EXPERIMENTAL STUDY OF CONJUGATE CONVECTION HEAT TRANSFER USING PLANE, 25% DEPTH ,50% DEPTH,75% DEPTH RECTANGULAR FINS

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ABSTRACT

Fins are extended surfaces used to enhance the rate of convective heat transfer. Different types of fins have been design on the basis of space, material, weight, manufacturing, availability, cost as well as thermal conductivity. Different profile of fins influences the thermal properties as well as rate of heat transfer. Our study deals with output of different fins profiles. The commonly used fins are plane rectangular fins, 25% (10mm) depth rectangular fins, 50% (20mm) depth rectangular fins and 75% (30mm) depth rectangular fins.

KEYWORDS: fins, conjugate convection, rectangular, rate of heat transfer enhancement, chimney flow, depth, thermal characteristics etc.

INTRODUCTION

1. History

Heat transfer was a major source in the industries, aviation, automobiles etc . Here the term conjugate problem was arise in late 1960s, which lead by scientists A. V. Luikov in the Soviet Union. He along with others, began to investigate with the researchers and started to solve the problems related to that with using different approaches and techniques . An early review specify that the problem related to that was found on the book by the Dorfman.

Though the conjugate convective heat transfer model was developed after the computers came into wide existence with their usage, on that the empirical relation between the proportionality of heat flux to temperature difference with heat transfer coefficient. Then, It was use since the time of Newton. These mathematical equation solves the problem and describe the heat transfer between a body and the fluid over and inside it, with the interaction of the two objects and their physical significations and the equations of the distribution with their temperature and heat flux conditions and eliminate the need for heat transfer coefficient.

2. Purpose of study

In engineering curriculum, beginner engineers were trying continuously on the field of heat transfers with the help of researchers , techniques with their design, operation, testing with the many forms of the heat transfer equipment in our scientific and industrial technology. Though the research and development were always finding new techniques with help of all the journals and thesis, with the computational dynamics and making available and patent towards the practical application on the field of heat transfer.

Electrical engineers applying the knowledge of heat transfer in cooling system for motors, transformer, generators. While mechanical engineer were trying to do in their specialization such as the internal combustion engines, steam generation, refrigeration and air conditioning and ventilation. All though chemical engineer were trying in the field of condensation, evaporation, heating and cooling of the fluids. As we seen that all the fields of the engineers, researchers and scientist has tremendously approaching towards advanced technologies with their efficient ways of the heat transfer**s.**

3. Definition

Conjugate convection is defined as the combination of natural convection and the forced convection. It is also known as the mixed convection.

4. Statement regarding problem

Presently we have to study about the conjugate convection heat transfer from plane rectangular, 25% depth rectangular, 50% depth rectangular and 75% depth rectangular fins on a horizontal base surface (base plate). In this experiment we work on the different parameters and after the observation we compare all these parameters.

5. Objective

The objective of this study is to enhance the rate of heat transfer take place in convective mode by using different types of fins.

6. Types of modes of heat transfer

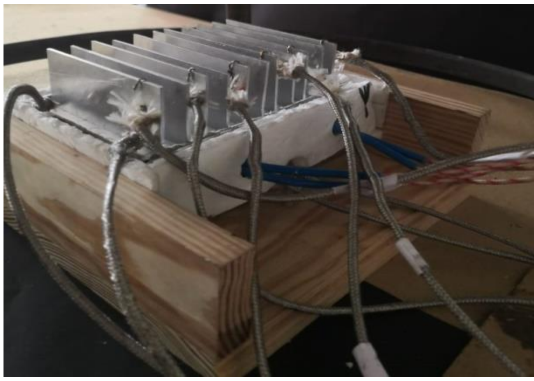
There are mainly three types of modes of heat transfer. Heat transfer is a type of energy which occurs due to temperature difference. The direction of heat flow always takes place from higher temperature body to lower temperature body. The three different modes are as fallow:

