Experimental And Numerical Heat Transfer Study Of Heated Vertical Tube With Different Metals Under Natural Convection

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Abstract – In this present paper heat transfer natural convection is experimentally and numerically investigating using different metals of heated vertical tube such as Copper, brass, aluminum and stainless steel. The heated vertical tube is made up of 38mm outer diameter for Cu, Brass and Al and Outer Diameter for Stainless steel is 33 mm, 500mm length of all metal tubes and duct size is 200mm x 200mm x 800mm. Experiments are performing on the surface heat transfer coefficient vertical heated tube under natural convection experimental setup at GEC Jagdalpur (C.G.) and numerical analysis is done by ANSYS fluent 15.0 and plotting the graph between various correlations of the natural convection.

Key Words: Natural Convection, Local Heat Transfer Coefficient, Vertical tubes, ANSYA Fluent 15.0, Temperature Distribution, Nusselt Number, Groshof Number, Heat Transfer, surface heat transfer, prandtl no .

1.0 INTRODUCTION :

Natural convection phenomenon is due to the temperature difference between the surface and the fluid and not is created by any external agency. The present experimental set up is to study the natural convection phenomenon from a vertical cylinder in terms of the variation of local heat transfer coefficient along the length and also the average heat transfer coefficient and its comparison with value obtained by using an appropriate correlation.

Among heat transfer problems, the natural convection heat transfer gains a special attention due to its wide applications in engineering systems. Free (natural) convection fluid flow is generated by the buoyancy due to the density variations resulting from temperature and/or concentration distribution. The free convection plays an important role in many engineering applications such as heat exchangers, drying processes, electrical components of transmission lines, nuclear energy fields, solar energy and thermal storage systems.

1.1 Apparatus

The apparatus consist of a brass tube fitted in a rectangular vertical duct. The duct is open at the top end forms an enclosure and serves the purpose of undisturbed surrounding. One side of the duct is made up of Perspex for visualization. An electrical heating element is kept in the vertical tube which in turns heat the tube surface. The heat is lost from the tube to the surrounding air by natural convection. The temperature of vertical tube is measured by an ammeter and a voltmeter and is varied by a dimmer star. The tube surface is polished to minimize the radiation losses.

1.2 Specification of Different Metals& Experimental Setup Table For Specification of Pipe Metals

Metal	Length	Outer Dia.	Wall thick	Emissivity ε
Cu	500 mm	38 mm	2mm	0.60
Brass	500 mm	38 mm	2mm	0.59
Al	500 mm	38 mm	5mm	0.19
S. S.	500 mm	33 mm	2mm	0.87

Duct size 200 mm x 200 mm x 800 mm

Multichannel Digital Temperature Indicator 0 – 300 °C using Chriomel/Alumel thermocouple.

Ammeter 0 –2 Amps. and Voltmeter 0 – 200 Volts.

Dimmer star2Amp. 240Volts.

Fig. 1.1 Experimental setup at GEC Jagdalpur

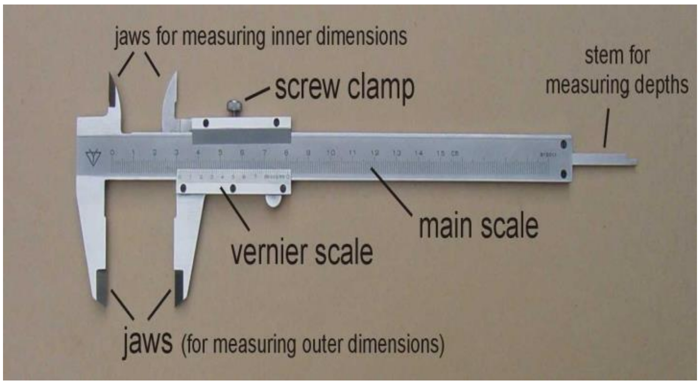

Fig:1.2 Vernier Caliper for measuring Outer Diameter of the pipe

Fig:1.3 Stainless steel Metal having a length of 500mm and outer dia 33mm.

Fig 1.4 Al Metal having a Length of 500mm & OD is 38mm.

Fig.1.5 Brass Metal having length 500mm and OD is 38mm.

2.0 LITERATURE SURVEY

Mack and Bishop: made a study in an annular space ranging between two horizontal concentric cylinders. They employed a power series truncated at the third power of the Rayleigh number to represent the stream function and temperature variables.

