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THERMAL ANALYSIS OF HEAT TRANSFER THROUGH A PARABOLIC PIN

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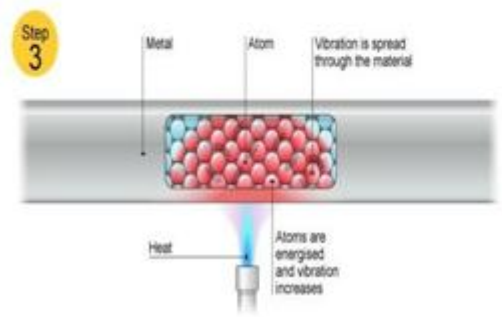
INTRODUCTION

What is heat transfer?

Heat transfer describes the exchange of thermal energy, between physical systems depending on the temperature and pressure, by dissipating heat. Heat transfer always occurs from a region of high temperature to another region of lower temperature. The fundamental modes of heat transfer are conduction or diffusion, convection and radiation. Heat transfer is the exchange of thermal energy between physical systems. The rate of heat transfer is dependent on the temperatures of the systems and the properties of the intervening medium through which the heat is transferred. The three fundamental modes of heat transfer are *conduction*, *convection* and *radiation*. Heat transfer, the flow of energy in the form of heat, is a process by which a system changes its internal energy, hence is of vital use in applications of the First Law of Thermodynamics. Conduction is also known as diffusion, not to be confused with diffusion related to the mixing of constituents of a fluid. The direction of heat transfer is from a region of high temperature to another region of lower temperature, and is governed by the Second Law of Thermo dynamics. Heat transfer changes the internal energy of the systems from which and to which the energy is transferred. Heat transfer will occur in a direction that increases the entropy of the collection of systems.

Conduction:

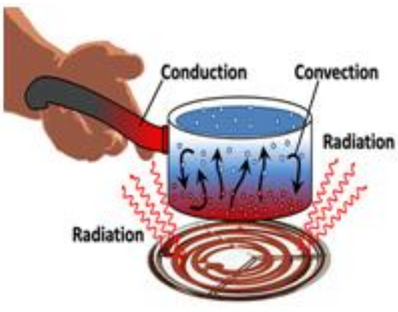
Conduction is a mode of heat transfer of energy within and between bodies of matter, due to temperature gradient. Conduction means collision and diffusive transfer of kinetic energy of particles of matter. Conduction takes place in all forms of matter, i.e. solids, liquids, gases.



Heat transfer by Conduction (migration of electrons)

Convection:

Convection is movement of molecules within fluids i.e. liquids, gases. It cannot takes place in solids, as neither bulk current flows nor significant diffusion can takes place in solids. Convection is one of the major modes of heat transfer and mass transfer. In the context of heat transfer convection refers to sum of adjective (transport mechanism of a fluid substance or conserved property from one location to another, depending on motion and momentum.) and diffusive transfer.



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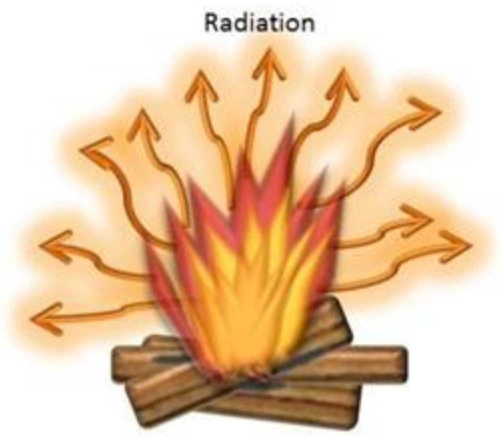
Modes of heat transfer

- Natural convection
- Forced convection

Radiation

Radiation is energy emitted by matter as electromagnetic waves due to the storage of thermal energy that all matter possesses that has a temperature above absolute zero. Thermal radiation propagates through the vacuum of space.



LITERATURE REVIEW

Introduction

Extended surfaces of fins are used to increase the heat transfer rate from a surface to a fluid , wherever it is not possible to increase the value of the surface heat transfer coefficient or the temperature difference between the surface and the fluid. The use of this is variety of shapes. Circumferential fins around the cylinder of a motor cycle engine and fins attached to condenser tubes of a refrigerator are a few familiar examples. The project deals with the analysis carried out by the pin fin apparatus using copper metal of cylindrical and parabolic shape of circular cross section, and their parameters are found and compared with each other.

FINS (EXTENDED SURFACES)

Copper parabolic fins

In the study of heat transfer, a fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection.

The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Increasing In the study In the study of heat transfer, a fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection.

Copper cylindrical fins

Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to an object, however, increases the surface area and can sometimes be an economical solution to heat transfer problems.

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FIN EFFICIENCY

Fin efficiency is one of the parameters which make a higher thermal conductivity material important. A fin of a heat sink may be considered to be a flat plate with heat flowing in one end and being dissipated into the surrounding fluid as it travels to the other. As heat flows through the fin, the combination of the thermal resistance of the heat sink impeding the flow and the heat lost due to convection, the temperature of the fin and, therefore, the heat transfer to the fluid, will decrease from the base to the end of the fin. Fin efficiency is defined as the actual heat transferred by the fin, divided by the heat transfer where the fin to be isothermal (hypothetically the fin having infinite thermal conductivity).

The problem of determination of heat flow through a fin requires the knowledge of temperature distribution through it. This can be obtained by regarding the fin as a metallic plate connected at its base to a heated wall and transferring heat to a fluid by convection. The heat flow through the fin is by conduction .Thus the temperature distribution in a fin will depend upon on properties of both the fin material and the surrounding fluid.

The efficiency of a fin is defined as the ratio of actual heat transferred by the fin to the maximum heat transferable by fin, if the entire fin area were at base temperature. The maximum heat transfer would occur if the temperature of the extended surface was equal to the base temperature.

