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Modeling and fabrication of a natural convection test rig for various fin geometries and heat transfer analysis on Nano coated fins

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Abstract: Natural convection heat transfer has been a reliable, cost-effective cooling method for the fast growing electronic industry where hundreds of thermal connection modules are accommodated on a small base. As the density of these heat producing modules increases day by day, for more compactness, the heat released should be transferred from the surface not only to protect them but also for longer life. There is often the need to cool the internal surfaces of vertical open-ended ducts by natural convection, despite the low rates of heat transfer that this convection process affords. Thus information on the behavior of natural convection flow through confined spaces has been found useful especially in the thermal fluid systems encountered in the diverse fields of nuclear and solar energy. Due to its importance, the natural convection problem has received increasing attention in the literature in recent years. At present, flow of gaseous heat carriers in vertical channels with natural convection is widely encountered in science and engineering. For example, in domestic convectors, cooling systems of radio electronic and electrical equipment, nuclear reactors with passive cooling systems, dry cooling towers, ground thermo siphons, etc. The purpose of this work is to study experimentally the natural convection pipe flows at different heating levels. The test section is a vertical, open-ended cylindrical pipe dissipating heat from the internal surface. The resulting density non-uniformity causes the air in the pipe to rise. Extended surface is used specially to enhance the heat transfer rate between a solid and an adjoining fluid. Such an extended surface is termed a fin. In a conventional heat exchanger heat is transferred from one fluid to another through a metallic wall. The main objective of this paper is to design and fabricate a natural convection test rig for various geometric nano coated fins.
Index words: Nano coating, fins, heat transfer

I. INTRODUCTION

The rate of heat transfer is directly proportional to the extent of the wall surface, the heat transfer coefficient and to the temperature difference between one fluid and the adjacent surface. If thin strips (fins) of metals are attached to the basic surface, extending into one fluid, the total surface for heat transfer is thereby increased. The use of fins in one side of a wall separating two heat-exchanging fluids is exploited most if the fins are attached to or made an integral part of that face on which the thermal resistivity is greatest. In such a case the fin serve the purpose of artificially increasing the surface transmittance. Thus, fins find numerous applications in electrical apparatus in which generated heat must be efficiently dissipated, in specialized installations of single and double-pipe heat exchangers, on cylinders of air cooled internal-combustion *engines. Recently*, finned surfaces are widely used in compact heat exchangers that are used in many applications such as air conditioners, aircrafts, chemical processing plants, etc. However, the average surface temperature of this strips (fins), by virtue of temperature gradient through them, tends to decrease approaching the temperature of the surrounding fluid. In this project there are three types of fins are used namely square fin, radial fin, and rectangular fin.

The subject of extended surface heat transfer is very extensive and is difficult to condense in a few pages. This attempt to summarize some important typical results, both analytical and experimental, is but an introduction to the subject.

II. FINS

Fins are used in a large number of applications to increase the heat transfer from surfaces. Typically, the fin material has a high thermal conductivity. The fin is exposed to a flowing fluid, which cools or heats it, with the high thermal conductivity allowing increased heat being conducted from the wall through the fin.

Fins are most commonly used in heat exchanging devices such as radiators in cars, computer CPU heatsinks, and heat exchangers in power plants. They are also used in newer technology such as hydrogen fuel cells. Nature has also taken advantage of the phenomena of fins. In addition, enhanced fin geometries also increase the heat transfer coefficient compared to that for a plain fin. Fins may also be used on the high heat transfer coefficient fluid side in a heat exchanger primarily for structural strength (for example, for high pressure water flow through a flat tube) or to provide a thorough mixing of a highlyviscous liquid (such as for laminar oil flow in a flat or a round tube). Fins are attached to the primary surface by brazing, soldering.

