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Thermal Analysis of Circular Inclined Pipe Subjected To Natural Convection Using CFD

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ABSTRACT
The present work deals with experimental studies and CFD technique on the heat transfer characteristics for Natural convection flow through inclined pipe. The parameters varied during the experimentation and software analysis are tube diameter, and heat supplied. The present investigation revealed that the temperature and the heat transfer coefficient are strongly influenced by the heat flux and the tube diameter, weak function of tube inclination. The experimental and CFD results is to be validate with each other. The Experimental results are to be Compare with the CFD results. Boundary condition, Geometry is created in GAMBIT and Solver; Boundary conditions are provided to the pipe in fluent software. From this work as parameters of pipe changes it affects the results of temperature.

Keywords **-** Buoyancy, Convection, inclined tube, induced flow, Heat flux

I. INTRODUCTION

The upward movement of the fluid due to addition of heat into the system is referred as thermsiphon effect. The fluid expands because of heat addition, becomes lighter and moves upwards in the system. Buoyant forces are dominant in such systems. Since no pump is required to cause the fluid motion, maintenance cost is lower for the thermo-siphon system and hence are preferred wherever possibility exists. The present work is aimed at performing experimental and CFD investigations on the heat transfer characteristics for buoyancy induced flow through inclined pipe. The present work is very useful for designing the solar water heater, Condenser and many heat exchanger pipe where natural convection phenomenon is used. The aim of the present investigation, therefore, is to establish correlations for heat transfer and flow characteristics for the buoyancy induced flow through inclined pipes. Considering the complexity of the problem, experimental approach is preferred. In order to produce required data, experiments were performed using inclined pipes. The exhaustive literature survey reported that very little work is done on the heat transfer and flow characteristics for buoyancy induced flow through pipe [7, 2] of various length and diameters at different angular positions .In this work the results of outlet temperature is validate with Experimental data and CFD. Hence this is a motivation for undertaking this work.

The knowledge of heat transfer coefficient in such buoyancy induced flow through inclined tubes [8] is essential for selecting the optimum diameter of the riser tube that will increase the efficiency of the system for a given collection area. A little consideration will

indicate that for better collector efficiency, the heat transfer coefficient should be as high as possible. However it is well known that any increase in the heat transfer coefficient is always associated with corresponding increase in the pressure drop [6]. This adversely affects the buoyancy induced flow inside a Pipe.

II. EXPERIMENTAL SET-UP

A schematic of the Experimental set-up is shown in figure 1.It consists of a long copper pipe called test section, provided with a heating coil, to create uniform heat flux boundary condition on the pipe surface. The power supplied is measured directly with the help of pre-calibrated wattmeter (accuracy ±1%). Copper Constantan Thermocouples (accuracy ±0.20C) were used to measure all the temperatures. The flow rates were measured using calibrated measuring jar (±1 %) and stop watch.

Fig.1 Experimental set-up

The experimental set-up was calibrated for the heat loss estimation and is validated for the 45 degree inclination of the tube (12 mm, 16 mm, 20 mm and 24 mm) tube diameter and 1 m. The comparison of the results shows that the two values are in good agreement with each other. The uncertainty analysis is done by statistical method. The error in the measurement of heat transfer coefficient is found to be within the range of ± 5%.

Table 1: Parameters varied during the experimentation.

Sr. No.	Parameter	Specifications
1	Tube length	1 m
2	Tube diameter	12 mm, 16 mm, 20 mm and 24 mm
3	Tube inclinations	45^0
4	Inner Insulation thickness	8 mm (Asbestos Rope)
5	Outer Insulation thickness	8 mm (Asbestos Rope)
6	Locations of thermo-couples	1. At the inlet and outlet of test section 2. At different locations on the surface of tube 3.On the inner and outer surfaces of outer insulation
7	Type of thermocouples used	T - type (Copper and constantan)
8	Heat supplied	20 Watts to 240 Watts in step of 20 Watts

III. RESULT AND DISCUSSION

The steady state data generated on the experimental set-up for different values of tube diameter and heat supplied is correlated for temperature as described below.

IV. CFD RESULTS

Table No.2 Boundary condition

Sr. No.	Zone	Boundary condition
1	Inlet	Velocity inlet
2	Pipe Wall	Wall
3	Outlet	Pressure outlet

The above boundary conditions were used for CFD analysis.

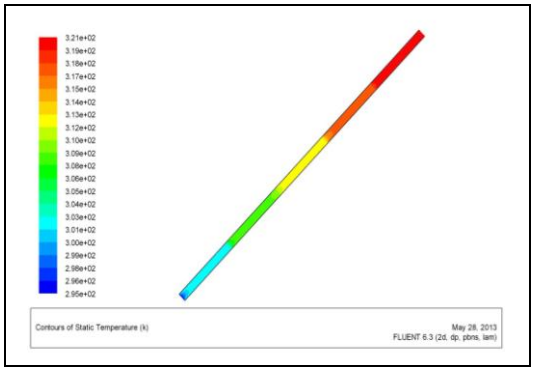

Fig.2 Contour of Temperature of pipe 24 mm dia. & inclination 45^o

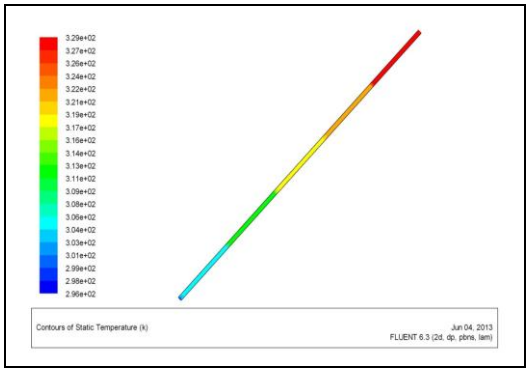

Fig.3 Contour of Temperature of Pipe 12 mm dia. & Inclination 45^o

The above fig.2 and 3 shows the various Contours of temperature of pipe having 24 and 24 mm diameter respectively and 45 degree angles. The color contours shows how the water gets heated and it moves upwards at the outlet of Pipe.

