
115	0.406	46.57	35.2	33.7	31.4	30

ISSN : 2394-2975 (Online)
ISSN : 2394-6814 (Print)

C. Experimental Setup Figure

Experimental figure for an annular composite fin by using zincs coating over the base fin is made of an annular steel plate.

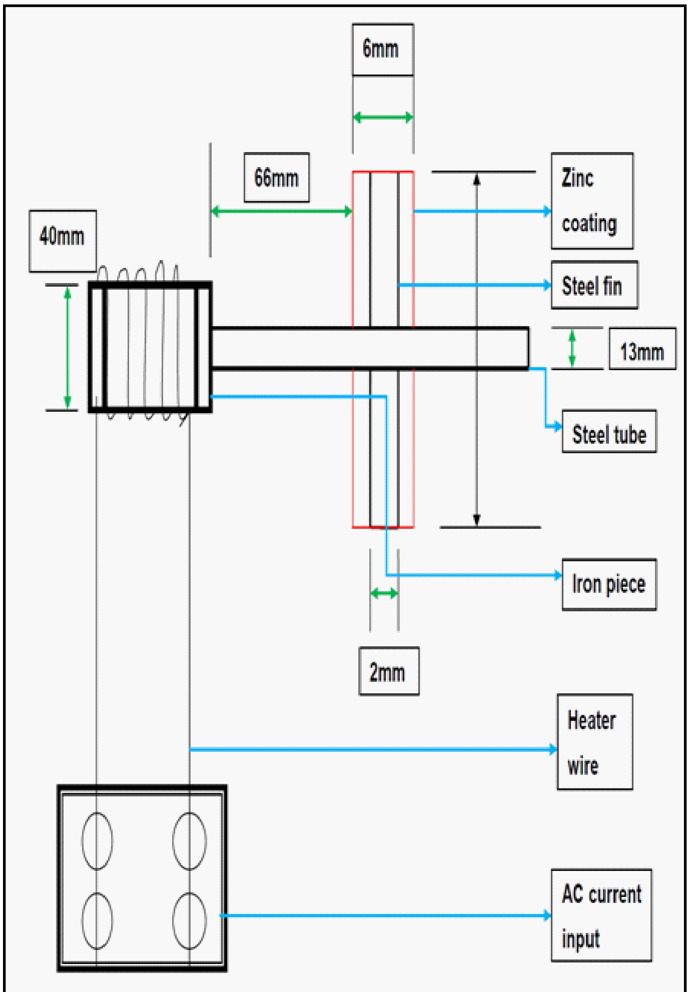

Figure 2.1 Layout of experimental setup in composite fin

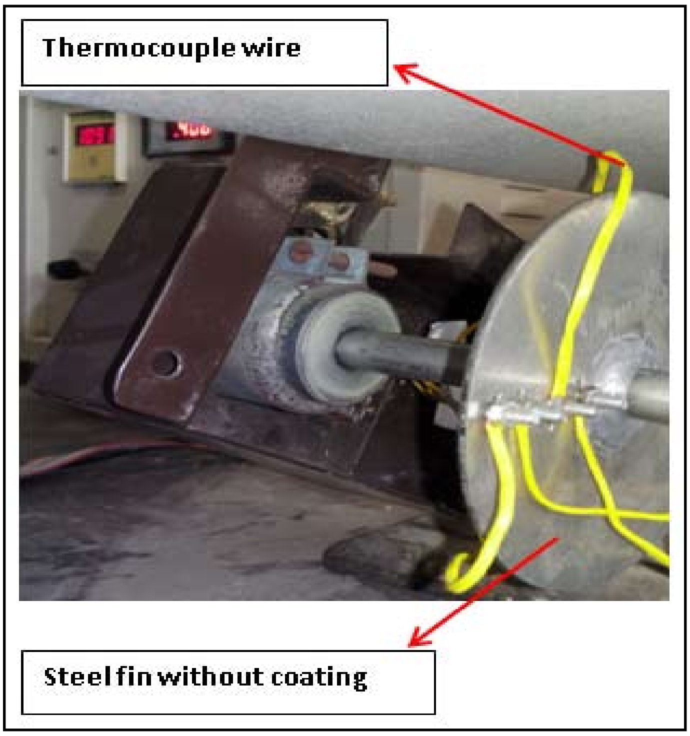

Fig. 4.3 : Steel fin without coating

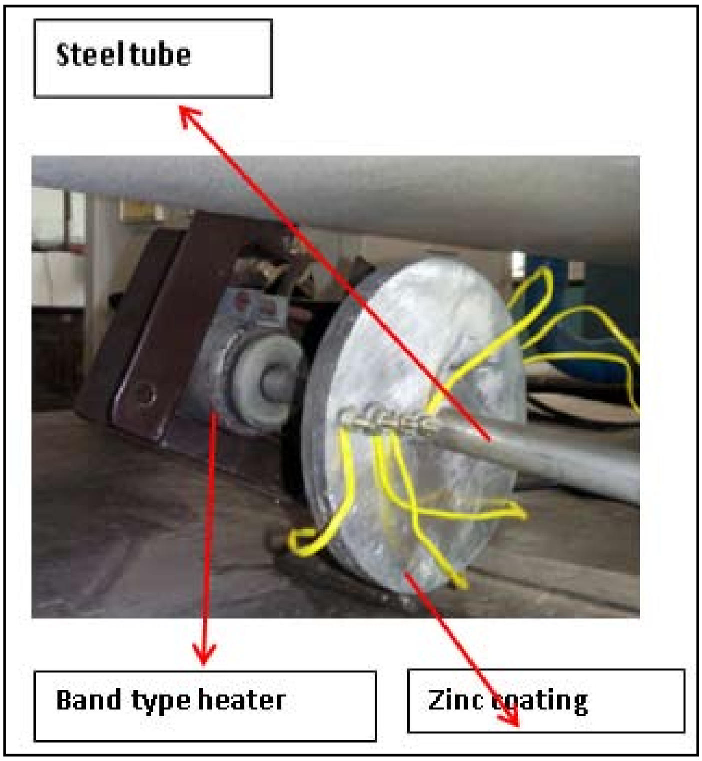

Fig. 4.3 : Composite annular fin (zinc coating over the steel)

V. Results and Discussion

From the above experimental data were drawn the graphs by the MATLAB software are given below -