Compare the heat transfer rate from the surface with fin to that which would be obtained without fin, calling this ratio as effectiveness.

$$\eta_f = \frac{\tanh(mL_c)}{mL_c}$$

$$mL_c = \sqrt{\frac{2h_f}{kt_f}}L_f$$

E = tanh mL/

√(h. A)
√(KP)

Where:

- h_f is the convection coefficient of the fin
  - Air: 10 to 100 W/(m^2K)
  - Water: 500 to 10,000 W/(m^2K)
- K is the thermal conductivity of the fin material
  - Copper : 230 to 360 W/mk
- L_f is the fin height (m)
- t_f is the fin thickness (m)

Fin efficiency is increased by decreasing the fin aspect ratio (making them thicker or shorter), or by using more conductive material (copper instead of aluminum, for example).

MATERIAL

Copper

copper rods

Copper is a chemical element with symbol **Cu** (from Latin: *cuprum*) and atomic number 29. It is a ductile metal with very high thermal and electrical conductivity. Pure copper is soft and malleable; a freshly exposed surface has a reddish-orange color. It is used as a conductor of heat and electricity, a building material, and a constituent of various metal alloys.

Aluminum

Aluminium or **aluminum** (in North American English) is a chemical element in the boron group with symbol **Al** and atomic number 13. It is a silvery-white,

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soft, nonmagnetic, ductile metal. Aluminum is the thi rd most abundant element in the Earth's cru st (after oxygen and silicon) and its most abundant metal. Aluminum makes up about 8% of the crust by mass, though it is less common in the mantle below. Aluminium metal is so chemically reactive that native specimens are rare and limited to extre me reducing environments. Instead, it is found combined in over 270 different minerals. The chief ore of aluminum is bauxite.

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Aluminum rods and sheets

Operations performed and steps followed

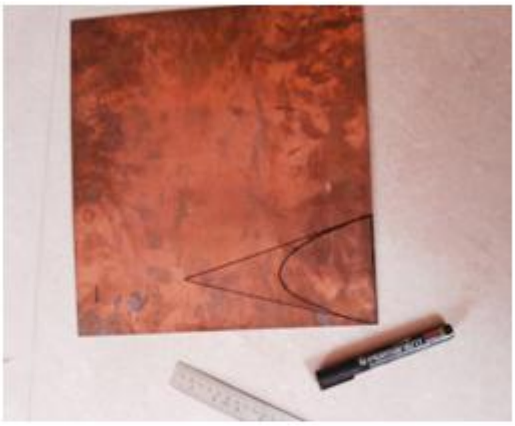
1. Material purchasing

Copper sheets

2. Material preparation

Turning copper cylindrical rod

3. Drawing



Drawing of a Parabola by tangent method

4. Cutting as per designed drawing

Cutting of a parabola from sheet

5. Grinding and machining

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Machining of rough surface

6. Welding

7. Grinding of surface area for finished parabolic shape

Materials preparing

For the preparation of materials, turning, brazing, drilling and tapping operations were performed

Turning

Finished rod

Turning is an engineering machining process in which a cutting tool, typically a non-rotary tool bit, describes a helical tool path by moving more or less linearly while the work piece rotates. The tool's axes of movement may be literally a straight line, or they may be along some set of curves or angles, but they are essentially linear (in the nonmathematical sense). Usually the term "turning" is reserved for the generation of *external* surfaces by this cutting action, whereas this same essential cutting action when applied to *internal* surfaces (that is, holes, of one kind or another) is called "boring". Thus the phrase "turning and boring" categorizes the larger family of (essentially similar) processes. The cutting of faces on the work piece (that is, surfaces perpendicular to its rotating axis), whether with a turning or boring tool, is called "facing", and may be lumped into either category as a subset.

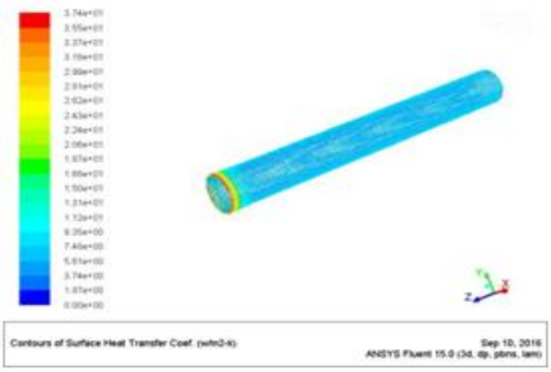
A 12mm diameter and 150mm long rods were selected, for which 44mm was made turning in order to obtain 11.9mm diameter (to insert in the heater)

CFD ANALYSIS

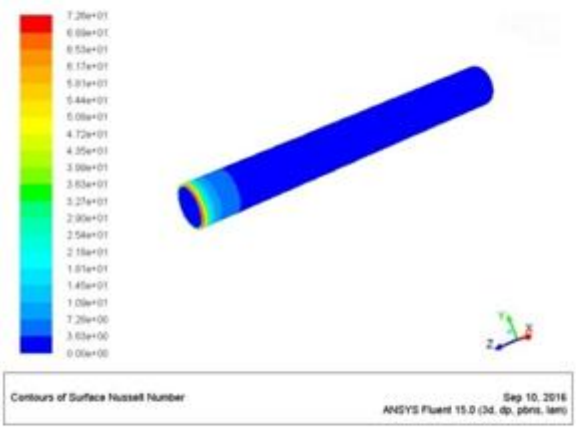
RESULTS

Natural Convection - Cylindrical fin (Copper material)

Wall Fluxes Vs Heat Transfer Coefficient Contour Plot



Wall Fluxes Vs Nusselt's Number



Natural Convection – Parabolic fin (Copper material)

