Study of Forced Convection Heat Transfer From Horizontal and Vertical Tubes

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Abstract

Forced convection is used in many parts of industry. It is important to demonstrate the effect of air speed on forced convection heat transfer coefficients since it is involved in many industrial applications use it. The procedure consists of measuring the temperature of a certain heating material in horizontal and vertical orientation. Experimental studies of forced convection heat transfer from horizontal and vertical heat sources in carried out. It is conducted to determine the effects of Reynolds number and nusselt number on heat transfer. The air stream velocity was varied from (28 to 72) m/s to obtain the large range of the Reynolds numbers .The experiment results for horizontal tubes are obtained for range of Reynolds number (2.6×10^4 to 6.4×10^4), Nusselt number (37.75 – 226.98) and for vertical tubes are obtained for the range of Reynolds number (4×10^4 to 6.9×10^4), Nusselt number (41.45 – 245.56). A correlation for the convective heat transfer coefficients is obtained. The present experimental correlation is compared with available correlation equations and experimental data. The comparisons show very good agreement.

Keywords: - Forced Convection, Heat transfer, Horizontal and Vertical heat sources.

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1. Introduction

Many applications require cooling cycle. For instance, a newly made component in a manufacturing plant may need to be cooled before being put into a larger assembly, using air conditioning for the house. Forced convection is used in many instances to increase the amount of heat transfer between an object and the fluid surrounding it. A particular application is using a fan at the condensing unit located outside of homes to induce forced convection to increase heat transfer. Circular tubes are almost exclusively used in the construction of heat exchangers, Prediction of forced convective heat transfer from a circular tube conveying a hot nanofluid is a basic but important problem in the field of heat transfer enhancement in recent years. Researchers and engineers are confronted with this problem in a wide variety of industries ranging from transportation, HVAC, heat exchangers, and textiles. All of these industries are limited by efficient heat transfer applied; hence, there is a strong need to improve fluid properties and the type of that can transfer heat more efficiently.

2. Review of Literature

Due to their fundamental and pragmatic significance, considerable research efforts have been expended in studying the momentum and heat transfer characteristics of cylinders and bars of square cross-section immersed in Newtonian and power-law type non-Newtonian fluids, spanning wide ranges of conditions. Current interest in such model flow configurations stems from both theoretical and pragmatic considerations. From a fundamental standpoint, experience has shown that such simple geometries have proved to be of value in gaining physical insights into the underlying physical processes. Undoubtedly, single and multiple circular cylinders have occupied the centre stage in this field for more than hundred years [1, 2].

Heat transfer from helical coiled tubes have received a considerable attention because of its practical importance in many industrial applications, such as air conditioning, piping systems, heat exchangers, storage tanks, and chemical reactors. During the past several decades, a number of theoretical and numerical studies have been presented for investigating the effects of the secondary flow motion, which is generated by the curvature effect and centrifugal force in the helical coils. These studies aimed to clarify the correlations between the friction factor and the Nusselt number [3].

Experimentally investigated film condensation R-113 on in-line bundles of horizontal finned tubes with vertical vapor down flow, Heat transfer measurements were carried out on a row-by-row basis. The heat transfer enhancement due to vapor shear was much less for a finned tube bundle than for a smooth tube bundle [4].

Local and average heat transfer by forced convection from a circular cylinder is studied for Reynolds number from 2×10^3 to 9×10^4 and Prandtl number from 0.7 to 176. For subcritical flow, the local heat transfer measurement indicates three regions of flow around the cylinder: laminar boundary layer region, reattachment of shear layer region and periodic vortex flow region. The average heat transfer in each region is calculated and correlated with the Reynolds number and the Prandtl number. The Nusselt number in each region strongly depends on the Reynolds number and the Prandtl number with different power indices. An empirical correlation for predicting the overall heat transfer from the cylinder is developed from the contributions of heat transfer in these three regions [5].

Forced convection heat transfer to incompressible power-law fluids from a heated circular cylinder in the steady cross-flow regime has been investigated. The dependence of the average Nusselt number on the Reynolds number ($5 \leq Re \leq 40$), power-law index ($0.6 \leq n \leq 2$) and Prandtl number ($1 \leq Pr \leq 1000$) has been studied in detail. The numerical results are used to develop simple correlations as functions of the pertinent dimensionless variables. In addition to the average Nusselt number, the effects of Re, Pr and n on the local Nusselt number distribution have also been studied to provide further physical insights. The role of the two types of thermal boundary conditions, namely, constant temperature and uniform heat flux on the surface of the cylinder has also been presented [6].