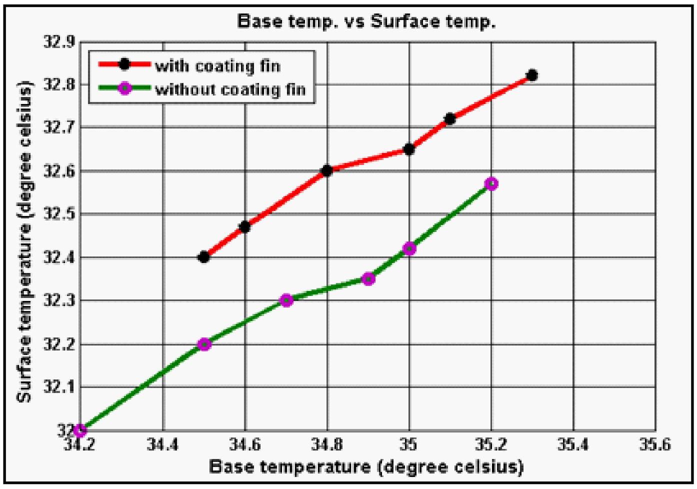

Fig.5.1 (a) Comparison of surface temperature in with and without coating fin against base temperature

Increasing the base temperature with increase the surface temperature of the zinc coating and without coating fin as shown in figure 5.1 (a).

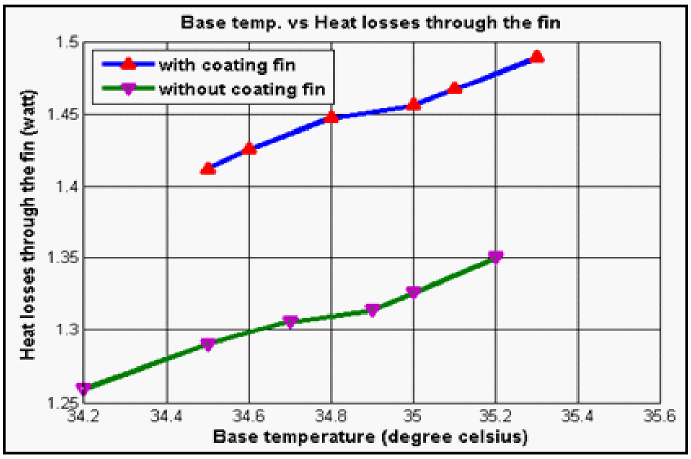

Fig. 5.2 (b) Comparison of heat loss through the fin in with and without coating against base temperature

Increasing the base temperature of both the fins with increasing the heat transfer losses through the fins as shown in figure 5.2 (b).