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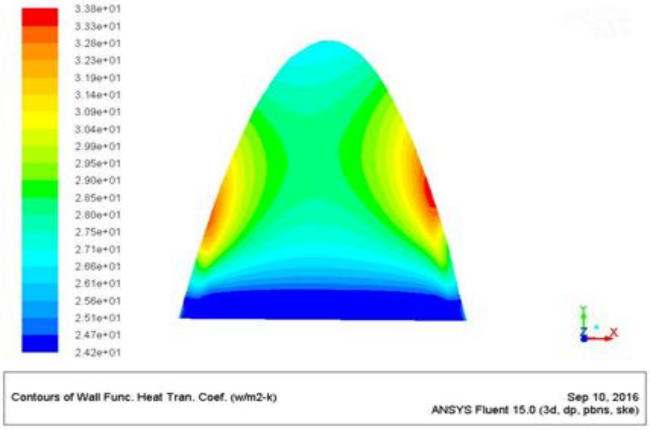
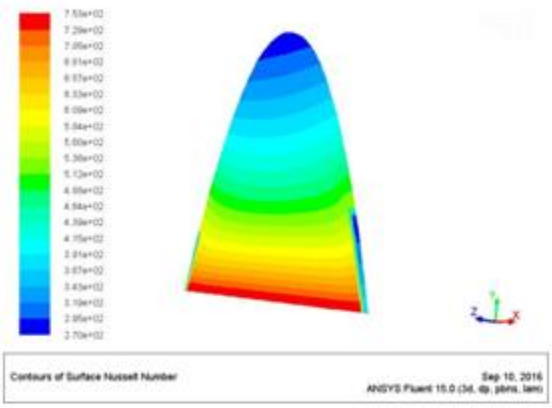
Wall Fluxes Vs Heat Transfer Coefficient Contour Plot

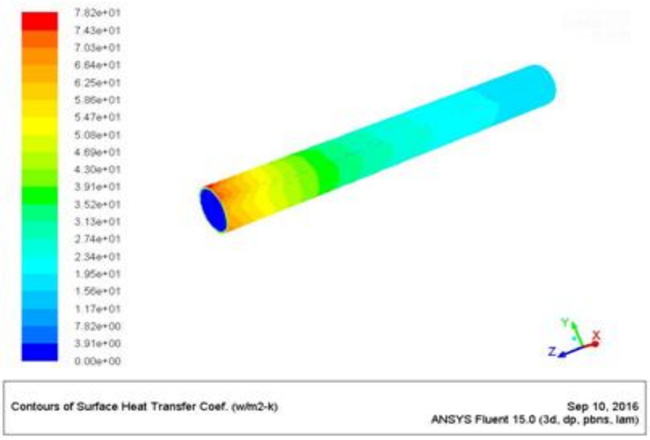


Wall Fluxes Vs Nusselt's Number

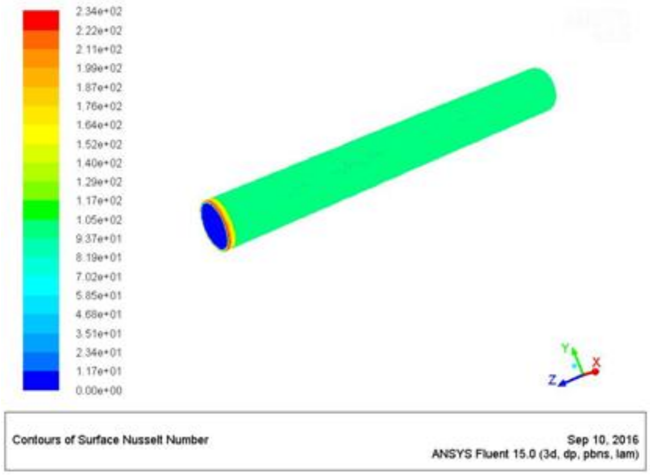


Forced Convection - Cylindrical fin (Copper material)

Wall Fluxes Vs Heat Transfer Coefficient Contour Plot

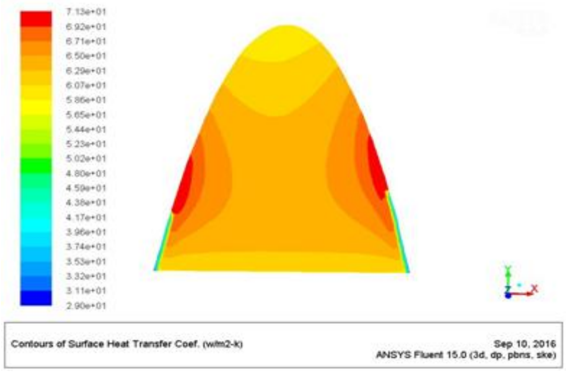


Wall Fluxes Vs Nusselt's Number

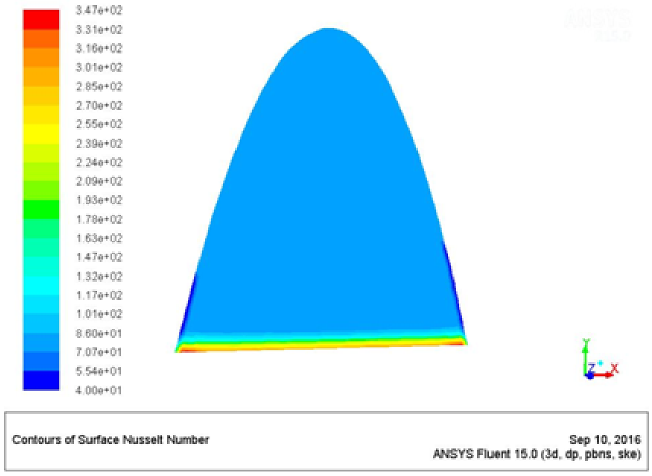


Forced Convection – Parabolic fin (Copper material)

Wall Fluxes Vs Heat Transfer Coefficient Contour Plot



Wall Fluxes Vs Nusselt's Number



Natural Convection – Cylinfrical fin (Aluminium material)

