International Journal of Engineering Innovation & Research
Volume 6, Issue 1, ISSN: 2277 – 5668

Experimental Investigation of Heat Transfer Characteristics from a Brass Alloy Base Tube with Corrugated Copper Fins

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Date of publication (dd/mm/yyyy): 21/02/2017

***Abstract* – The heat transfer rate for flow through tube/pipe can be augmented by one or more from the following:**

1) **By creating turbulence in the flow.**
2) **By increasing the friction.**
3) **By increasing the surface area.**

The heat transfer area can be increased by providing fins. These fins may be integral or externally attached to the tube. The fins can be made up of various shapes and the material can be of the same or different than base tube material. In the present experimental work, investigation has been carried out for the heat transfer characteristics of a brass alloy base tube with corrugated copper fins.

The investigation has been carried for water temperature varying from 40^0 C to 60^0C and water velocity1.2 m/sec to 3 m/sec; and air velocity 1.4 m/sec to 14 m/sec. The thermal performance of this tube has been studied and on this basis heat transfer characteristics has been analysed.

***Keywords* – Heat Transfer Co-Efficient($H"_{Air}$), Overall Heat Transfer Co-Efficient(U_{oall}), Brass Alloy Base Tube, Corrugated Copper Fins.**

I. INTRODUCTION

In the present work the experimental investigation has been carried out for a specific type of bi - metallic finned tube. Bi - metallic finned tube is a tube in which the fins are of different material than the material of the base tube. The bi - metallic finned tube which is being investigated is a brass alloy base tube with corrugated copper fins of uniform thickness. The investigation has been carried out for water temperature varying from 40^0C to 600C, water velocity 1.2m/s to 3m/s and air velocity 2.6 m/s to 14 m/s. These ranges have been selected to suit the conditions prevailing the practice. The thermal performance of this tube has been studied and on this basis heat transferred characteristics has been analysed.

Assumptions: For the derivation of fin efficiency and its characteristics it is necessary to impose the limitations and assumptions given by Murray and later by Gardner. These are as follows:

1. The heat flow and temperature distribution throughout the fin is independent of time i.e. heat flow is steady.
2. The fin material is homogeneous and isotropic.
3. There is no heat source in the fin itself.
4. The heat flow to or from the fin surface at any point is directly proportional to temperature difference between the surface at that point and the surrounding fluid.
5. The thermal conductivity of the fin is constant. 6. The heat transfer coefficient is the same over the entire fin surface.
7. The temperature of the fluid surrounding the fin is uniform.
8. The temperature of the base of the fin is uniform.
9. The film thickness is so small compared with its height that is why, the temperature gradients across the width of the fin may be neglected.
10. The heat transferred through the outer most edge of the fin is negligible compared with that passing in to the fin throughout its sides.
11. The joint between the fin and the tube is assume to offer no bond resistance.

II. EXPERIMENTAL SETUP

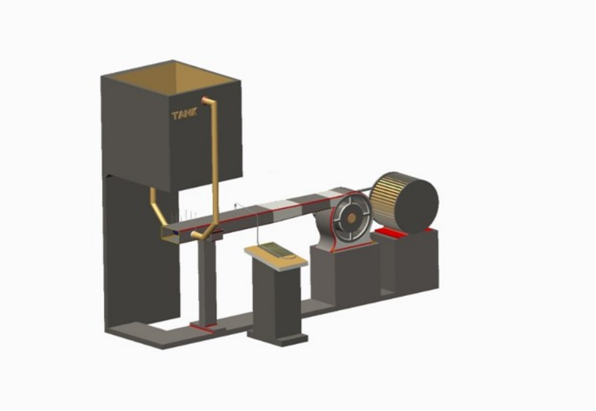

Figure II A: The Experimental setup

The heat exchanger is fitted in the wind tunnel with the help of rubber pipes clamped with clips. Also the heat exchanger pipe is supported by an angle iron frame resting on a vibration damped foundation.

The heat exchanger is a single flow type for both air and water side. It is found by approximate heat balances expected that the decrease in temperature on the water side, even with sufficiently high turbulent flow of air, was very small. Hence the experimental accuracy is very much curtailed in-spite of using accurate instruments for measuring temperature.

There are seven holes drilled on air tunnel to put thermometers and pitot tube. One pitot tube and three thermometers are arranged along rubber cork before the heat exchanger tube and three thermometers are after it. Pitot tube is connected to the water column so as to find the velocity of air in the tunnel. In the air tunnel one mesh is provided to get proper mixing of air before it passed over the heat exchanger pipe. There is an arrangement of gearing system in order to vary the amount of air flow.

