Prediction of The Coefficient on Heat Transfer For Heat Transfer For Single – Phase Flow In A Annular Passage on Vertical Tube By Foeced Convection Heat Flow

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Keywords

Turbulent zone, Forced convection, Developing flow, forced convection heat flow.

Abstract

The forced convection hypothesis poses a challenge to the employ of smooth vertical circular tubes due to the low heat flux wanted to prevent buoyancy effects by increasing the coefficient of heat transfer. Previous research on the turbulent zone has mainly focused on mixed convection, via limited studies on forced convective heat transfer. The aim of this study is to predict the behaviour of the coefficient of heat transfer under specific convection conditions. Prandtl number, and Reynold number. The turbulent zone in the turbulent developing zone was determined for all heat flows, and turbulent flow happened at all rates of mass flow for all heat fluxes. The Reynolds number increased with an increase in heat flux for the characteristics of heat transfer under isothermal flow. The experiments involved the use of water that had a Prandtl number between (2.09 and 2.12). Reynolds numbers varied between (28352.75 and 57442.32), while heat fluxes ranged from (424.62 to 2547.77 W/m^2). The tests were conducted at a single-phase to coefficient of heat transfer for annular passage of (2.09 to 3.64 Kw/m^2.K), with heat inputs ranging from (50 to 300 watts). The turbulent flow zone width was determined in the developing turbulent zone.

Research Article :
Submission Date : 13.04.2023
Accepted Date : 12.08.2023

1. INTRODUCTION

The flow within a tube that has turbulent and convective can either be due to forced convection or mixed convection. It is important to be able to differentiate between the two types because the Reynolds number varies significantly between them. This difference has significant.Both fully developed and developing flows had examined. While there has significant literature on transitional flow zones in vertical tubes, most of

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these studies focus on natural or mixed convection..The study examined the heat transfer through forced convection in the transition zone of vertical heat exchangers with a co-current flow, by Reynolds number between (4000 and 10000). However, depending on the inlet geometry and rate of heating, the transition to turbulent flow in the tubes occurred much earlier than a Reynolds number of (4000), (Everts et al.,, 2018; Ghajar et al., 1994; Bashir et al., 2019; Holman, 2012; Alsulaiei et al., 2023; SHAKIR, 2022a, 2022b; Shakir, 2020, 2021b, 2021a, 2022, 2023; SHAKIR, 2023) the study conducted a numerical analysis on forced convection, looking at laminar and turbulent flows on mini-channels by varying boundary conditions. They identified the area where quasi-turbulent and turbulent flows occur as the transition zone. So, this zone has been defined as the portion of the quasi-turbulent zone and turbulent flow zone. Since there were no empirical data from practical experiments, the study solely relied on predictive analysis through heat transfer equations. These equations were used for hypothetical setups that resemble real-world lab tests conducted under the same circumstances.The main goal of this research is to develop an advanced numerical iterative method that utilizes a prediction software to determine the characteristics of forced convection heat transfer and fluid flow.

2. NUMERICAL METHODOLOGIES

The equations that control the phenomenon are solved using the finite method on the Excel software algorithm, which also solves the temperature of the fluid and all wanted fluid properties. To predict the phenomenon, a program was employed that used over (700) correlations of heat transfer, and these correlations had then transmitted to the Excel software using an iterative technique. Figure.1 shows that heat movement only occurs at the solid-water boundary, which has why the 2-D array can be configured in such a way that the main effect on the wall line has perpendicular to the water flow, parallel to the water flow, as well as thermal conductivity, can be traced by the stages seen in Figure.1. (Shakir, 2020; Shakir, 2021b).

$$\delta^2 T/\delta y^2 + \delta^2 T/\delta z^2 = 0 \quad (1)$$

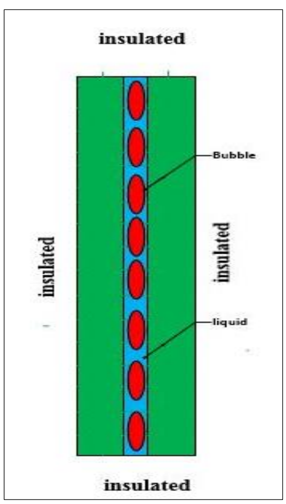

Figure 1. Test section

Which has temperature (T) was measured on the copper wall, while (y) is perpendicular to the axis of water flow, in order to calculate heat transfer using equation (1) by dividing it by the area of the square cell (0.05 m) squared. (Shakir, 2020; Shakir, 2021b).