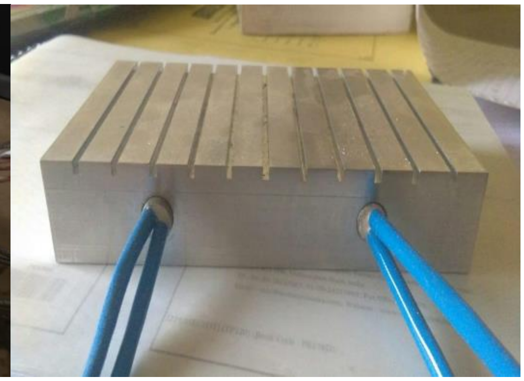
- Conduction
- Convection
- Radiation

APPARATUS

i) Base plate

Base plate (140mm×85mm×25mm) is an important part of our set up, which is used to support the fins in slot of *2mm* on the upper surface of the base plate and it also consists of two drilled holes in which cartridge heaters are fitted as shown in figure. The material used for the base plate is *aluminum* having the thermal conductivity of 203W/mk.

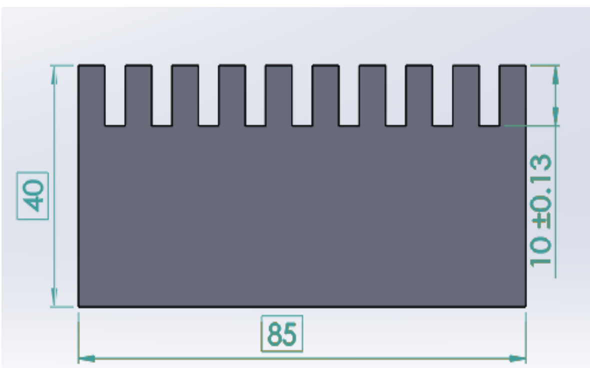




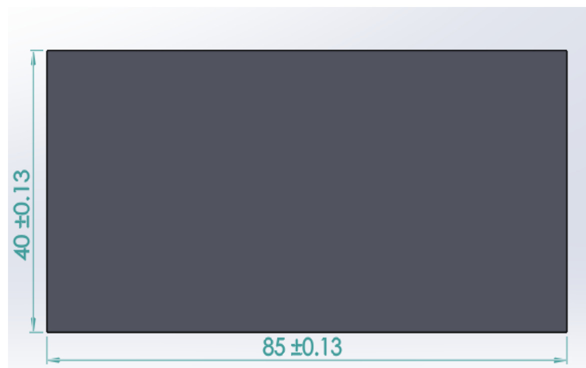
ii) Fins

The material used for the fins is aluminum and different types of fins as follow:

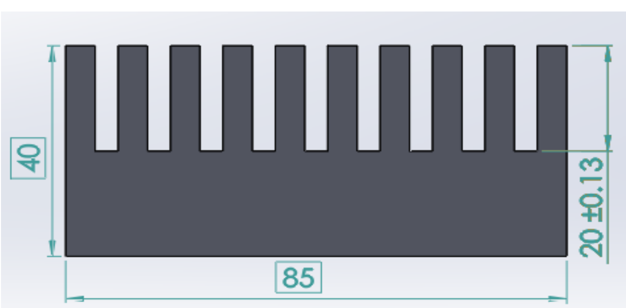
plane rectangular fins (85mm×40mm×2mm),



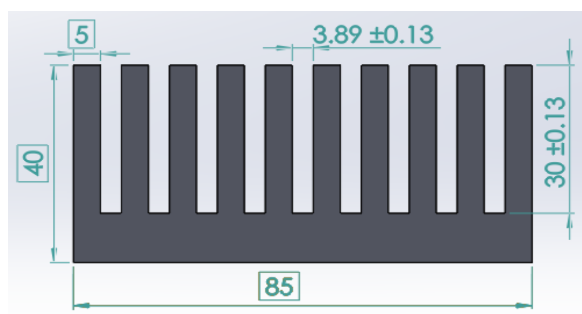
25% (10mm) depth rectangular fins (85mm×40mm×2mm)