III. HEAT TRANSFER COEFFICIENT

The heat transfer coefficient or film coefficient, in thermodynamics and in mechanics is the proportionality coefficient between the heat flux and the thermodynamic driving force for the flow of heat (i.e., the temperature difference, ΔT):

$$h = q/\Delta T$$

Where
q: heat flux, W/m^2 i.e., thermal power per unit area, $q = dQ/dA$
h: heat transfer coefficient, W/ (m^{2}K)
ΔT: difference in temperature between the solid surface and surrounding fluid area, K

It is used in calculating the heat transfer, typically by convection or phase transition between a fluid and a solid.

The heat transfer coefficient has SI units in watts per square meter Kelvin W/ (m^{2}K).

This is used for building materials (R-value) and for clothing insulation.

There are numerous methods for calculating the heat transfer coefficient in different heat transfer modes, different fluids, flow regimes, and under different thermo-hydraulic conditions. Often it can be estimated by dividing the conductivity of the convection fluid by a length scale. The heat transfer coefficient is often calculated from the Nusselt number (a dimensionless). There are also online calculators available specifically for heat transfer fluid applications**.**

IV. COMPONENTS AND DESCRIPTION

The main components of this project are,

A. Regulator. Test Section: Aluminum Tube Of 20mm ID, 40mm OD And 350 mm Long (Optional: copper),

B. Boxsize:100mm*400mm.
Heater: Externally Heated, (250w),

C. Voltmeter: Voltmeter Of Range 0-300v Ac,

D. Ammeter: Ammeter Of Range 0-6amps Ac,

E. Temperature Indicator: Digital Temperature Indicator Of Range 0-400°c,

F. Thermocouples: Teflon Coated Cr –al (J-type)-6 No.

V. CALCULATION OF HEAT TRANSFER COEFFICIENT

Convection is the concerted, collective movement of groups or aggregates of molecules within fluids (e.g., liquids, gases) either through advection or through diffusion or as a combination of both of them. Convection of mass cannot take place in solids, since neither bulk current flows nor significant diffusion can take place in solids. Diffusion of heat can take place in solids, but that is called heat conduction. Convection can be demonstrated by placing a heat source (e.g. a Bunsen) at the side of a glass full of a liquid, and observing the changes in temperature in the glass caused by the warmer fluid moving into cooler areas.

Convective heat transfer is one of the major modes of heat, and convection is also a major mode of mass in fluids. Convective heat and mass transfer take place both by diffusion – the random Brownian motion of individual particles in the fluid – and by advection, in which matter or heat is transported by the larger-scale motion of currents in the fluid. In the context of heat and mass transfer, the term "convection" is used to refer to the sum of adjective and diffusive transfer.[1] In common use the term "convection" may refer loosely to heat transfer by convection, as opposed to mass transfer by convection, or the convection process in general. Sometimes "convection" is even used to refer specifically to "free heat convection" (natural heat convection) as opposed to forced heat convection. However, in mechanics the correct use of the word is the general sense, and different types of convection should be properly qualified for clarity.

Convection can be qualified in terms of being natural, forced, gravitational, granular, or thermomagnetic. Heat transfer by natural convection plays a role in the structure of Earth's atmosphere, its oceans, and its mantle.

VI. DESIGN PROCEDURE

A. Selection Of Thermocouple

Calibration Type: J
Conductors Positive: Iron (Magnetic)
Negative: Constantan (Non Magnetic)
Temperature Range: 0°C to 300°C
Limits of Error - Standard: ±2.2°C
Extension Wire Jacket Colour: Black
Coding: White+ Red

B. Design Of Fin

Surface area calculations for various Fins:

Square=a^2

Where,

a=side of a square=>100mm,

Circle=πr^2

Where,

r=radius of the radial =>56mm,

Rectangle=lxw

Where,

l=length of the rectangle=>67mm,

w=width of the rectangle=>150mm.