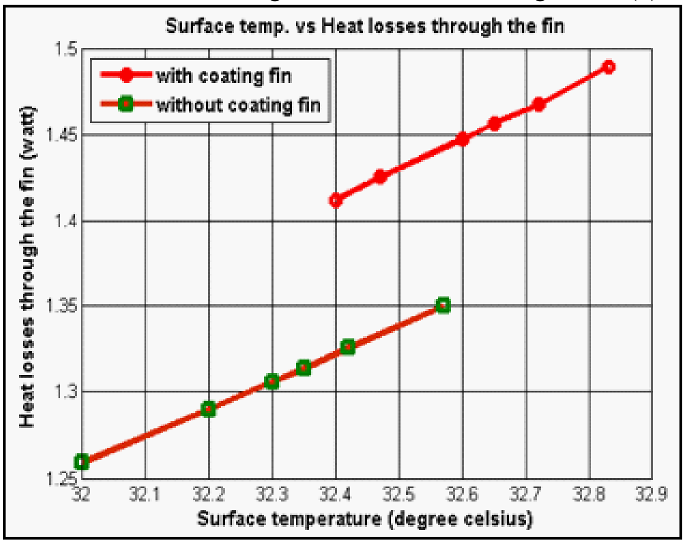

Fig. 5.3 (c) Comparison of heat loss through the fin in with and without coating against surface temperature

Increasing the surface temperature of both the fins with increasing the heat transfer losses through the fin as shown in fig. 5.3 (c).

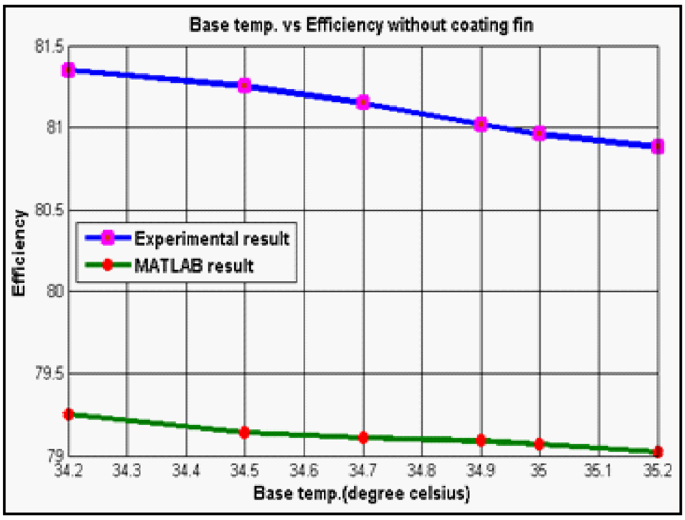

Fig. 5.4(d) Comparison of without coating efficiency in Matlab and experimental data against base temperature

Increasing the base temperature of without coating fin with respect to decreasing the efficiency of the fin as shown in figure 5.4 (d) then compare the experimental data with the MATLAB data and experimental efficiency increasing 2.5% as compare to Matlab efficiency.

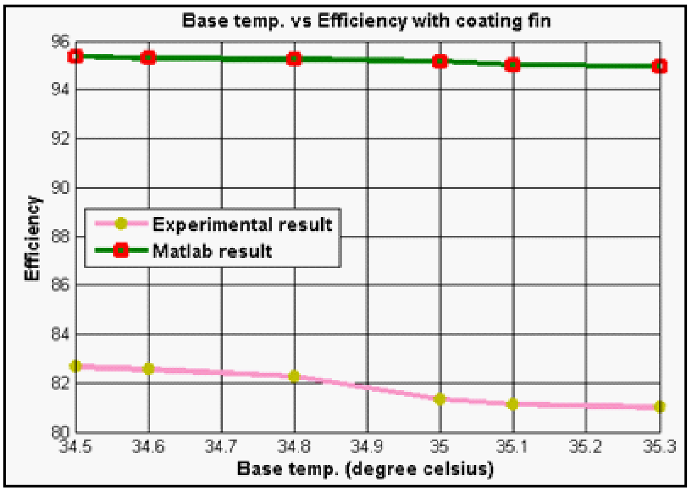

Fig. 5.5(e) Comparison of with coating efficiency in Matlab and experimental data against base temperature