$$T_{i,j} = \delta y^2 \left(T_{i+1,j} + T_{i-1,j}\right) + \delta z^2 \left(T_{i,j+1} + T_{i,j_1}\right) / 2\ (\delta y^2 + \delta z^2) \quad (2)$$

3. MATHEMATICAL EQUATIONS

The flow temperatures, (T_L), at any axial location, (Holman, 2012)

$$T_L = T_{in} + (T_{out} - T_{in}/L)\ x \quad (3)$$

To get the area of tube flow, (Holman, 2012)

$$A = \pi/4 \left(D_{out}{}^2 - D_{in}{}^2\right) \quad (4)$$

The hydraulic diameter can be found by:- (Holman, 2012)

$$D_h = D_{out} - D_{in} \quad (5)$$

To calculate the fluid of mean velocity by, (Holman, 2012)

$$u = m/\rho\ A \quad (6)$$

To obtain the Re by, (Holman, 2012)

$$Re = \rho u D_h/\mu \quad (7)$$

To get the (Pr) by, (Holman, 2012)

$$Pr = C_p \mu / K_f \quad (8)$$

To obtain the (St) by, (Holman, 2012)

$$S_f = E_{st} R_e{}^{-0.205} P_r{}^{-0.503} \quad (9)$$

To obtain the (E-St) by, (Holman, 2012)

$$E_{st} = -0.0225\ exp^{\left(-0.0225\ (\ln Pr)^2\right)} \quad (10)$$

To obtain the (Nu-T) by, (Holman, 2012)

$$N_U = 0.023\ R_e{}^{0.8} P_r{}^{0.4} \quad (11)$$

To obtain the (h-T) by, (Holman, 2012)

$$h_T = \rho\ u C_p S_t \quad (12)$$

4. RESULTS

The data seen in Figure 2 illustrates the Reynolds number plotted against the rate of mass flow. Through a polynomial curve fit of the forced convection heat transfer results for vertical upward and downward flows, a revised correlation for developing turbulent forced convection Reynolds number can be obtained, which takes into account the increase in Reynolds number with the rate of mass flow rate.Figure.2 indicates that this correlation has valid for Reynolds numbers ranging from (28352.75 to 57442.35). The increase in the temperature of liquid reduces the viscosity of a liquid, which in turn raises the Reynolds number. Additionally, the geometry of the inlet and outlet can be significantly affected the Reynolds number range mentioned.

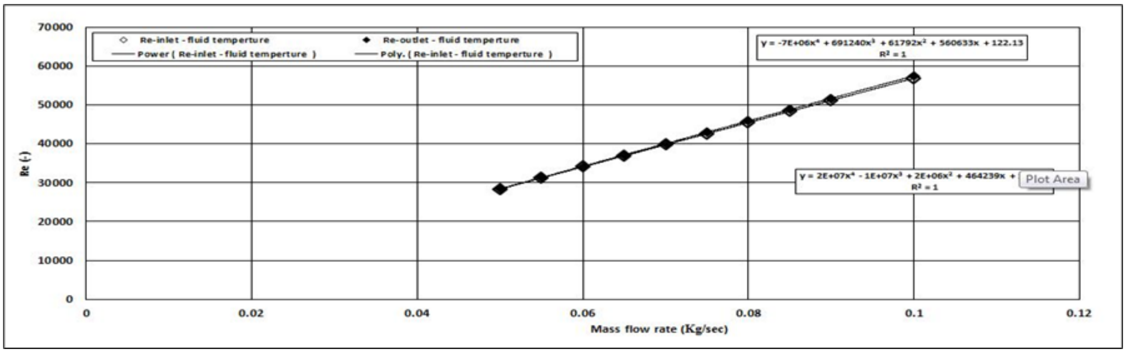

Figure 2.Variation to (Re) versus rate of mass flow

The information presented in Figure 3 demonstrates that the Reynolds number, as a function of the thermal entrance length (x/Di), is affected by forced convection and heat flux in upward and downward flows due to the reduction in viscosity caused by an increase in temperature. The Reynolds number remained relatively constant along the length of the tube until it reached the thermal entrance length, indicating that flow development occurred for all flow orientations and under forced convection conditions in vertical tubes. so Increasing the thermal entrance length had a significant impact on raising the Reynolds number for all inlet and outlet data. Additionally, (4) thermocouples are employed in this study to analyze by developing and turbulent flow in the range of ($7.14 < x/Di \leq 71.42$), which has much smaller than the thermal entrance.