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3. Experimental system and procedure

3.1 Experimental system

Forced heat transfer apparatus is used for this study. The device consists of a square duct, motor, fan, power supply, manometer, pitote tube and chamber as shown in figure [1].

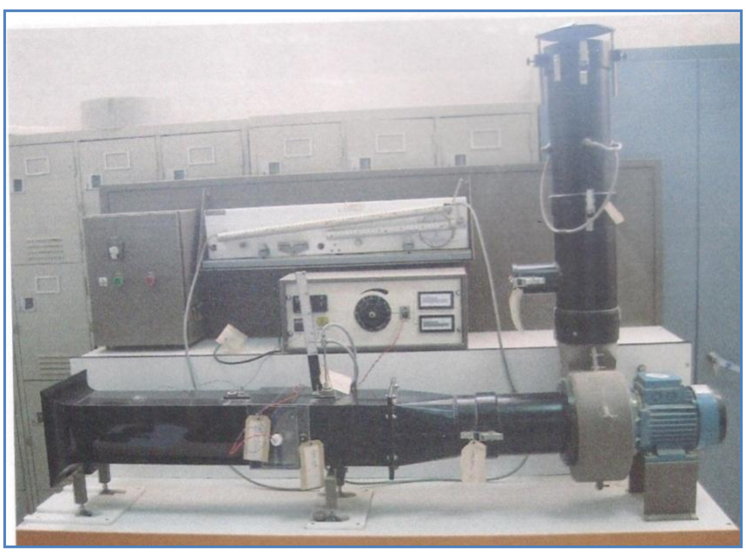

Figure. 1. Photograph of the completely assembled

Square duct follow by a motor driven fan with different opening, fitting with a pitote tube for measuring velocity of air flow and power supply consists of a selector for changing the current and voltage thermocouples for measuring the ambient temperature and different temperature between the heat source wall temperature and ambient temperature. A cylindrical rode resistance supplied by electricity is used as the heat source supply and schematic diagram for the device is shown in figure [2].

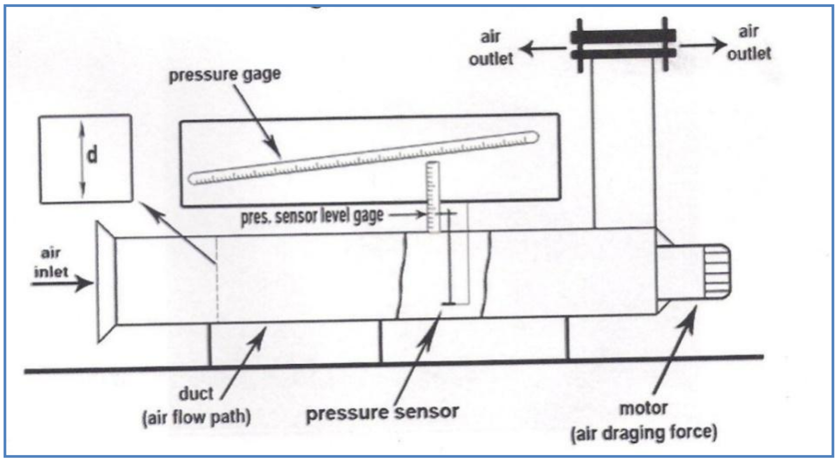

Figure 2: Schematic diagram of the completely assembled.

A range of experiments in the field of Heat Transfer has been developed for the basic Air Flow Bench to meet the needs of this growing area of study. In each of the individual cases described, the local convective heat transfer from the heated wall surface to the air is examined by measuring the power used to maintain the surface of the electrically heated model at constant temperature. The amount of heat used has minimal effect on the bulk temperature of the air flow, thus greatly simplifying the experimental technique.

The relationship between Nusselt, Prandtl and Reynolds numbers can be investigated by varying the air flow rate, the electrical power to the model and hence the surface temperature. The effect of the change of air flow rate on the pressure drop over the test models can also be investigated. The velocity of the air flow in the test section is determined by means of a pitot static tube. Provision is made part way along the air flow tunnel to install any one of the two interchangeable model inserts supplied. One insert allows a single heated tube of either 12.7 mm or 9.5 mm diameter to be located across the horizontal centre line of the duct. The other insert is a tube bundle model in which a heated tube can be placed in any one row of the bundle. The test section affords a means of simulating a Cross Flow Heat Exchanger, a series of blank tubes being inserted transversely within the section. Various configurations can be achieved, comprising a single tube or, up to four tube blanks. An electrically heated tube complete with surface mounted thermocouple is provided, to replace any of the blank tubes within the test section. A low voltage power source complete with wattmeter indicates the power dissipated by the electrical heater. These items are mounted in a control box along with a mill voltmeter for indicating the output from the surface temperature thermocouple mounted on the heater. The unit comes complete with two heated tubes of different diameters.