Wall Fluxes Vs Heat Transfer Coefficient Contour

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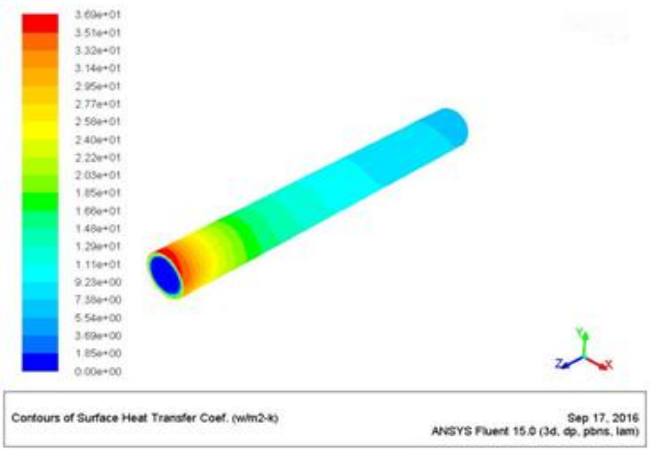
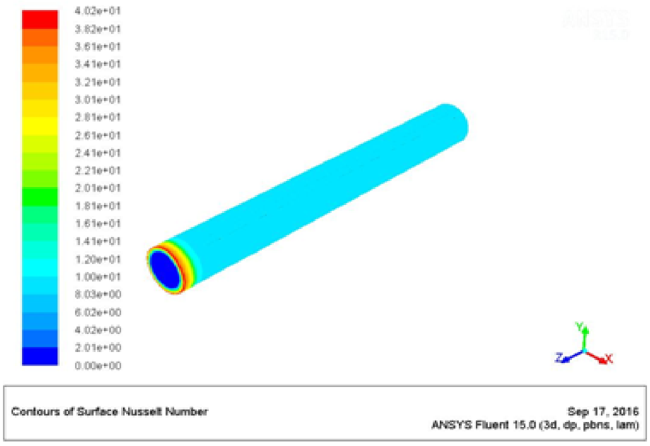
Plot

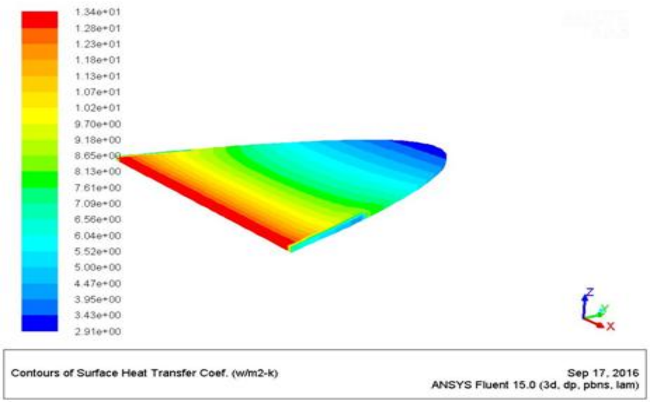


Wall Fluxes Vs Nusselt's Number

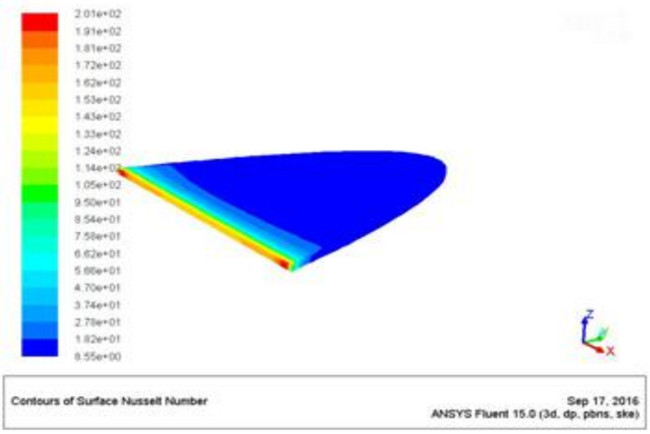


Natural Convection – Parabolic fin (Aluminium material)

Wall Fluxes Vs Heat Transfer Coefficient Contour Plot

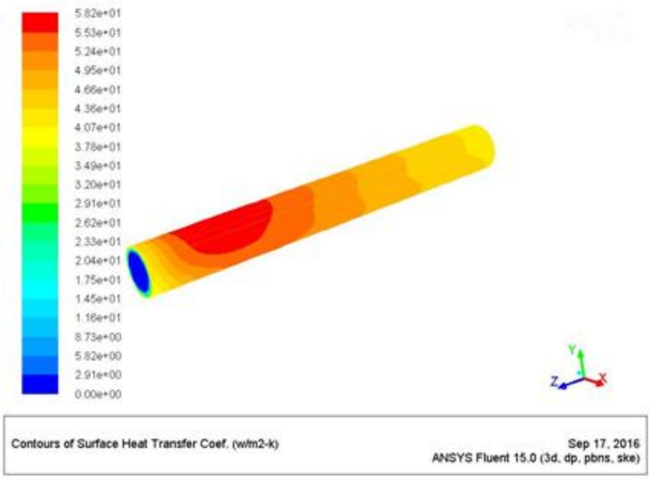


Wall Fluxes Vs Nusselt's Number

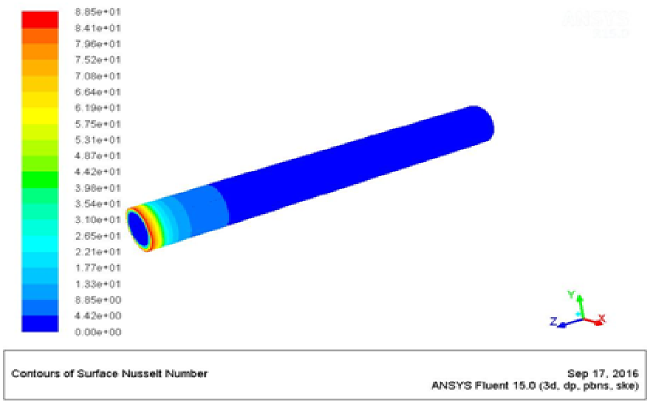


Forced Convection – Cylindrical fin (Aluminium material)