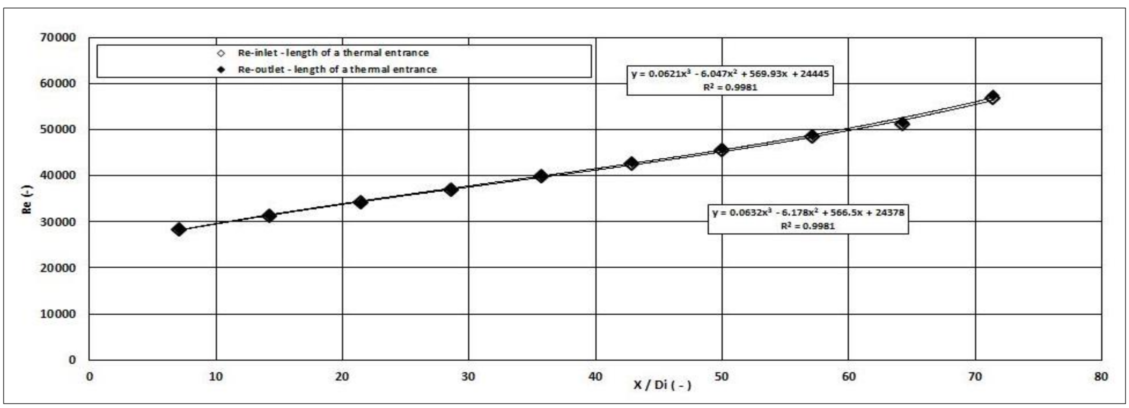

Figure 3.Variation to (Re) as a function of (x/Di)

Figure 4 illustrates the investigation of the relationship between the temperature of the fluid and the coefficient of heat transfer. The coefficient of heat transfer has been studied for both upward and downward flows and can be represented by a simple polynomial curve fit. The consequences of vertical upward and downward flows are reflected in this curve. The data obtained from the study show that at the outlet, a higher increase in temperature of the fluid (represented by the black line) occurred at a Reynolds number of (28339.98-57442.33), with a mass flow rate of (0.05-0.1 kg/s) and a heat flux of (424.62-2547.77 W/m^2). Similar rates of mass flow and heat fluxes, but different Reynolds numbers (28352.75-56844.02), were obtained at the inlet with data on the coefficient of heat transfer and the temperature of the fluid.

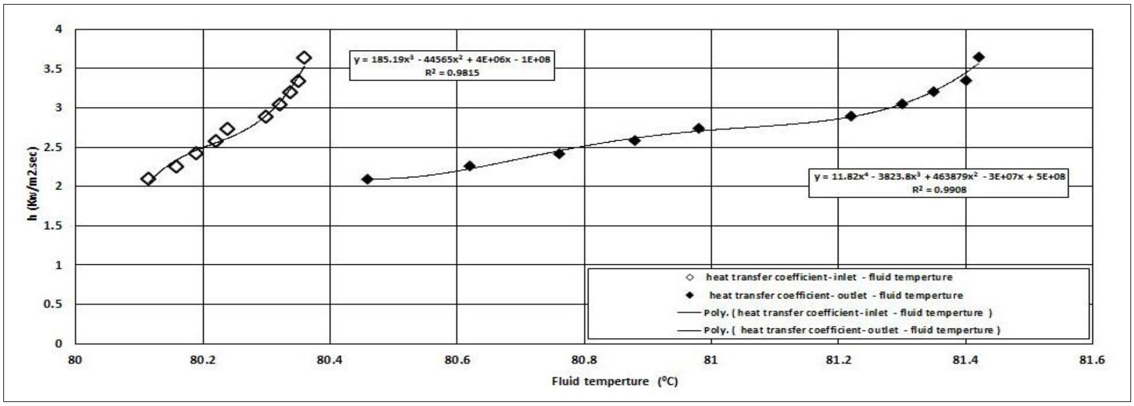

Figure 4. Variation of coefficient of heat transfer as function fluid temperature