In the water side amount of flow is measure with the help of rotameter. Here also two thermometer pockets are provided. Just after the delivery of the pump one by pass line is fitted with a control valve so as to decrease the amount of water pressure in the heat exchanger pipe. Amount of flow can be controlled with the help of valves. After passing through heat exchanger pipe the water is taken back into the water tank.

III. RANGE OF INPUT PARAMETERS

1. Air velocity : 2.61 m/s to 14.05 m/s
2. Water velocity : 1.24 m/s to 2.91 m/s
3. Avg. air inlet temp. : 38^{0}C to 48^{0}C
4. Water inlet temp. : 40^{0}C to 60^{0}C

IV. SPECIFICATIONS OF DEVICES USED

1. Power of air blower (induction motor): 5 H.P.
2. Power of water pump : 5 H.P.
3. Capacity of immersion heators : 1.5 KW (7no.)
4. Rotometer :20 to 200 lit./min. accuracy of 5lit/min

V. PROGRAMS

A. C-Program for calculating air velocity and mass flow rate

```
 #include<stdio.h>
#include<conio.h>
#include<math.h>
void main()
{
float r,l,h;
float v;
float g=9.81
float area=0.0610235sq.m;
float density=1.128kg/cu.m;
float M;
printf("\n Enter the value of r& l");
scanf("%f%f",&r,&l");
if(r>l) h=r-l;
else h=l-r;
v=sqrt(2000*g*h*0.01*0.173648 );
printf("\n velocity in m/sec.is% f ",v);
v=v*3600 in m/hr;
M=density*area*v;
printf(\n value of M in kg/hr is %f",M);
getch();
}
```

Results:

Value of r & l: 31.2 & 31; v = 2.6103 m/sec & M = 646.858 kg/hr Value of r & l: 30.4 & 31.8; v = 6.9063 m/sec & M = 1711.421 kg/hr

Value of r & l: 29.9 & 32.3; v = 9.0425 m/sec & M = 2240.777 kg/hr

Value of r & l: 29.2 & 33; v = 11.3782 m/sec & M = 2819.583 kg/hr

Value of r & l: 28.9 & 33.3; v = 12.2436 m/sec & M = 3034.0271 kg/hr

Value of r & l: 28.7 & 33.5; v = 12.788 m/sec & M = 3168.9377 kg/hr

Value of r & l: 28.2 & 34; v = 14.057 m/sec & M = 3483.429 kg/hr

B. C – Program for calculating Q & U for Air

```
#include<stdio.h>
#include<conio.h>
#include<math.h>
#define c=1.005
void main()
{
float ti,to,M,U;
float Q,td,tavg;
float area=0.41854424 sq.m;
printf("\n enter the value of ti&to&M");
canf("%f%f%f",&ti,&to,&M);
td=to-ti;
Q=M*1.005*td;
printf("\n heat transfer in kj/hris%f",Q);
tavg=(ti-to)/2;
U=Q/(area*tavg);
printf("\nvalue of heat transfer coefficient in kj/sq.m-
deg.C-hr is%f",U);
getch();
}
```

VI. RESULTS & DISCUSSIONS

The investigation have been carried out for brass alloy base to with corrugated copper fins of uniform thickness and results have been plotted in figures A, B, C, D & E.

The results have been plotted for the finned tube H. E. for air velocity varying from 2.61 m/s to 14.05 m/s Vs over all heat transfer co-efficient for water velocity varying from 1.24 m/s to 2.91 m/s.

A. Variation of Overall Heat Transfer Co-efficient With Air Velocity at Constant Water Velocity:

Table VI A. Representing values of U_{oall} V_{air} at constant V_w

V_{air} in m/sec	U_{oall} at V_w=1.24 m/s	U_{oall} at V_w=1.66 m/s	U_{oall} at V_w=2.07 m/s	U_{oall} at V_w=2. 28m/s	U_{oall} at V_w=2.49 m/s	U_{oall} at V_w=2.9 1 m/s
2.61	59.89	60.06	60.14	59.56	60.2	59.63
6.9	71.62	71.86	71.98	71.69	71.72	71.78
9.04	73.81	73.54	74.19	73.73	73.76	73.83
11.37	74.86	74.81	75.25	75	75.03	75.11
12.24	75.74	76.01	76.14	76.22	76.25	76.32
12.78	75.98	76.25	76.38	76.45	76.48	76.56
14.05	76.19	76.46	76.59	76.67	76.7	76.78