Thus, we have made all the surface areas to be equal, which is approximately 10^4sq.mm. In order to make sure that the rate of heat transfer occurring between the fins to be the same

C. Apparatus Design

Length of the board: 700mm
Width of the board: 600mm
Thickness of the board: ¾"
Material: plywood

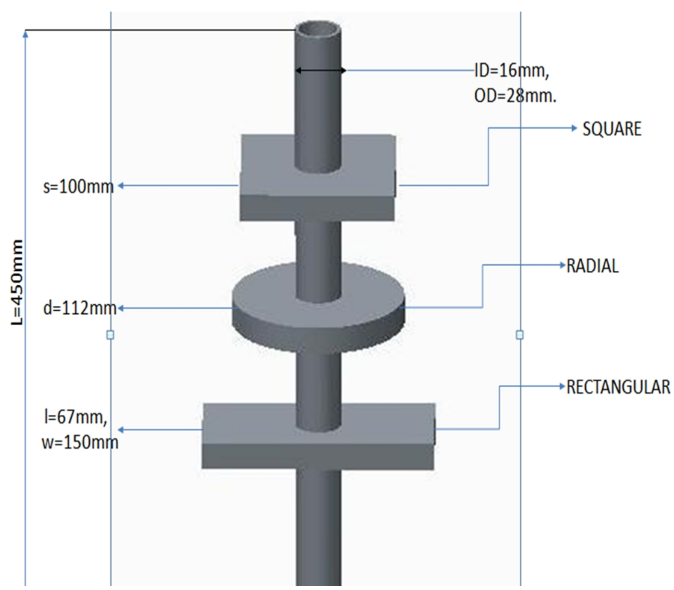

Fig 1:Fin Design

D. Assumption Made On Design

1. Steady state
2. Constant material properties (independent of temperature)
3. No internal heat generation

4. One-dimensional conduction
5. Uniform cross-sectional area
6. Uniform convection across the surface area

E. Model Calculation

Q=VxI=230x0.2=46w
Q=hAΔT=hA (T_0-T_a)
For Square fin,
46=hx (0.01) x (100-35)
h=70.769w/m^2k.
For Radial fin,
46=hx (0.01) x (109.33-35)
h=61.886w/m^2k.
For Rectangle fin,
46=hx (0.01) x (120.67-35)
h=53.69w/m^2k.
For square fin,
m=hP/kfA= (70.769x0.4)/ (204.2x0.01)
m=3.723
Perimeter of a square fin=4a
4a=4(0.1) =0.4m(a=0.1m)
$T_0=100^0$c
K_f=204.2w/mk
For **Square Fin**,
m=hP/k_fA= (70.769x0.4)/ (204.2x0.01)
m=3.723
Heat transferred by fin
$Q=(T_b-T_\alpha)x(tanh(mL)+(h_L/mk)/(1+(h_L/mk)xtanh(mL)))x(hPkA)^{0.5}$
=(100x35)x(tanhx(3.723x0.1)+(970.769xtanh(3.723x0.1))x(70.769x0.4x204.2x0.01)/(3.723x204.2))/(1+(70.769/(3.723x204.2))
Q=214.78w
Temperature distribution:
X=0
$(T-T_b)/(T_b-T_\alpha)$=cosh[(m(L-X)]+[(h_L/mk)sinh(m/L-X)]/[cosh(mL)+(h_L/mk)sinh(mL)
=cosh[3.723(0.1-0)]+[70.769/3.723x204.2]sinh(3.723(0.1-1))/[cosh(3.723x0.1)+(70.769/3.723x204.2)sinh(3.723x0.1)]

(T-35)/ (100-35) = (1.07+ (0.093x0.3809)/ (1.07+ (0.093x0.3809))

$T=100^0$c

X=0.05m

(T-35)/ (100-35) = (1.017+ (0.093x0.1873)/ (1.07+ (0.093x0.3809))

$T=95.82^0$c

X=0.1m

(T-35)/ (100-35) = (1+ (0.093x0)/ (1.07+ (0.093x3.809)) =93.8^0c.