50%(20mm) depth rectangular fins (85mm×40mm×2mm)



75% (30mm) depth rectangular fins (85mm×40mm×2mm)



iii) Wood casing with thermocol

It is used to support the base plate on which fins are fitted and also act as an insulator. When temperature of the base plate will increases than it does not allow the heat to escape in all direction except the upper direction.

iv) Thermocouple

In our experiment we have used the *K-Type thermocouple*. Thermocouples are used as a temperature sensor to measure the temperature of fins and base plate and it is also used for measuring the temperature of ambient at inlet and outlet of the blower.

v) Digital temperature indicator

It indicates the temperature of base plate and temperature of different fins according to the voltage and current output. We use the 12 node temperature indicator which consists of a rotating knob to indicate the different temperature.

vi) Control panel

- **Dimmer stat**
  It is used to regulate the voltage provided to the cartridge heater.
- **Voltmeter**
  It display the amount of voltage supplied to the heating element.
- **Ammeter**
  It display the amount of current supplied to the heating element**.**

vii) Funnel (chimney)

It is used for guiding the heated air flow over the heated fins.

viii) Cartridge heater

It is a heater which is used to heating the base plate. It is fitted inside the drilled hold of base plate with proper arrangement.

ix) Blower

It is fitted at the top of the funnel and rotates at a particular speed according to our requirement. It sucked the air over the fins and exhaust to the atmosphere.

x) Blower regulator

It uses to regulate the speed of blower.