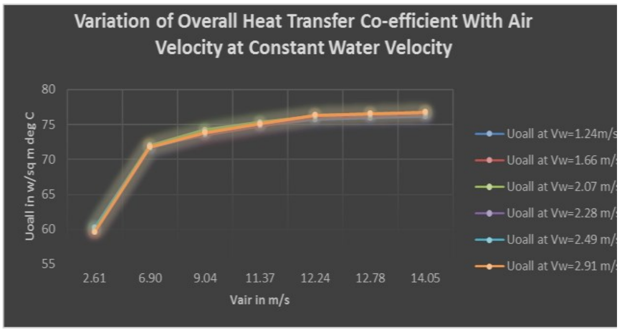

Figure VI A: Plot between air velocity and overall heat transfer co-efficient at constant water velocity

It indicates as the air velocity (V_a) increases from 2.61 m/s to 6.9 m/s, overall heat transfer co-efficient (U_{oall}) is increased sharply and after that U_{oall} increases gradually. The reason for this could be that the air flow is laminar at 2.61 m/s of air velocity and it may become turbulent at 6.91 m/s of air velocity due to this turbulence the U_{oall} increases suddenly. But as the air velocity increases after 6.91 m/s and further the air flow remains turbulance that's why U_{oall} increases gradually.

B. Variation of Air Side Film Co-efficient with Air Velocity At Constant Water Velocity:

TableVI B. Representing values of h"$_{air}$ at constant V_w

V_{air} in m/sec	h"$_{air}$ at V_w=1.24 m/s	h"$_{air}$ at V_w=1.66 m/s	h"$_{air}$ at V_w=2.07 m/s	h"$_{air}$ at V_w=2.28 m/s	h"$_{air}$ at V_w=2.49 m/s	h"$_{air}$ at V_w=2.91 m/s
2.61	627.97	627.97	627.97	609.54	627.97	609.54
6.9	1200.85	1200.85	1200.85	1173.74	1173.74	1173.74
9.04	1393.49	1342.92	1393.49	1342.92	1342.92	1342.92
11.37	1503.33	1469.27	1503.33	1469.27	1469.27	1469.27
12.24	1608.16	1608.16	1608.16	1608.16	1608.16	1608.16
12.78	1637.98	1637.98	1637.98	1637.98	1637.98	1637.98
14.05	1665.64	1665.64	1665.64	1665.64	1665.64	1665.64

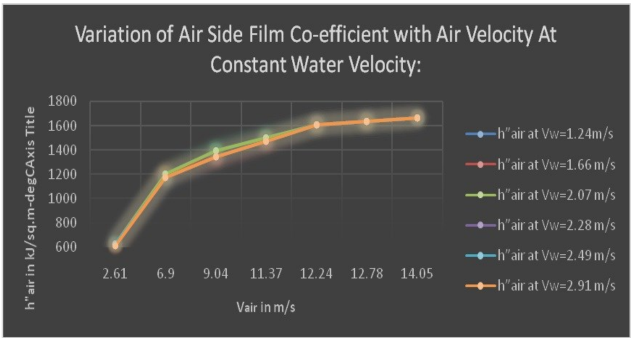

Figure VI B: Plot between air velocity and air side heat transfer co-efficient at constant water velocity

It indicates air side heat transfer co-efficient increases suddenly when air velocity changes from 2.61 m/s to 6.9 m/s and after 6.9 m/s it increases gradually. The reason for this is the same as explained for figure 1.

Since the water side heat transfer co-efficient is constant for different air velocities at constant water velocity in all cases therefor the air side heat transfer co-efficient mainly affects the overall heat transfer co-efficient of the given heat exchanger. the overall heat transfer co-efficient changes proportionally as the air side heat transfer co-efficient increases with respect to air velocity from 2.61 m/s to 14.05 m/s at constant water velocity in all cases i. e. V_w= 1.24, 1.66, 2.07, 2.28, 2.49 & 2.91 m/s .

