Validation of Experimental Results of Heat Transfer Coefficient using CFD Simulation

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Abstract- **Heat transfer coefficient h, determines the rate of heat transfer. The phenomenon of forced convection with turbulent flow can be solved experimentally and by CFD simulation. The value of h was found by CFD simulation, for a velocity input of 2.5 m/s, for a steel pipe at an inclination of 60^o. This was then compared with the experimental results of Dr. Krishpersad Manohar & Kimberly Ramroop [1].The result was further compared with correlation data obtained using relations given by HILPERT, Fand & Keswani and Morgan. CFD simulation result validated the above correlation.**

Key words: Heat Transfer Coefficient, Turbulent flow, Inclined Steel Pipe, Forced Convection.

I INTRODUCTION

In the study of thermodynamics, the average heat transfer coefficient, *h*, is used in calculating the convection heat transfer between a moving fluid and a solid. This is the single most important factor for evaluating convective heat loss or gain. Knowledge of *h* is necessary for heat transfer design and calculation and is widely used in manufacturing processes, oil and gas flow processes and air-conditioning & refrigeration systems. The heat transfer coefficient is critical for designing and developing better flow process control, resulting in reduced energy consumption and enhanced energy conservation. Application of external flow forced convection heat transfer coefficient range from the design of heat exchangers and aircraft bodies to the study of forced convection over pipes.

With the continued increase in design complexity and the modernization of process plant facilities, the study of forced convection over cylindrical bodies has become an important one. By the formulation of correlations, which consist of dimensionless parameters, such as *Nusselt* number (*Nu*), *Reynolds* number (Re) and *Prandtl* number (Pr), for different geometries, the values of *h* can be calculated without having to analyze experimental data in every possible convective heat transfer situation that occurs. Dimensionless numbers are independent of units and contain all of the fluid properties that control the physics of the situation and involve one characteristic length. It is advantageous to present data in the form of dimensionless parameters since it extends the applicability of the data. Correlations using dimensionless numbers are developed for particular geometries & situations and are applicable within that range. Therefore, it is impractical to use correlations developed for horizontal pipes to determine the *h* for inclined pipes.

II LITERATURE SURVEY

A review of literature on heat transfer coefficients indicated very little work reported for cross-flow pipe arrangement at various angles of inclination.

In this study, forced airflow of 2.5 m/s across steel pipe of diameter 0.034m with pipe orientation inclined at 60^o to the horizontal position was taken. A comparison of the experimentally determined h [1] with CFD simulated h has been done.

Data from experiments carried out by Dr. Krishpersad Manohar & Kimberly Ramroop were obtained from (International Journal of Engineering (IJE), Volume: 4, Issue: 4) and CFD simulation has been carried out.

The relevant datum of h pertaining to 60^o inclination and velocity of 2.5 m/s is **21.22** and the corresponding Nusselt number is **26.06**.

III CFD TEST RESULTS

For CFD simulation to be valid for comparison with the experimental results, the study was undertaken for an inclined steel pipe of dia0.034m, length 1.22 m at60^oinclination and a flow velocity of 2.5m/s. The boundary conditions forth is study were as follows:-

A *Inlet*

Subsonic Normal speed=2.5m/s.

Medium intensity=5%

Heat transfer:

Static temp=307 K

B *Outlet*

Pressure=Atmospheric Pressure

C *Wall*

Wall heat flux=90/π D l = 690.64W/m^2K

Wall Option: no slip and smooth wall.

The temperature profile of the fluid through the pipe is given in Fig I. The computed h across the tube is given in Fig II. The weighted average of the value of h came out as h_{CFD} = 22.22 W/m^2K (From Fig II). For comparing the result of CFD simulation with that of theoretical correlations of Hilpert, Fand & Keswani and Morgan, the respective value of h was computed as follows:-

D *Hilpert Correlation*

$Nu_D = \frac{hD}{k} = CRe_D^m pr^{1/3}$ [1]

Re= VD/υ= 3339.88 (Properties of air is obtained at mean fluid temp of 120^0C)
According to Reynolds number, values of c & m are 0.683 and 0.446 respectively.
Nu_D = 22.46. h = **22.33**W/m^2K.

E *Fand & Keswani Correlation*

$Nu_D = \frac{hD}{k} = CRe_D^m pr^{1/3}$ [1]

C= 0.583
m=0.471 (based on Reynolds number)
Nu= 23.48

h= **23.05**W/m^2K.