Wall Fluxes Vs Heat Transfer Coefficient Contour Plot



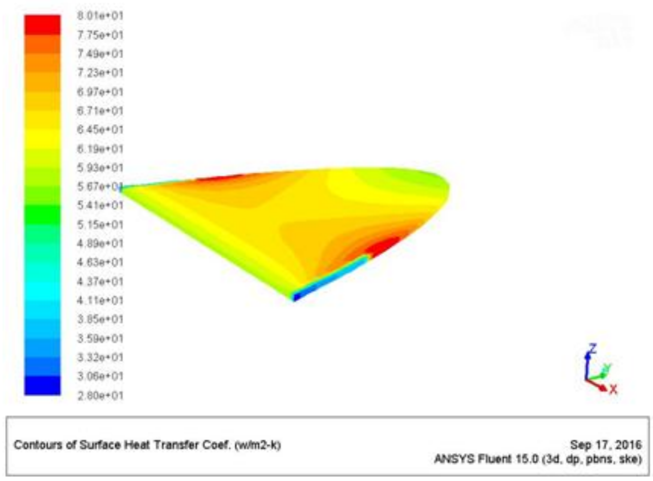
Wall Fluxes Vs Nusselt's Number



Forced Convection – Parabolic fin (Aluminium material)

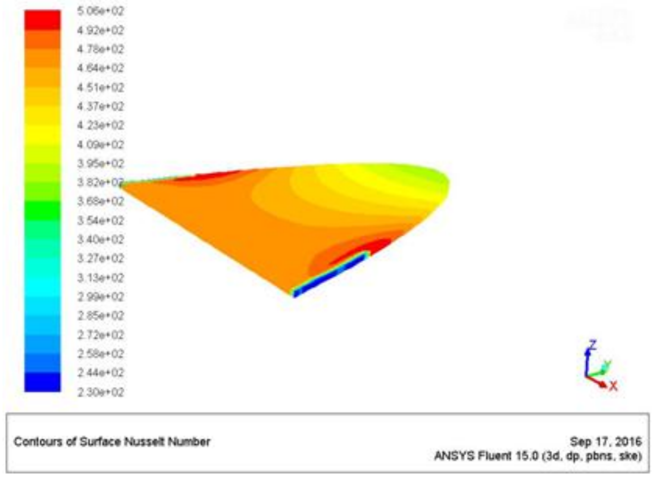
Wall Fluxes Vs Heat Transfer Coefficient Contour

Plot



Wall Fluxes Vs Heat Transfer Coefficient Contour Plot

Wall Fluxes Vs Nusselt's Number



EXPREMENTATION METHODOLOGY

DESCRIPTION OF APPARATUS

The apparatus consists of

- Pin type fin of diameter 12mm and 150mm long with suitable temperature points.
- Heater of 250w capacity.
- Heater regulator to supply the regulated power input to the heater.
- Digital voltmeter and Ammeter to measure power input to the heater.
- Thermocouples at suitable position to measure the surface temperatures of the fin.
- Digital temperature indicator with channel selector to measure the temperatures.
- Blower unit to blow air through the duct with orifice meter and acrylic manometer to measure the air flow rate from the blower. A control valve is provided to regulate the air flow.

  Control panel to house all the instrumentation.

  With this the whole arrangement is mounted on an aesthetically designed self sustained MS powder coated frame with a separate control panel

Fig 6.1(a) Pin fin apparatus

PROCEDURE

- Switch on the MCB and then console ON switch to activate the control panel.
- Switch on the heater and regulate the power input using the heater regulator.
- Switch on the blower unit and adjust the flow of air using gate valve to a desired difference in manometer (for forced flow only otherwise skip to step 3).
- Wait for reasonable time to allow temperatures to reach steady state.
- Measure the voltage, current and temperatures from T1 to T6 at known time interval.
- Calculate the effectiveness & efficiency of the fin using the procedure given.

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- Repeat the experiment for different values of power input to the heater and blower air flow rates.

FORMULAS

1. For free convection condition,

$Nu = C\,(Gr.\,Pr)^n$

$G_r = \rho^2.\,\beta.g\,L^3\,\Delta T/(\mu^2)$ or $.\,\beta.g\,L^3\,\Delta T/(v^2)$

Pr $=\mu Cp/K$ = Prandtl number

2. For forced convection,

$Nu = C.(R_e)^n(Pr)^{0.333}$

$R_e = \rho Vd/\mu$ or Vd/v = Reynold's number

All the properties are to be evaluated at the mean film temperature

$T_f = (T_m + T_a)/2.$

- ρ = Density of air, Kg / m^3
- d = Diameter of pin-fin, m
- μ = Dynamic viscosity, $N.sec/m^2$
- C_p = Specific heat, KJ/Kg-.k
- v = Kinematic viscosity, m^2/Sec
- K = Thermal conductivity of air, $W/m\,^0C$
- g = Acceleration due to gravity, $9.81m/sec^2$
- Tm = Average fin temperature

$= (T_1 + T_2 + T_3 + T_4 + T_5)/5$

$\Delta T = T_m - T_a$

β = Coefficient of thermal expansion

$= 1/(T_f + 273)$

Velocity of air in the duct.

The velocity of air can be obtained by calculating the volume flow rate through the duct.

$V=0.62*(\pi/4)*(D_1^2)*\sqrt{2*g*H}\ /(\pi/4)*(D_2^2)$

Where, H = Difference of levels in manometer,

C_d = Coefficient of discharge= 0.62

D_1 = Diameter of the orifice = 20mm.