Kuehn et al. compiled a comprehensive review of the available experimental results for natural convection heat transfer between horizontal concentric and eccentric cylinders and proposed correlating equations using a conduction boundary-layer model.

El-Sherbiny: Investigated numerically the natural convection in air between two infinite horizontal concentric cylinders at different constant temperatures. The study covered a wide range of the Rayleigh number, Ra from 10^2 to 10^6, and the Radius Ratio, (RR) was changed between 1.25 and 10.

Djezzar et al. :simulated the case of natural convection in a space annulus between two elliptic confocal cylinders; they could detect multi-cellular flows, for certain geometries when the number of Grashof increases.

Isahai & Hattori: Numerically studied natural convection with few experiments, using vertical cylinders of different triangular pitch at modified Grashof number (Gr*) from 10^4 to 10^8. They used boundary fitted coordinate system in their investigations. They also studied the laminar region.

Chughtai et al. reported a correlation for Nusselt number based upon numerical results. They used the computational fluid dynamics technique and compared their results with actual experimental data of a tank in pool type reactor. For step increase in power, they presented the temperature and velocity profiles and transient response of Nusselt number

P. Venkata Reddy a, G.S.V.L. Narasimham b,* : A numerical study of the conjugate natural convection in a vertical annulus with a centrally located vertical heat generating rod is performed. The formulation in primitive form is solved using a pressure-correction algorithm. A parametric study is conducted by varying the heat generation based Grashof number, aspect ratio and the solid-to-fluid thermal conductivity ratio over wide ranges with the Prandtl number fixed at 0.7. Results are presented for the temperature distributions and Nusselt numbers. The average Nusselt numbers on the inner and outer boundaries show an increasing trend with the Grashof number.

3. METHODOLOGY

Heat Transfer coefficient is given by

$$h = \frac{Q - Q1}{As \times (Ts - Ta)} \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_ (1)}$$

Where, h = Average surface heat transfer coefficient (W/m^2 °C)

Q = Heat transfer rate (Watts)

As = Area of heat transfer surface = π d l (m^2)

Ts = Average surface temperature

Ts = T1 + T2 + T3 + T4 + T5 + T6 + T7 / 7 °C

Ta = Ambient temperature in the Duct = T8 °C

Q1 = heat loss by radiation = σ A ε (Ts^4- Ta^4)

Where, σ = Stefan Boltzmann constant = 5.667 x 10^{-8} W/m^2 ° K

A = Surface area of pipe = 0.59 m^2

ε = Emissivity of pipe material = 0.6

Ts & Ta = Surface and Ambient temperatures in °K

The surface heat transfer coefficient, of a system transferring heat by natural convection depends on the shape, dimensions and orientations of the fluid and temperature difference between heat transfer surface and the fluid. The dependence of 'h' on all the above mentioned parameters is generally expressed in terms of non dimensional groups as follows:

$$Gr = \frac{g\beta (Ts - Ta)\, \delta^3}{\nu^2} = \text{Grashof Number}$$

Where

g = gravitational acceleration, m/s^2

β = coefficient of volume expansion, 1/K

δ = characteristic length of the geometry, m

ν = kinematics viscosity of the fluid, m^2/s

Ts & Ta = Surface and Ambient temperatures in °K.

For gases, β = 1/(Tf + 273) °K.

Tf = (Ts + Ta)/ 2

Pr = μ c_p / k = Prandlt number

Where,

μ = absolute or dynamic viscosity (kg/m s)

c_p = specific heat (J/kg K)

k = thermal conductivity (W/m K)

Nu= hL/k , hD/k = Nusselt number

Where,

h = convective heat transfer coefficient (W/m^2)

L= representative dimension (e.g., diameter for pipes, length of the pipes), (m) and

k= the thermal conductivity of the fluid (W/m K).

For a vertical cylinder losing heat by natural convection the following empirical correlation's

$$\frac{h \times L}{k} = 0.59(GrPr)^{1/4} \text{ for } 10^4 < GrPr < 10^9$$

Laminar GrPr < 10^9 __________(2)

For Higher values of Gr.Pr & Constant heat flux/ constant wall temperature.

h x L/ k = 0.10(GrPr)$^{1/3}$ for 10^9 > GrPr < 10^{13}

Turbulent GrPr > 10^9 ___________(3)

For both constant heat flux and constant wall temperature.

L = length of the cylinder.

All the properties of the fluid are determined at the mean film temperature (Tf).