F *Morgan Correlation*

$Nu_D = \frac{hD}{k} = CRe_D^m pr^{1/3}$ [1]

C= 0.583
m=0.471 (based on Reynolds number)
Nu = 23.48

h= **23.05**W/m^2K. (values of c & m obtained from [1])

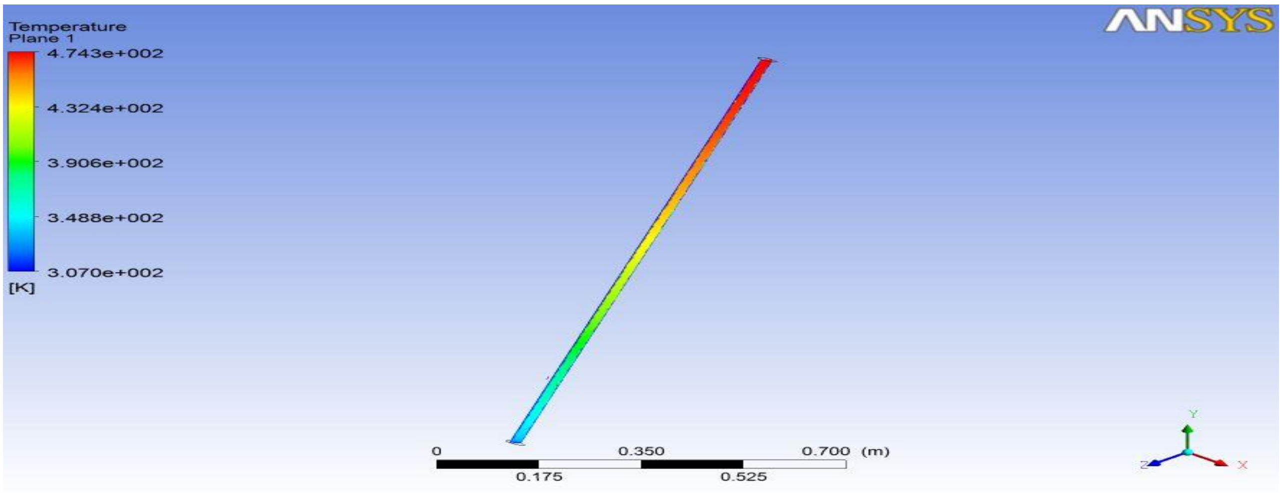

FIG I TEMPERATURE PLANE

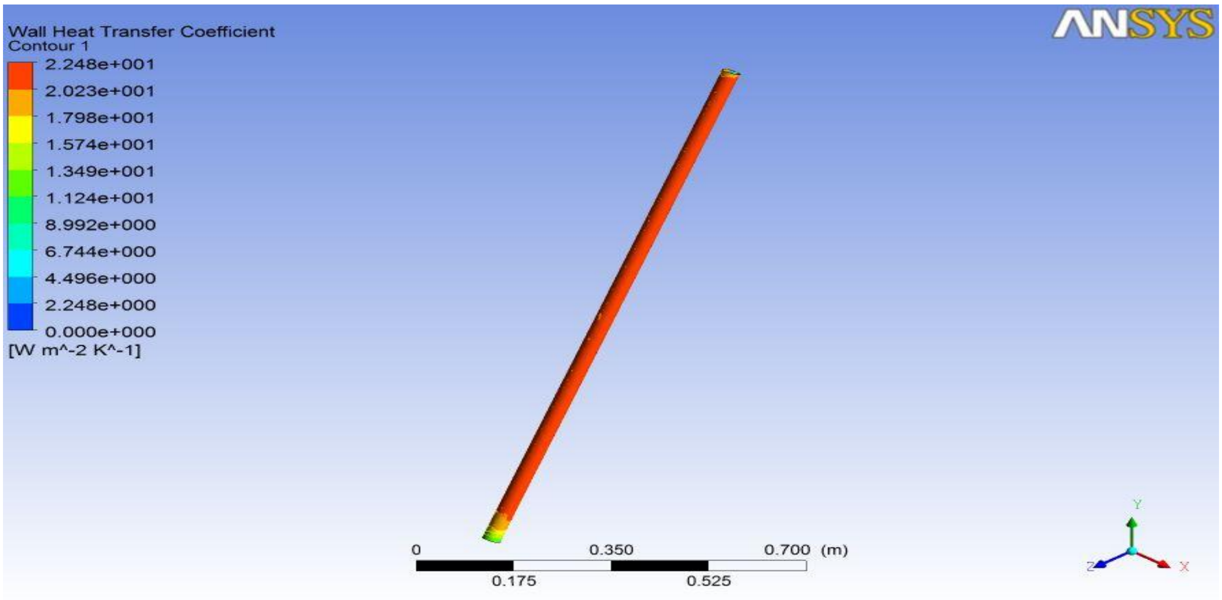

FIG II HEAT TRANSFER COEFFICIENT

All the results are tabulated below in Table I.

TABLE I
COMPARISON OF RESULTS

	h (W/m^2K)	% of Error
CFD	22.22	
EXPERIMENT	21.22	4.71
HILPERT	22.33	-0.49
FAND & KESWANI	23.05	-3.60
MORGAN	23.05	-3.60

The study produced a result of h as 22.22 W/m^2K. This compared well both with the experimental results vide [1] and the calculations based on the correlation relations given by Hilpert, Fand & Keswani and Morgan. In all the four cases, the CFD result was within ±5%.

References :

1) Comparison of Correlations for Heat Transfer from Inclined Pipes **(International Journal of Engineering (IJE), Volume: 4, Issue: 4)**

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