D_2= flow diameter =40mm

Use this velocity in the calculation of R_e and find the value of Nu

The rate of heat transfer from the fin can be calculated as,

$Q = \sqrt{h.\,P.\,K_f.\,A}\ x\,(Tm - Ta)\tanh mL$

And the efficiency and effectiveness of the fin can also be calculated as,

$\eta = \tanh mL / mL$

$E = \tanh mL / \sqrt{h.\,A/KP}$

EXPREMENTATION METHODOLOGY

COPPER CYLINDRICAL (Natural Convection)

Length of the fin =150mm

Diameter of fin =12mm

- **Natural convection :**

TABULAR COLUMN

SI NO	Heat input		Air temperature (in deg)	Surface temperatures (in deg)				
	V	I	T6	T1	T2	T3	T4	T5
1	90	0.4	29.3	120	97	86	71	63

$G_r = (\rho^2.g.\beta.\,L^3\,\Delta T) / \mu^2$ or $(g.\beta.\,L^3\,\Delta T) / v^2$

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$Nu = 0.13\ (Gr.\ Pr)^{0.33}$
$Nu = h*d/K$
$h = (Nu*Kair) / d$
$A_c=1.13*10^{-4} m^2$,
$P = 0.0376$ m
Kf = 350 W/ mK
m= Root of (h. P/ K_f*A_c) or Root of (4h/Kd)
m = 5.2

Q = √(h. P. K. A) x (Tm – Ta) tanhmL = 5.52 W
η = tanh (mL)/(mL)
η = 0.91 or 91%
E = tanh(mL)/ √(h. A/ KP)
E = 28.6

COPPER PARABOLIC (Natural Convection)

Length of the fin =100mm = 0.1m
Height of the fin =100mm = 0.1m

- **Natural convection :**

TABULAR COLUMN

SI NO	Heat input		Air temperature (in deg)	Surface temperatures (in deg)				
	V	I	T6	T1	T2	T3	T4	T5
1	90	0.41	30.2	132	124	116	98	86

$G_r = (\rho^2.g.\beta.\ L^3\ \Delta T) / \mu^2$ or $(g.\beta.\ L^3\ \Delta T) / v^2$
$Nu = 0.6\ (Gr.\ Pr)^{0.333}$
$Nu = h*L/K$
$h = (Nu*Kair) / L$
$A_c=6.6*10^{-3} m^2$ or $0.0066\ m^2$,
P=0.232 m
Kf=350 W/ mK
m= Root of (h. P/ K_f*A_c)
m = 1.8

Q = √(h. P. K. A) x (Tm – Ta) tanhmL =58.5 W

η = tanh (mL)/(mL)

η = 0.98 or 98%

E = tanh(mL)/ √(h. A/ KP)

E = 3.56

COPPER CYLINDRICAL(Forced Convection)

Length of the fin =150mm

Diameter of fin =12mm

- **Forced convection :**

SI NO	Manometer reading, mm of mercury		Heat input		Air temperature (in deg)	Surface temperatures (in deg)				
	H1	H2	V	I	T6	T1	T2	T3	T4	T5
1	110	13	90	0.41	33	110	86	70	59	56

Let d_o = Diameter of orifice = 20mm or 0.02m

$A_o = 0.00031\ m^2$

d_p = Diameter of a pipe = 40mm or 0.04m

$A_d = 0.15*0.1 = 0.015\ m^2$

$B = d_o / d_p = 0.5$

ρ_m = Density of a manometric fluid or mercury = 13600 kg/m^3

ρ_a = Density of a air = 1.17 kg/m^3

V_o = Discharge through orifice

$V_o = 0.62\ \sqrt{[2gh(\rho_m - \rho_a)/(\rho_a(1-B))]}$

V_o = 130.4 m/s

Area of orifice * velocity of air in the orifice = Area of a duct* velocity of a air in the duct

$A_o*V_o = A_d*V_d$

V_d = 130.4*0.00031/(0.015) = 3.21 m/s

$R_e = \rho VD/\mu$ or $V_d *d/v$

$R_e = 3.21*0.012/(18.46*10^{-6})$

$R_e = 2086.6$

$Nu = 0.683(Re)^{0.466}.(Pr)^{0.33}$

Nu = h*d/ Kair

h = (Nu*Kair) /d

$A_c = 1.13*10^{-4} m^2$ or $0.00013\ m^2$

P = 0.0376m

Kf = 350*W/m-k*

m = √(h. P/Kf*A) or √(4h/Kf*d)

m = 7

Q = √(h. P. K. A) x (Tm – Ta) tanhmL =7.72 W

η = tanh(mL)/(mL)

η = 0.86 or 86 %
E = tanh(mL)/ √(h. A/ KP) = 26.8

COPPER PARABOLIC (Forced Convection)

Length of the fin =100mm = 0.1m

Height of the fin =100mm = 0.1m

Forced convection

S I NO	Mano meter reading, mm of mercury		Heat input		Air temperature (in deg)	Surface temperatures (in deg)				
	H1	H2	V	I	T6	T1	T2	T3	T4	T5
1	110	13	90	0.41	36	104	96	85	72	51

Let d_o = Diameter of orifice = 20mm or 0.02m

$A_o = 0.00031\ m^2$

d_p = Diameter of a pipe = 40mm or 0.04m

A_d = Area of a duct = 0.15*0.1 = 0.015 m^2

$B = d_o/d_p = 0.5$

ρ_m = Density of a manometric fluid or mercury = 13600 kg/m^3

ρ_a = Density of a air = 1.17 kg/m^3

V_o = Discharge through orifice

$V_o = 0.62 \sqrt{[2gh(\rho_m - \rho_a)/(\rho_a(1-B))]}$

V_o = 130.4 m/s

Area of orifice * velocity of air in the orifice = Area of a duct* velocity of a air in the duct

$A_o*V_o = A_d*V_d$

$V_d = 130.4*0.00031/(0.015) = 3.21$ m/s

$R_e = \rho VD/\mu$ or $V_d *d/v$

$R_e = 3.21*0.1/(18.46*10^{-6})$

$R_e = 17388.94$

$Nu = 0.085(Re)^{0.84}.(Pr)^{0.33}$

Nu = h*d/ Kair

h = (Nu*Kair) /d

$A_c = 6.6*10^{-3} m^2$ or $0.0066\ m^2$
P = 0.232m

Kf = 350*W/m-k*

m = √(h. P/Kf*A)

m = 2.82

Q = √(h. P. K. A) x (Tm – Ta) tanhmL =81.83 W

η = tanh(mL)/(mL)