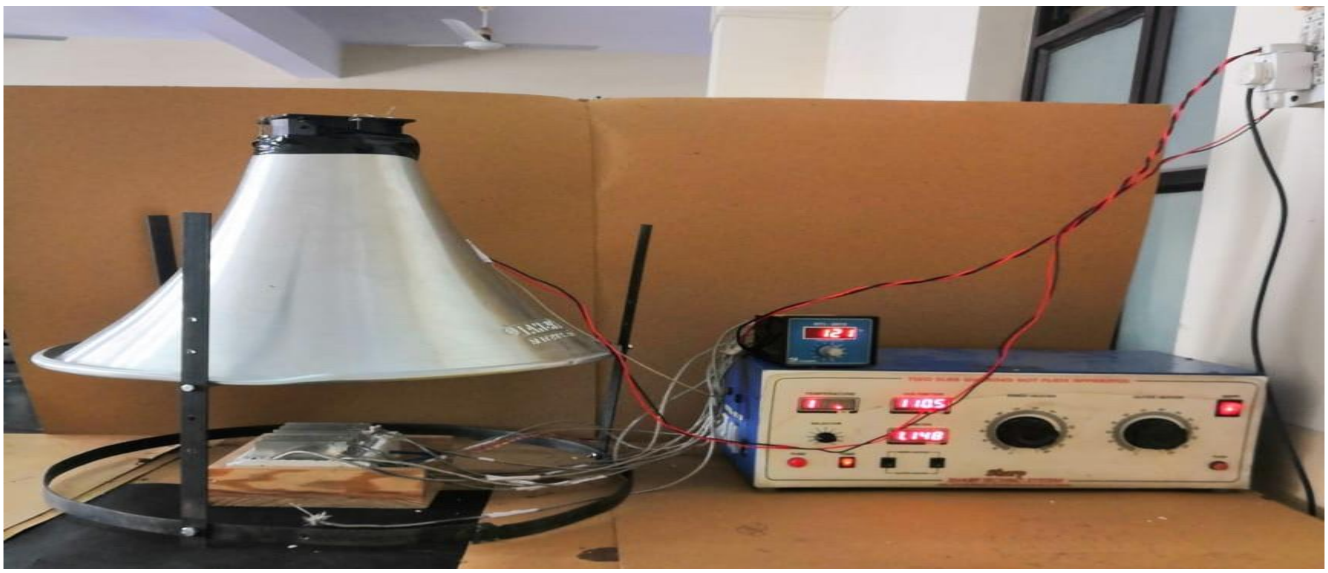
xi) Anemometer

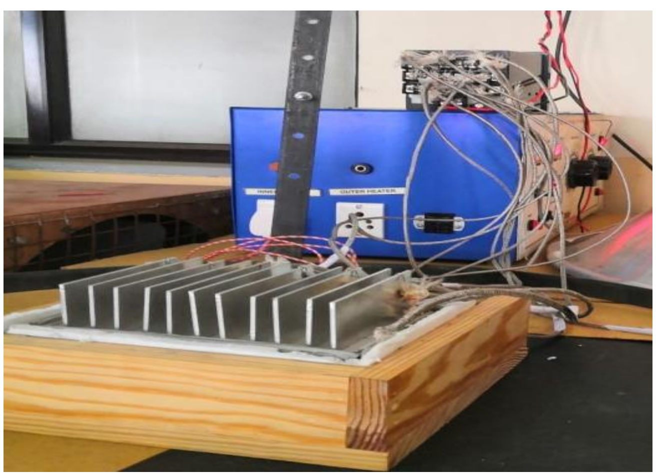
It is a device which is used to measure the speed of the air from blower.

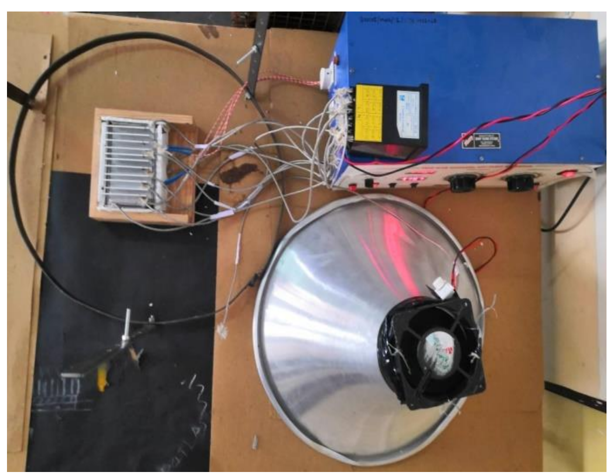
EXPERIMENTAL SETUP

Our project works is based on the conjugate convection heat transfer through plane rectangular, 25% depth rectangular, 50% depth rectangular and 75% depth rectangular fins. We have taken the reading at different velocities and different power output. And we have also studies the effects of different powers output and different velocities on the coefficient of convective heat transfer in conjugate convection. The steps involve to take the reading on fins are as fallow:

1) Connect the fins to temperature indicator through thermocouple for measuring the temperature.
2) Arrange the fins on the slots at the upper surface of the base plate in which heating element is already fitted.
3) Connect the wire of heating element to the control panel.
4) Make the arrangement of funnel and the blower.
5) Check the connection of the thermocouples and then switch on power supply and simultaneously start the blower and fixed the speed with the help of regulator.
6) We use dimmer stat of control panel to adjust the voltage input to the heating element (cartridge heater) where electric energy is converted in to the heat energy.
7) Due to increase in temperature of heating element base plate get heated to a high temperature and due to which fins which are attached to the base plate also get heated.
8) After sometimes when steady state comes than start to take reading (temperature) with the help of temperature indicator of different fins , inlet air ,exhaust air, base plate and outside the insulation (asbestos sheet).