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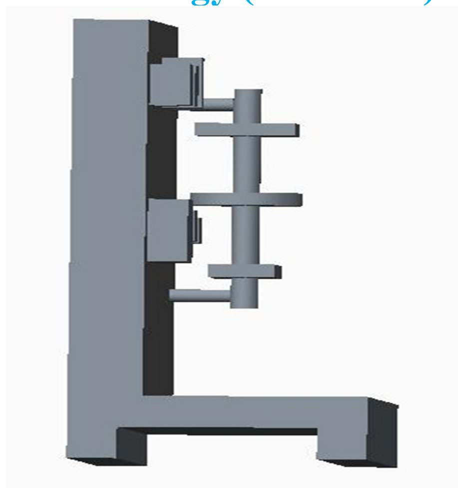

Fig 2: Side View

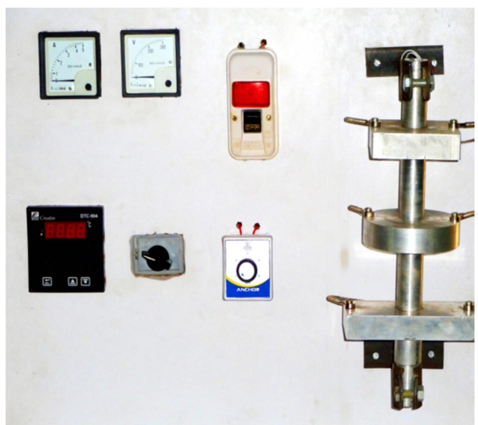

Fig 3: Test rig

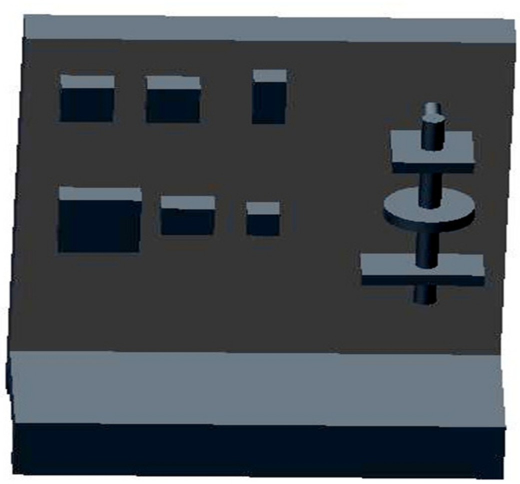

Fig 4: Front view

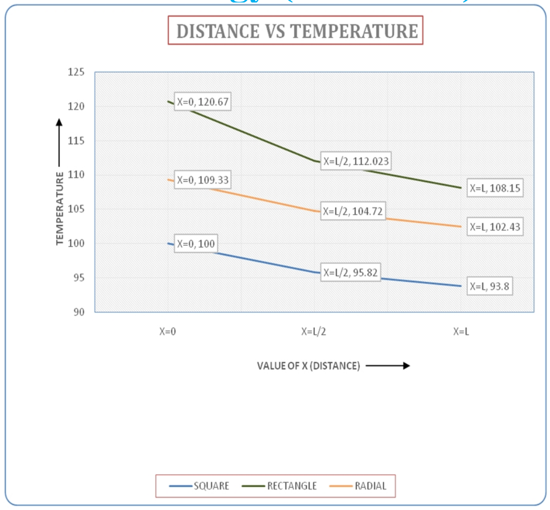

Fig 5: Distance vs. Temperature plot

VI. CONCLUSION

- This setup is very much useful to find the heat transfer rate and temperature distribution profile of various fin geometries using natural convection apparatus in steady state.
- This method is also used for other experiments like Pin Fin & forced convection test rig.
- Most importantly the nano coated fins have high heat transfer rate than conventional fins.

A. Advantages

1) Economical Aspect

a) Least maintenance cost,
b) No blower required for operation

2) Technical Aspect

a) No moving parts, thus long life
b) Noiseless operation
c) No operators required for the system

3) Manufacturing Aspect

a) Compact in size
b) Only Light materials are used

4) Safety Aspect

a) Pollution free
b) Less chance of accidents

B. Applications

1) We can find the heat transfer rate and temperature distribution profile for any fin geometry.
2) In steady state we can find the heat transfer coefficient.

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