η = 0.97or 97%

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E = tanh(mL)/ √(h. A/ KP) = 3.41

ALUMINIUM CYLINDRICAL (Natural Convection)

Length of the fin =150mm

Diameter of fin =12mm

- **Natural convection :**

TABULAR COLUMN

SI NO	Heat input		Air temperature (in deg)	Surface temperatures (in deg)				
	V	I	T6	T1	T2	T3	T4	T5
1	90	0.4	34	126	113	94	70	60

$G_r = (\rho^2.g.\beta.\ L^3\ \Delta T) / \mu^2$ or $(g.\beta.\ L^3\ \Delta T) /\nu^2$

$Nu = 0.13\ (Gr.\ Pr)^{0.33}$

Nu = h*d/K

h = (Nu*Kair) / d

A_c=1.13*10^{-4}m^2 ,

P = 0.0376 m

Kf = 200 W/ mK

m= Root of (h. P/ K_f*A_c) or Root of (4h/Kd)

m = 6.82

Q = \(/h. P. K. A) x (Tm – Ta) tanhmL = 5.1W

η = tanh (mL)/(mL)

η = 0.86 or 86%

E = tanh(mL)/ √(h. A/ KP)

E = 29

ALUMINIUM PARABOLIC (Natural Convection)

Length of the fin =100mm = 0.1m

Height of the fin =100mm = 0.1m

- **Natural convection :**

TABULAR COLUMN

SI NO	Heat input		Air temperature (in deg)	Surface temperatures (in deg)				
	V	I	T6	T1	T2	T3	T4	T5
1	90	0.41	32	125	118	96	87	79

$G_r = (\rho^2.g.\beta.\ L^3\ \Delta T) / \mu^2$ or $(g.\beta.\ L^3\ \Delta T) /\nu^2$

$Nu = 0.6\ (Gr.\ Pr)^{0.333}$

Nu = h*L/K

h = (Nu*Kair) / L

A_c=6.6*10^{-3}m^2 or 0.0066 m^2 ,

P=0.232 m

Kf = 200 W/ mK

m= Root of (h. P/ K_f*A_c)

m = 2.16

Q = \(/h. P. K. A) x (Tm – Ta) tanhmL = 41.8 W

η = tanh (mL)/(mL)

η = 0.98 or 98%

E = tanh(mL)/ √(h. A/ KP)

E = 3.41

ALUMINIUM CYLINDRICAL (Forced Convection)

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Length of the fin =150mm

Diameter of fin =12mm

- **Forced convection :**

S I NO	Mano meter reading , mm of mercury		Heat input		Air temperature (in deg)	Surface temperatures (in deg)				
	H1	H2	V	I	T6	T1	T2	T3	T4	T5
1	110	13	90	0.41	33	110	79	68	54	49

Let d_o = Diameter of orifice = 20mm or 0.02m

$A_o = 0.00031\ m^2$

d_p = Diameter of a pipe = 40mm or 0.04m

$A_d = 0.15*0.1 = 0.015\ m^2$

$B = d_o/d_p = 0.5$

ρ_m = Density of a manometric fluid or mercury = 13600 kg/m^3

ρ_a = Density of a air = 1.17 kg/m^3

V_o = Discharge through orifice

$V_o = 0.62\ \sqrt{[2gh(\rho_m - \rho_a)/(\rho_a(1\text{-}B))]}$

V_o = 130.4 m/s

Area of orifice * velocity of air in the orifice = Area of a duct* velocity of a air in the duct

$A_o*V_o = A_d*V_d$

V_d = 130.4*0.00031/(0.015) = 3.21 m/s

$R_e = \rho\ VD/\mu$ or $V_d *d/v$

$R_e = 3.21*0.012/(17.95*10^{-6})$

R_e = 2145.96

$Nu = 0.683(Re)^{0.466}.(Pr)^{0.33}$

Nu = h*d/ Kair

h = (Nu*Kair) /d

$A_c = 1.13*10^{-4}m^2$ or 0.000113 m^2

P = 0.0376m

Kf = 200 *W/m-k*

m = √(h. P/Kf*A) or √(4h/Kf*d)

m = 9.21

Q = $\sqrt{(h. P. K. A)}$ x (Tm – Ta) tanhmL = 5.89 W

η = tanh(mL)/(mL)

η = 0.78 or 78 %

E = tanh(mL)/ √(h. A/ KP) = 26.2

ALUMINIUM PARABOLIC (Forced Convection)

Length of the fin =100mm = 0.1m

Height of the fin =100mm = 0.1m

- **Forced convection**

S I NO	Mano meter reading , mm of mercury		Heat input		Air temperature (in deg)	Surface temperatures (in deg)				
	H1	H2	V	I	T6	T1	T2	T3	T4	T5
1	110	13	90	0.41	33	105	89	76	69	50

Let d_o = Diameter of orifice = 20mm or 0.02m

$A_o = 0.00031\ m^2$

d_p = Diameter of a pipe = 40mm or 0.04m

A_d = Area of a duct = 0.15*0.1 = 0.015 m^2

$B = d_o/d_p = 0.5$

ρ_m = Density of a manometric fluid or mercury = 13600 kg/m^3

ρ_a = Density of a air = 1.17 kg/m^3

V_o = Discharge through orifice

$V_o = 0.62 \sqrt{[2gh(\rho_m - \rho_a)/(\rho_a(1-B))]}$

V_o = 130.4 m/s

Area of orifice * velocity of air in the orifice = Area of a duct* velocity of a air in the duct