The graph in Figure 5 shows the relationship between the temperature of the fluid and the velocity of the fluid, which was obtained by fitting third and second-degree polynomial curves to all the forced convection heat transfer data for the vertical upward and downward flow. For vertical upward flow, the temperature of the wall remained constant and was less than the uncertainty of temperature measurement, indicating that buoyancy effects are negligible and forced convection was the dominant heat transfer mechanism. This resulted in similar circumferential wall temperatures at a given location. A similar result was obtained for other heat flux and Reynolds number, as well as for downward flow. The similarity of the results for upward and for downward flow so confirmed that buoyancy effects can be ignored.

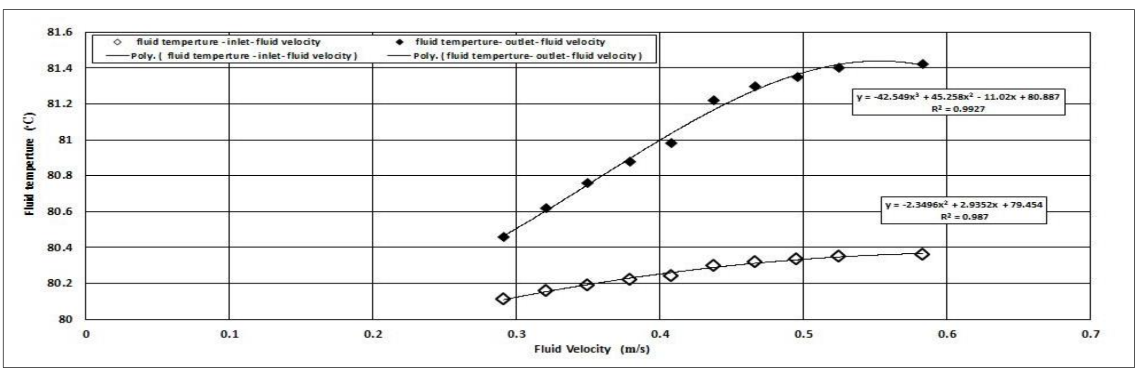

Figure 5. Variation of fluid temperature as function fluid velocity

5. CONCLUSIONS

The existing literature on predicting outcomes has noted that there has been a lack of research on internal forced convection in turbulent zone. To account for forced convection and minor buoyancy effects, predictions are made using a test section that was oriented both vertically downward and upward. In situations of pure forced convection, the transition range (Re) in the developing zone increased as heat flow increased, and it was turbulent. This paper suggests using uncertainty assessments in predicting (Re). Increasing heat flow by increasing temperature and by decreasing viscosity could be raised (Re). Predictions in this paper are made using a copper tube test section by

Reynolds number ranging from (28,352.75 to 57,442.32). Pure forced convection resulted in the cessation of turbulent flow in the developing region at higher Reynolds numbers with an increase in heat flux. Furthermore, the width of the flow regime changed with different heat flux values, and equations were formulated to determine the boundaries of the turbulent flow regime in pure forced convection. The study discovered that, like isothermal flow, turbulent flow happened at different mass flow rates for all heat fluxes. However, Reynolds numbers increased with heat flux, which was attributed to the drop in viscosity as the temperature rise.

NOMENCLATURE

A	area of tube flow (mm^2)
C_p	specific heat of water,(kJ/(kg .K)
D_h	hydraulic diameter, mm
E-st	factor of Stanton number (-)
h_T	turbulent coefficient of heat transfer, (W/(m2.K)
K_f	thermal conductivity of fluid, (W/(m .K)
K_c	thermal conductivity of copper, (W/(m .K)
L	tube length (m)
m	mass water flow rate,(kg/s)
Nu	Nusselt number (-)
Pr	Prandtl number (-)
St	Stanton number (-)
Re	Reynolds number (-)
T	temperature,(C^o)
TL	Fluid temperature,(C^o))
Tin	Inlet temperature,(C^o))
Tout	Exit temperature,(C^o))
V	water velocity,(m/sec)
ρ	water density, (Kg/m2)
μ	dynamic velocity (Pa .S)

Conflict of Interest

The author participated in this study without any conflicts of interest, receiving no financial support and having no situations that could lead to financial or personal benefits.

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