OBSERVATION TABLE

Voltage input (volt)						130						
Current input (ampere)						1.35						
Velocity (m/s)						3						
Ambient temperature(T) (C)						35						
T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11a}	T_{11b}	T_{12}
164	94	164	155	36	151	141	151	147	149	100	95	34

Voltage input (volt)						120						
Current input (ampere)						1.26						
Velocity (m/s)						3						
Ambient temperature(T) (C)						35						
T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11a}	T_{11b}	T_{12}
151	110	151	147	36	142	136	147	139	137	68	82	34

Voltage input (volt)						110						
Current input (ampere)						1.16						
Velocity (m/s)						3						
Ambient temperature(T) (C)						35						
T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11a}	T_{11b}	T_{12}
133	83	133	130	36	121	122	126	122	121	68	81	34

Voltage input (volt)						100						
Current input (ampere)						1.05						
Velocity (m/s)						3						
Ambient temperature(T) (C)						34.5						
T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11a}	T_{11b}	T_{12}
110	70	110	108	35	105	100	105	100	100	64	68	34

Voltage input (volt)						100						
Current input (ampere)						1.04						
Velocity (m/s)						2						
Ambient temperature(T) (C)						35.5						
T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11a}	T_{11b}	T_{12}
116	71	115	112	38	110	105	110	106	105	65	70	33

Voltage input (volt)						110						
Current input (ampere)						1.15						
Velocity (m/s)						2						
Ambient temperature(T) (C)						36						
T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11a}	T_{11b}	T_{12}
134	85	134	132	37	127	119	125	118	120	85	80	35

Voltage input (volt)						120						
Current input (ampere)						1.257						
Velocity (m/s)						2						
Ambient temperature(T) (C)						36						
T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11a}	T_{11b}	T_{12}
152	95	152	149	38	143	135	142	136	135	97	89	35

Voltage input (volt)						130						
Current input (ampere)						1.35						
Velocity (m/s)						2						
Ambient temperature(T) (C)						37						
T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11a}	T_{11b}	T_{12}
167	103	166	164	40	162	148	156	150	149	105	95	34

SAMPLE CALCULATION

- Here we are showing the sample calculation of one reading on rectangular fins.
  Theoretical calculation:

$$T_s = \frac{T_4+T_6+T_7+T_8+T_9+T_{10}}{6}$$

$$= \frac{155+151+141+151+147+149}{6}$$

$$T_s = 149°C$$

$$T_s = 149°C \; and \; T_\infty = 35°C$$

$$T_{mf} = \left(\frac{149+35}{2}\right) = 92°C$$

$$R_e = \frac{\rho VD}{\mu} = \frac{VD}{v}$$

$$= \frac{3\times 0.14}{22.10\times 10^{-6}}$$

R_e= **19004.52** (Turbulent Flow)

Now,

$$Pr = 0.690$$

$$Nu = 0.028\times (19004.52)^{0.8} \times (0.690)^{0.4}$$

Therefore, Nu = 63.94

Also,

$$Nu = \frac{hD}{k}$$

$$h = \frac{63.94\times 0.03128}{0.14}$$

h = 14.28 W/$m^2 k$

Experimental calculation:

$$\rho_a = 0.972 \text{ kg}/m^3$$

Now, **Q = Area (A) × Velocity (v)**

$$=\frac{\pi(0.14)^2\times 3}{4}$$

Q= 0.046158m^3/s

So, $$\boldsymbol{m = \dot{Q} \times \rho_a}$$

= 0.046158$\times$ 0.972

= 0.0448655 $\frac{kg}{s}$

Then,

q =m C_p(ΔT)

ΔT=$(\boldsymbol{T_{ao} - T_{ai}})$

= 36-34= 2℃

= 0.0448655$\times$ 1009 $\times$ 2

q = 90.53 J

So,

$$\textbf{h=} \frac{\boldsymbol{q}}{\boldsymbol{A(\Delta T)}}$$

$$\textbf{ΔT=} \boldsymbol{T_s - T_\infty = T_s - \left(\frac{T_{ai}+T_{ao}}{2}\right)}$$