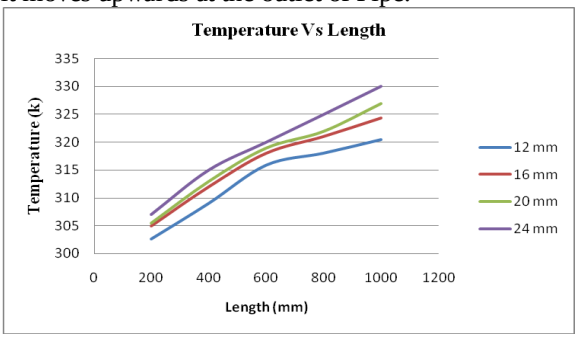

Fig.4 Result of 45 degree inclination and heat flux=1061 w/m^2

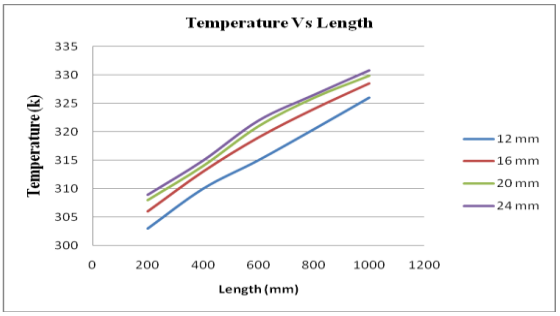

Fig.5 Result of 45 degree inclination and heat flux=1590 w/m^2

It can be seen from the figures 4 and 5 that the temperature is increases with increasing pipe length. As pipe length increases area increase and hence heat transfer rate also increases due to which temperature is gradually increases. There is 1.5 % reduction in temperature between 12 mm and 16 mm diameter pipe.3% reduction in temperature between 16 mm and 20 mm diameter pipe and 5.5% reduction in temperature between 16 mm and 24 mm diameter pipe.

V. COMPARISON OF CFD AND EXPERIMENTAL RESULTS

It has been observed that, there is less amount of error found during this work and hence presents work is valid. The following figure 6 and table 2 shows the results of temperature with percentage of error. The fig.6 shows that it is a good combination of Experimental and CFD Results.

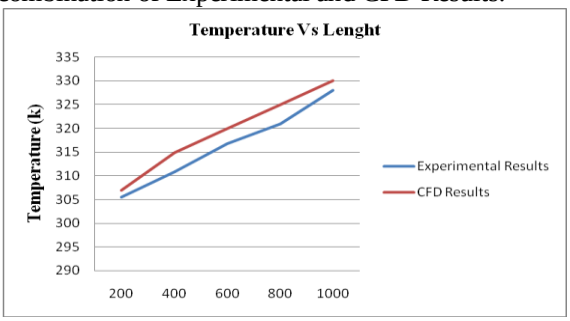

Fig.6 Comparison of experimental and CFD results for temperature for 24 mm dia.

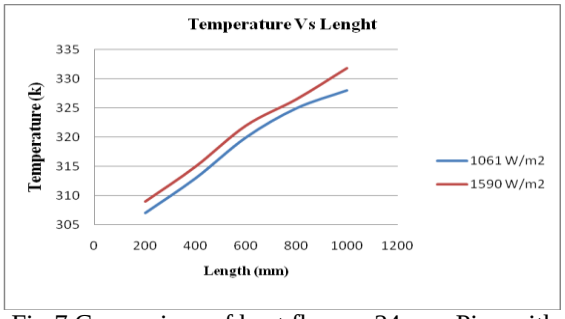

Fig.7 Comparison of heat flux on 24 mm Pipe with 45 degree of inclination for temperature

It has been observe from the figure 7 that, as the heat flux is increases it also affects on the temperature of the pipe. As the heat flux increases the heat transfer rate in the pipe increases and hence temperature gradually increases with respect to the length of the pipe.

Table 3: Comparison of results for 24 mm & 1 m pipe

Heat Flux W/m^2	Inclination	Experimental Results Out-let Temp. ^0C	CFD Results ^0C	Error %
1061	45 degree	47	47.4	0.8
1590		50	49.7	0.6

The Table 3 shows the comparison of results of experimental and CFD work. From these table 3 we shows that there is a less error between these two results and hence the accuracy is good for designing any application related to this and with the help of CFD the designing is easy and reducing the time.

VI. CONCLUSION

- The temperature is found more in large diameter pipe. It reduces with decrease in pipe diameter. The change in temperature was found about 20 % with increase in pipe diameter from 12 mm and 24 mm.
- As the heat supply increases it will affect on the output temperature and it also increases.

Hence it is concluded that the temperature is strongly influenced by heat flux, diameter of the pipe and its inclination.

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