Increase the base temperature of with coating fin with respect to decrease efficiency of the fin as shown in figure 5.5 (e) than compare experimental data with the MATLAB data and Matlab efficiency increasing 16.5% as compare to experimental efficiency.

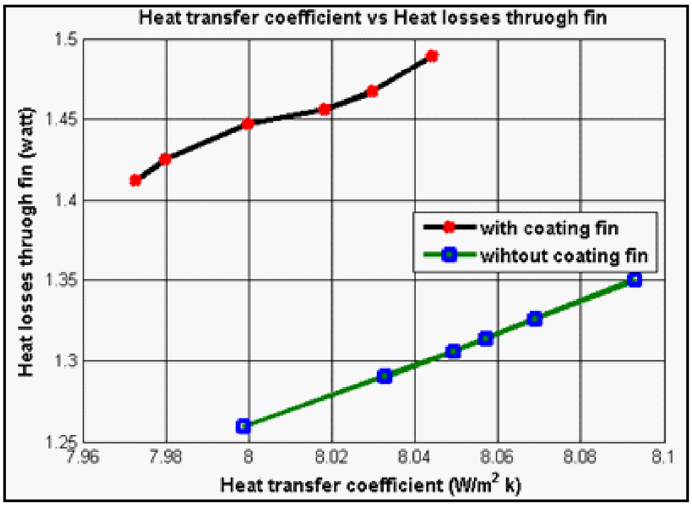

Fig. 5.6(f) Comparison of heat loss through fin in with and without coating against heat transfer coefficient

Increasing the heat transfer coefficient of both the fins with increasing the heat transfer losses through the fin as shown in figure 5.6 (f).

ISSN : 2394-2975 (Online)
ISSN : 2394-6814 (Print)

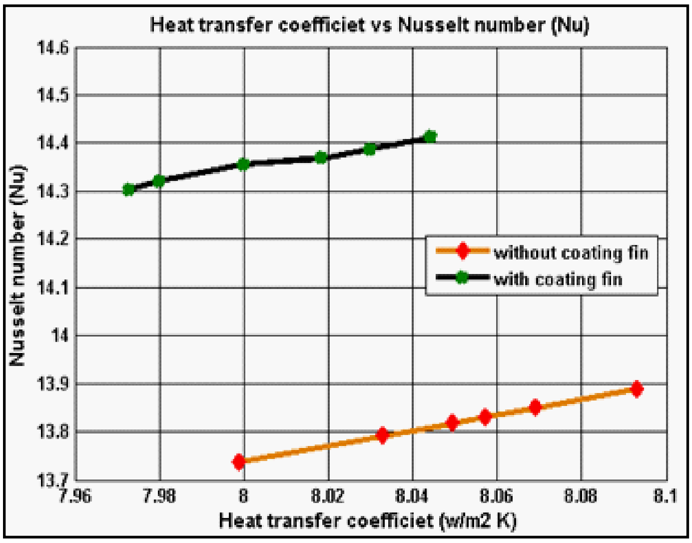

Fig.5.7 (g) Comparison of Nusselt's number in with and without coating fin against heat transfer coefficient

Increasing the heat transfer coefficients of both the fins with increasing the Nusselt number of the fin as shown in fig. 5.7 (g)