C. Variation of Heat Transfer Co-efficient (For Heat Exchanger Without Fins &With Fins) With Air Velocity at Constant Water Velocity:

Table VI C. Representing values of U_{oall} with and without fins at constant V_w

V_{air} m/s	U_{oall} without fins at Vw=1.24 m/s	U_{oall} with fins at Vw=1.24m /s
2.61	3.92	215.62
6.9	10.132	257.85
9.04	7.77	265.74
11.37	41.44	269.5
12.24	49.78	272.69
12.78	47.346	273.53
14.05	37.225	274.29

V_{air} m/s	U_{oall} without fins at Vw=1.66m/ s	U_{oall} with fins at Vw=1.66 m/s
2.61	22.038	216.22
6.9	57.599	258.72
9.04	50	264.76
11.37	40.59	269.32
12.24	49.79	273.66
12.78	17.15	274.51
14.05	12.96	275.27

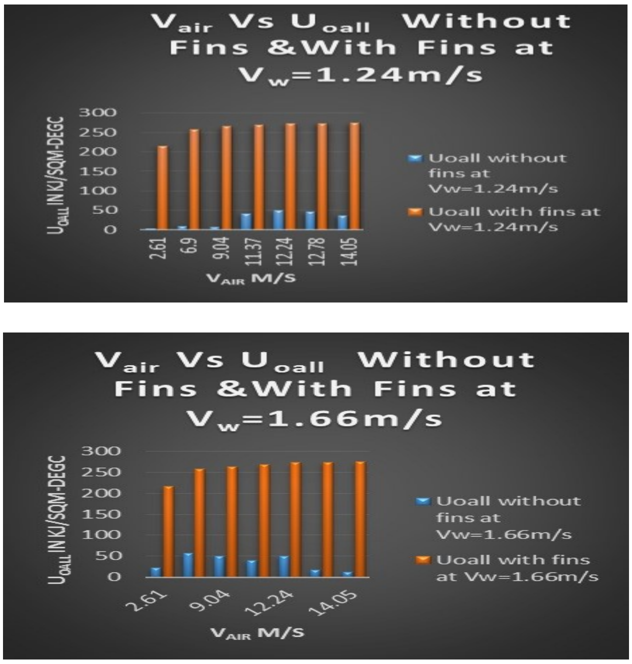

Figure VI C:(a)&(b)- Bar chart between air velocity and overall heat transfer co-efficient of H.E. with fins and without fins at constant water velocity

By taking the same inner diameter and outer diameter, and the length of the base tube of similar metal for a heat exchanger without fins and a heat exchanger with fins; and then plot a bar chart between air velocity and their individual over all heat transfer co-efficient at constant water velocity.

This bar chart shows very clearly how fins play their role for deciding over all heat transfer co-efficient. Because fins, which are attached to the base tube, increase the total available area for heat transfer. As the heat transfer area increases, the rate of heat transfer through the heat exchanger is also increased; which ultimately increases the overall heat transfer co-efficient. Hence over all heat transfer co-efficient of a H.E. with fins is far greater than that of a H.E. without fins. Therefor for H.E. of the same length first one (i.e. H.E. with fins) is far better than that of second one (i.e. H.E. without fins). In other words for same rate of heat transfer the H.E. with fins is very compact then that of the H.E. without fins.

D. Variation of$(T_i)_{avgair}$ With V_{air} at Constant Water Flow Rate

Table VI D. Representing values of $(T_i)_{avg}$ at constant V_w

V_{air}in m/sec	V_w 1.24 m/s	V_w 1.66 m/s	V_w 2.07 m/s	V_w 2.28 m/s	V_w 2.49 m/s	V_w 2.91 m/s
2.61	39.6	42.1	41.7	42.6	42.4	42.7
6.9	40.5	42.2	41.7	42.8	42.5	43.1
9.04	41.5	42.8	42.2	43.4	42.7	43.7
11.37	42.3	43.2	42.6	43.9	43.1	44.2
12.24	42.9	43.7	43.3	44.9	44	44.7
12.78	43.8	44.3	44.7	45.4	44.8	45.6
14.05	44.8	45.13	45.6	45.9	45.5	46.1

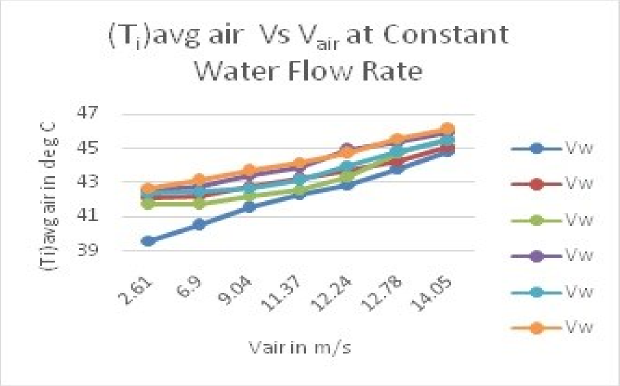

Figure VI D: Plot between air velocity and avg. air inlet temp. at constant water flow rate)

It shows as the air velocity increases the inlet air temperature also increases gradually. The reason could be same as velocity increases the flow becomes turbulent due to this internal energy of the air particles increase, which ultimately increases the average air inlet temperature.