$A_o*V_o = A_d*V_d$

V_d = 130.4*0.00031/(0.015) = 3.21 m/s

$R_e = \rho VD/\mu$ or V_d*d/v

$R_e = 3.21*0.1/(18.4*10^{-6})$

R_e = 17455.6

$Nu = 0.085(Re)^{0.84}.(Pr)^{0.33}$

Nu = h*d/ Kair

h = (Nu*Kair) /d

$A_c = 6.6*10^{-3} m^2$ or 0.0066 m^2

P = 0.232m

Kf = 200*W/m-k*

$m = \sqrt{(h. P/Kf*A)}$

m = 3.72

$Q = \sqrt{(h. P. K. A)}$ x (Tm – Ta) tanhmL = 77.5 W

$\eta = \tanh(mL)/(mL)$

η = 0.95 or 95%

$E = \tanh(mL)/\sqrt{(h. A/ KP)} = 3.35$

APPLICATIONS

For both modes of convective heat transfer i.e. natural and forced, fin is used to increase the rate of heat transfer from a surface to a fluid where heat transfer coefficient of surface and temperature difference between them is not possible to increase. Fins increase the surface area available for heat transfer. Fins are vastly used on the radiator surface, on the boiler water tubes, heat exchanger tubes and sometimes on electronic equipment.

i. Its main applications are in industrial facilities,
ii. Power plants,
iii. Solar thermal water systems,
iv. HVAC systems,
v. Gas water heaters,
vi. Forced air heating and cooling systems,

RESULT AND EVALUATION

We have performed the analysis using various metals of cylinder and ellipsoidal shape in the pin fin apparatus and found the efficiencies & effectiveness of those metals and are compared with each other as show in the table.

S.NO	FIN TYPE AND MATERIAL	CONVECTION TYPE	ANSYS FLUENT ANALYSIS (h in w/m*2 k)	PRACATICAL
1	Cylindrical fin - Copper	Natural Convection	h = 1.8 to 37.4	28.13
			Nu = 3.63 to 72.6	11.66
2	Parabolic fin - Copper	Natural Convection	h = 2.4 to 33.8	30.7
			Nu = 270 to 753	103.66
3	Cylindrical fin - Copper	Forced Convection	h = 3.9 to 78.2	51.2
			Nu = 1.1 to 234	21.35
4	Parabolic fin - Copper	Forced Convection	h = 2.9 to 71.3	79.6
			Nu = 40 to 347	274.98
5	Cylindrical fin - Aluminium	Natural Convection	h = 1.85 to 36.9	26.3
			Nu = 2.01 to 40.2	11.3
6	Parabolic fin - Aluminium	Natural Convection	h = 2.9 to 13.4	26.6
			Nu = 8.5 to 201	89.8
7	Cylindrical fin - Aluminium	Forced Convection	h = 2.9 to 58.2	50.98
			Nu = 4.42 to 88.5	21.64
8	Parabolic fin - Aluminium	Forced Convection	h = 28 to 80.1	78.9
			Nu = 230 to 506	275.86

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Heat transfer rate

S.NO	MATERIALS		NATURAL CONVECTION	FORCED CONVECTION
1	COPPER	Cylindrical	Heat transfer rate (Q) = 5.52W	Heat transfer rate (Q) =7.72W
		Parabolic	Heat transfer rate (Q) =58.5W	Heat transfer rate (Q) =81.83W
2	ALUMINIUM	Cylindrical	Heat transfer rate (Q) = 5.1W	Heat transfer rate (Q) =5.89W
		Parabolic	Heat transfer rate (Q) = 41.8W	Heat transfer rate (Q) =77.5W

Efficiency

S.NO	MATERIALS		NATURAL CONVECTION	FORCED CONVECTION
1	COPPER	Cylindrical	Efficiency= 0.91 OR 91%	Efficiency= 0.86 OR 86%
		Parabolic	Efficiency= 0.98 OR 98%	Efficiency= 0.97 OR 97%
2	ALUMINIUM	Cylindrical	Efficiency= 0.86 OR 86%	Efficiency= 0.78 OR 78%
		Parabolic	Efficiency= 0.98 OR 98%	Efficiency= 0.95 OR 95%

Effectiveness

S.NO	MATERIALS		NATURAL CONVECTION	FORCED CONVECTION
1	COPPER	Cylindrical	Effectiveness= 28.6	Effectiveness= 26.8
		Parabolic	Effectiveness=3.5	Effectiveness= 3.4
2	ALUMINIUM	Cylindrical	Effectiveness= 29	Effectiveness= 26.2
		Parabolic	Effectiveness=3.41	Effectiveness= 3.35

CONCLUSION

A curious but interesting question is whether the addition of fins to a surface always results in increased heat transfer. There may be situations where adding fins may actually decrease the heat transfer from a given surface. The effectiveness of the fins must be greater than unity to justify their addition to surface dissipating heat to the surroundings. In practice however, finning is hardly justified unless h is less than 0.25(KP/A).In other words, finning is only justified where h is small. If the value of h is large as, experienced in boiling, condensation and high velocity liquids the fins may actually produce a reduction in heat transfer. It is also apparent that finning will be more effective with materials of large thermal conductivities.

The different metals are showing different results for cylindrical and parabolic shape. From the table we can observe that the efficiency of the cylindrical structure is less compared to parabolic but the effectiveness is more in both natural and forced conditions. It is clear from the table that copper is the best choice for the selection, as the other materials are showing less values than copper. It is thus obvious that the heat dissipated by the every segment of a fin of uniform cross sectional area is not the same. In fact, the part of the fin away from the base or root is much less effective than the cross section at the base. The material near the tip is not properly utilized. A fin of Parabolic profile is very effective in the sense that it dissipates the maximum amount of heat at minimum material cost.

RECOMMENDATION

Copper has excellent heat sink properties in terms of its thermal conductivity, corrosion resistance, efficiency. Copper has around twice the thermal conductivity of aluminum and faster, more efficient heat absorption. The fin material near the tip is not properly utilised .A fin of Parabolic profile is very effective in the sense that it dissipates the maximum amount of heat at minimum material cost.Its main applications are in industrial facilities, power plants, solar thermal water systems, HVAC systems, gas water heaters, forced air heating and cooling systems, geothermal heating and cooling, and electronic systems.

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