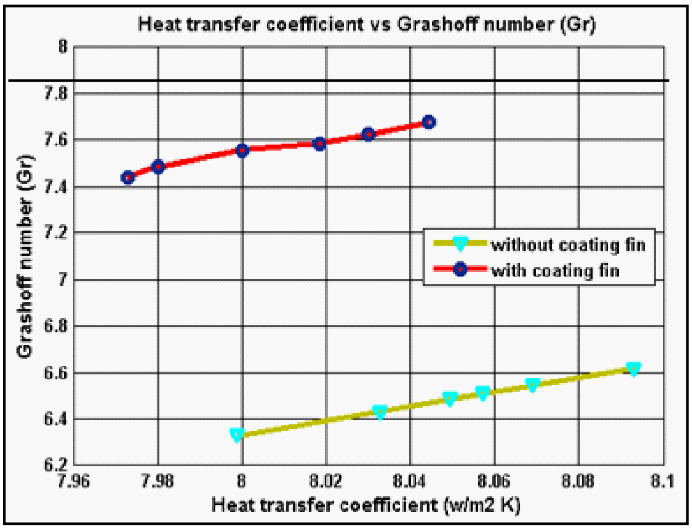

Fig. 5.8 (h) Comparison of Grashoff's number in with and without coating fin against heat transfer coefficient

Increasing the heat transfer coefficient of both the fins with increasing the Grashoff's number of the fin as shown in figure 5.8 (h)

VI. Conclusion

In this project report, study or focus on the efficiency of an annular composite fin by the variation of heat transfer coefficient but the radius of the both (with and without coating) fins is constant. When zinc coating over the base fin (steel) metal under the 2-D steady state condition.

The following conclusions were drawn is given below

1. At increased the heat transfer coefficient, the efficiency of the fin is decreasing but the efficiency ratio is increase and same has been obtained experimentally.
2. Experimental efficiency is increasing 2.5% as compare the calculated through Matlab efficiency for without coating fin.
3. Experimental efficiency is increasing 14.2% as compare the calculated through Matlab efficiency for with coating fin.
4. Increasing heat transfer coefficient with increasing the Nusselt number (Nu) but decrease the Prandtl's number (Pr).
5. Coating is more efficient for the thinner fin.
6. Increase the heat transfer through the fin with increase the heat transfer coefficient
7. If surface temperature is increase then the efficiency of the fins is decrease.

VII. Acknowledgments

IIt is my pleasure to express my heartfelt thanks to my project guide prof. (Dr.) **Sudarshan singh**, Professor, Department of Mechanical Engineering, National Institute of Technology Patna, Patna-800005 for permitting me to carry out the project under his esteemed guidance.

I express my sincere thanks to Professor **Dr. Om Prakash, HOD**, Department of Mechanical Engineering, and NIT Patna for providing me the necessary facilities in the department

.

References

[1] *K.Balaji , B.N.V Sriniva and R. lalithanarayan (Oct. 2012) "Effect of coatings on fin efficiency of Annular fin", International Journal of Research in Mechanical Engineering & Technology, Vol. 2, Issue 2, Pages 18 - 21.*

[2] *B.Kundu&P.K.Das,(May 2002)"Performance Analysis and Optimization of Straight Taper Fins with Variable Heat Transfer Coefficient", International Journal of Engineering Science & Technology, Vol.126, pages 862-867.*

[3] *S.Lalot, C.Tournier and M.Jensen (1999) "Fin efficiency of annular fins made of two materials",International Journal, Heat and Mass Transfer, Vol. 42, pages 3461-3467.*

[4] *Kraus Allan D & Aziz Abdul & Welty James (2001) "Extended Surface Heat Transfer", John Wiley & Sons, Inc.*

[5] *Webb,R.L.,(1994),Principles of Enhanced Heat Transfer, John Wiley & Sons, NewYork.*

[6] *N. Nagarani& K. Mayilsamy (2010) "Experimental Heat Transfer Analysis on Annular Circular and Elliptical Fins", International Journal of Engineering Science and Technology, Vol. 2(7), Pages 2839-2845.*

[7] *Campo Antonio, (May 2008) "Approximate Analytic Temperature Distribution and Efficiency for Annular Fins of Uniform Thickness" International Journal of Thermal Sciences, doi:10.1016/j.ijthermalsci.2008.05.012.*

[8] *Chi-Yuan Lai (2009) "Recursive formulation on thermal analysis of an annular fin with variable thermal properties" Applied Thermal Engineering, Vol.29, pages 779-786.*

[9] *Mokhimer Esmail M.A. (2002)"Performance of Annular fins with different profiles subject to variable heat transfer coefficient", International Journal of Heat & Mass Transfer, Vol. 45, Issue 17, pages 3631-3642.*