E. VARIATION OF (T_O) V_{AVGAIR} WITH V_{AIR} AT CONSTANT WATER FLOW RATE

Table VI E. Representing values of $(T_o)_{avg}$ at constant V_w

V_{air} in m/sec	V_w 1.24m/s	V_w 1.66 m/s	V_w 2.07 m/s	V_w 2.28 m/s	V_w 2.49 m/s	V_w 2.91 m/s
2.61	39.6	42.7	42.5	43.6	43.5	43.8
6.9	40.6	42.8	42.5	43.7	43.5	44.1
9.04	41.56	43.2	42.9	44	43.8	44.5
11.37	42.56	43.46	43.2	44.4	44.1	44.9
12.24	43.3	44	43.8	45.2	44.7	45.5
12.78	43.9	44.4	44.9	45.9	45.4	46
14.05	45	45.2	46	46.2	46.1	46.6

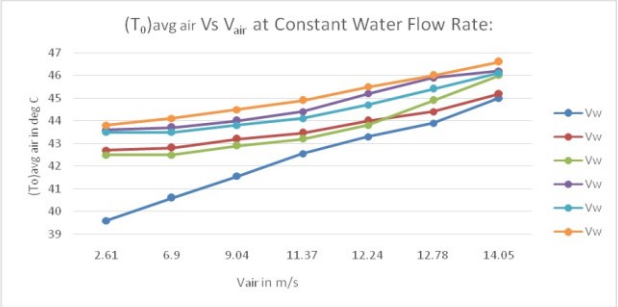

Figure VI E: Plot between air velocity and avg. air outlet temp. At constant water flow rate)

It shows that avg. air outlet temperature increases gradually with respect to air velocity. And as the avg. air inlet temp. increases, the avg. air outlet temp. definitely increases because in this case air is working as a cold fluid thus air abstracts heat from hot fluid i.e. water and becomes somewhat hot than the avg. air inlet temp.

VII. CONCLUSION

We have conducted multiple experiments and arrived on the below conclusion. For the given operating parameters (with the given range of water flow rate & Air Flow rate) Maximum Overall Heat Transfer coefficient could be achieved as 76.78 w/m^2- ^{0}C at Air Velocity 14.05m/sec and Water Velocity 2.91m/sec.

V_{air} in m/sec	U_{oall} at V_w=1.24 m/s	U_{oall} at V_w=1.66 m/s	U_{oall} at V_w=2.07 m/s	U_{oall} at V_w=2.28 m/s	U_{oall} at V_w=2.49 m/s	U_{oall} at V_w=2.91 m/s
14.05	76.19	76.46	76.59	76.67	76.7	**76.78**

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AUTHOR'S PROFILE

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The author of this paper is working as an Assistant Professor in Mechanical Engineering Department of Shri G. S. Institute of Technology & Science, Indore. She has thirteen years of teaching experience in this institute. She has done her B.E. Mechanical Engineering from M.I.T.S., Gwalior and M.Tech. in Thermal Engineering from M.A.N.I.T., Bhopal; both in 1st division with distinction. Her areas of research interest are: Heat Transfer, Refrigeration & Air Conditioning and Components used in Power Plant. She has got an experience of eleven P.G. Dissertation Guidance. Prof. Swati has had seven publications in International Journals so far viz. IJAME, IJAER and IJTEL in 2014; INPAC-2015(accepted); IJARSE(2papers) and International Journal "Discovery Engineering" in 2016. She has attended four International Conferences viz "AMAEAP 2014"-4th International Conference organized by JNU, New Delhi; International Conference on Trends in Industrial and Mechanical Engineering (IC TIME2016), February 4-6, 2016; 4th International Conference on recent trends in Engineering Science and management (ICRTESM - 2016), Goa (India) on 7th August 2016; 7th International Conference (ICRISEM-16) held at The Institution of Engineers, New Delhi (India) on 16th September 2016. She is the lifetime member of Indian Society of Technical Education (ISTE).