=149 - $(\frac{34+36}{2})$

= <u>114℃</u>

A = 11$\times$ $(0.085 \times 0.040) = 0.0374m^2$

h = $\frac{90.53}{0.0374\times 114}$

h= <u>21.23W/m^2K</u>

Natural convection:

T_s= 149 ℃

$$\boldsymbol{T_{mf}} = \frac{\boldsymbol{T_s + T_\infty}}{\boldsymbol{2}} = 92$$

$$\boldsymbol{\beta} = \frac{\mathbf{1}}{\boldsymbol{T_{mf}} + \mathbf{273}} = \frac{1}{92+273} = 2.73\times10^{-3}$$

$$\boldsymbol{Gr} = \frac{\boldsymbol{L^3 g\beta(\Delta T)}}{\boldsymbol{\nu^2}}$$

$$= \frac{(0.04)^3 \times9.81\times2.73\times10^{-3}\times(149-35)}{(22.10\times10^{-6})^2}$$

$$= \frac{0.195\times10^{-3}}{(22.10\times10^{-6})^2}$$

$$G_r = 4.001\times10^5$$

$$P_r = 0.690$$

$$G_r P_r = 2.76\times 10^5 \text{(laminar flow)}$$

So, According to Mc Adam;

(1) Laminar Flow – $N_u = 0.53(G_r P_r)^{0.25}$ for $(10^4 < G_r P_r < 10^9)$
(2) Turbulent Flow – $N_u = 0.13\ (G_r P_r)^{.33}$ for $(10^9 < G_r P_r < 10^{12})$

So,

$$N_u = 0.53(2.76\times10^5)^{0.25}$$

$$N_u = 12.148$$

$$\boldsymbol{h} = \left(\frac{\boldsymbol{K}}{\boldsymbol{L}}\right)\boldsymbol{N_u}$$

$$= \left(\frac{0.03128}{.040}\right)(12.148)$$

$$\mathbf{h = 9.5W/}\boldsymbol{m^2}\mathbf{K}$$

RESULT TABLE :

S.No.	VELOCITY (m/s)	NATURAL convection ($h_{exp.}$) (W/m^2K)	FORCED CONVECTION		CONJUGATE CONVECTION ($h_{conjugate}=h_{natural}+h_{forced}$)
			$h_{theo.}$ (W/m^2K)	$h_{exp.}$ (W/m^2K)	
1.	3	9.5	14.28	21.235	30.725
2.	3	9.36	14.28	27.99	37.35
3.	3	8.98	14.462	28.11	37.05
4.	3	2.95	14.69	18.706	21.656
5.	2	4.40	10.624	41.56	45.96
6.	2	3.48	10.45	18.97	22.45
7.	2	4.12	10.328	31.036	35.156
8.	2	4.55	10.57	40.54	45.09

CONCLUSION:

Hence we can conclude from the result table that the coefficient of heat transfer in conjugate convection ($h_{conjugate}$) is more than the coefficient of natural and forced convection individually. So the rate of heat transfer is more in conjugate convection rather than natural and forced convection. Because according to Newton Law of cooling i.e.;$\mathbf{Q} = \mathbf{h} \times \mathbf{A} \times (\mathbf{T\,s} - \mathbf{T}\infty)$

Hence ,$h_{conjugate}$is directly proportional to rate of heat transfer (Q).

FUTURE SCOPE:

The present study of conjugate convection heat transfer from a vertical rectangular plane fin array ,25% depth ,50% depth,75% depth rectangular fins can be extended to study further in future:

- We will do the experiment on more other fins of different shapes of depth like semicircular depth, triangular depth and trapezoidal depth. So we will minimize the material of and reduce cast and enhance the more heat transfer.
- The concept of decoupling may be extended to other types of fin to quantify the exact magnitude of required fan power.
- It may also be possible to change the material from aluminum to copper A alloy of cast iron due to the heat transfer rate & the thermal conductivity is for different material is different .

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