3.1 PROCEDURE:

1. Put ON the supply and adjust the dimmer star to obtain the required heat input. (ex. 40W, 60 W, 70 W etc.)
2. Wait till the steady state is reached, which is conformed from temperature readings. (T1 to T7).
3. Measure surface temperature at the various pionts. i. e. T1 to T7
4. Note the ambient temperature. i. e. T8.
5. Repeat the experiment at different heat inputs. (Do not exceed 80 w).

3.2 EXPERIMENTAL OBSERVATION TABLE

Outer diameter of the cylinder = 38 mm

Length of the cylinder = 500 mm

Input to heater = V x I Watts.

Sr. No	Volts	Ampere		Temperature ° C							
	V	I	T1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	Time
1											
2											
3											

3.3 CALCULATIONS :

Calculate the value of average heat transfer coefficient, neglecting end losses using equation (1).

Calculate and plot the variation of local heat transfer coefficient along the length of the tube.

T = T1 to T7 and

$$h = \frac{Q}{As \times (T - Ta)}$$

Compare the experimentally obtained value with the prediction of the correlation equations (2) Or (3).

3.4 MATREIAL SELECTION

COPPER: The word copper comes from the Latin word 'cuprum', which means 'ore of Cyprus'. This is why the chemical symbol for copper is Cu. Copper has many extremely useful properties, including:

good electrical conductivity, good thermal conductivity, corrosion resistance, easy to alloy, antimicrobial, easily joined , ductile, tough , non-magnetic , attractive, recyclable ,catalytic

BRASS: Brass is an alloy made primarily of copper and zinc. The proportions of the copper and zinc are varied to yield many different kinds of brass. Basic modern brass is 67% copper and 33% zinc. However, the amount of copper may range from 55% to 95% by weight, with the amount of zinc varying from 5% to 40%. Lead is commonly added to brass at a concentration of around 2%. The lead addition improves the machinability of brass.

Brass Properties

- Brass often has a bright gold appearance, however, it can also be reddish-gold or silvery-white. A higher percentage of copper yields a rosy tone, while more zinc makes the alloy appear silver.
- Brass has a higher malleability than either bronze or zinc.
- Brass has desirable acoustic properties appropriate for use in musical instruments.
- The metal exhibits low friction.
- Brass is a soft metal that may be used in cases when a low chance of sparking is necessary.
- The alloy has a relatively low melting point.
- It's a good conductor of heat.
- Brass resists corrosion, including galvanic corrosion from salt water.
- Brass is easy to cast.
- Brass is not ferromagnetic. Among other things, this makes it easier to separate from other metals for recycling.

ALUMINIUM

The Properties

- Aluminium has been termed "The Magic Metal" or "The Wonder Metal". The reasons for these accolades lie in the very diverse range of physical, chemical and mechanical properties enjoyed by the metal and its alloys in both cast or wrought forms:-
- A key property is low density. Aluminium is only one-third the weight of steel.
- Aluminium, and most of its alloys, is highly resistant to most forms of corrosion. The metal's natural coating of aluminium oxide provides a highly effective barrier to the ravages of air, temperature, moisture and chemical attack, making aluminium a useful construction material.
- Aluminium is a superb conductor of electricity. This property, allied with other intrinsic qualities, has ensured the replacement of copper by aluminium in many electrical applications.
- Aluminium is non-magnetic and noncombustible, properties invaluable in advanced industries such as electronics or in offshore structures.
- Aluminium is non-toxic and impervious, qualities that have established its use in the food and packaging industries since the earliest times.
- Aluminium is strong and ductile, properties that, combined with low density, have resulted in extensive use of aluminium in transport applications.

- Aluminium is easily recycled, and can be recycled repeatedly without loss of quality, making it a highly sustainable material. Other valuable properties include high reflectivity, heat barrier properties and heat conduction. The metal is malleable and easily worked by the common manufacturing and shaping processes

STAINLESS STEEL

- The advantageous properties of stainless steels can be seen when compared to standard plain carbon mild steel. Although stainless steels have a broad range of properties, in general, when compared with mild steel, stainless steels have:
- Higher corrosion resistance ,Higher cryogenic, toughness Higher work hardening rate, Higher hot strength, Higher ductility ,Higher strength and hardness, A more attractive appearance

3.5 PRECAUTIONS:

1. Proper earthing is necessary for the equipment.

2. Keep dimmer star to ZERO volt position before putting ON main switch and increase it slowly.

3. Keep at least 200 mm space behind the equipment.

4. Operate the change over switch of temperature indicator gently from one position to another position.

5. Never exceed input above 80 Watts.

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