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3.2 Experimental Procedure

A- When the Heater is fixed horizontal.

1. Turn on the device.
2. Open the chamber and fix it at the specific opened.
3. Give the value of the current and voltage supply for five reading each time the value is changed.
4. For each case the value of the temperature (T_α) of air using thermometer and (ΔT) step by step at small time are recorded**.**
5. For each case when the chamber opening changes the (ΔP) for the different level of the pitote tube recorded.
6. The chamber opening changes for five times and repeat all procedures above.

B- When the heater is fixed vertically at this case all procedures above repeated.

4. Result and Discussion

4.1 Calculation procedure

For each run, the primary data is used to calculate the heat transfer coefficient and dimensionless like, Reynolds number Nusselt number, using the following relationships [7].

$$Nu = C\,\mathrm{Pr}^n\,\mathrm{Re}^m \quad (1)$$

$$Q = I \times V = h \times A \times (T_\omega - T_\infty) \quad (2)$$

$$\mathrm{Re} = \rho v d / \mu \quad (3)$$

$$Nu = hD/k \quad (4)$$

$$Nu = C\,\mathrm{Re}^m \quad (5)$$

Physical properties of air are obtained [7]. The calculation of heat transfer rates is required, for the determination of the fluid properties such as kinematics viscosity, thermal conductivity and Prandtl number,the average temperature is found

$$T_f = (T_w + T_\alpha)/2 \quad (6)$$

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4.2 Discussion

Nusselt number (Nu) variation with Reynolds numbers when the tube heater is horizontal, Fig. 3 shows that the Nusselt number increases as the heat input increased for the horizontal tube, and increases with increasing of the Reynolds numbers from the closed system.

Nusselt number (Nu) variation with Reynolds numbers when the tube heater is Vertical. Fig. 4 shows that the Nusselt number increases as the heat input increased for the Vertical tube, and increases with increasing the of Reynolds numbers from the closed system.

Variation of Heat transfer coefficient with total heat input (Q_{total}) .Fig. 5 shows the effect of total heat input on the heat transfer coefficient at different orientation tubes. It has been observed that the heat transfer coefficient is increasing with increasing the heat input for the different orientation of tube.

Variation of total heat transfer with Nusselt number at different Orientation Tube. Fig. 6 shows the effect of total heat input on the Nusselt number at different orientation tubes. It has been observed that the Nusselt number is increasing with increasing of the heat input for the different orientation tubes.

Variation of total heat transfer with Reynolds numbers at different Orientation Tube. Fig. 7 shows the effect of total heat input on the Reynolds numbers at different orientation tubes. It has been observed that the Nusselt number is increasing with increasing the heat input for the different orientation tubes.

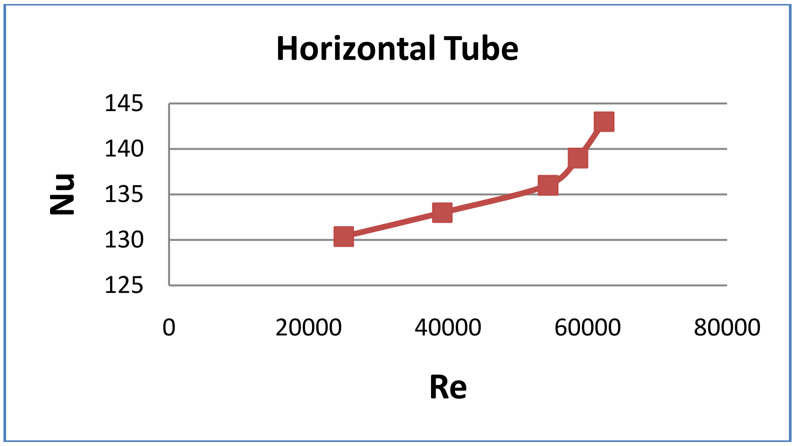

Figure 3: Variation of Reynolds number with Nusselt number when the tube is Horizontal.

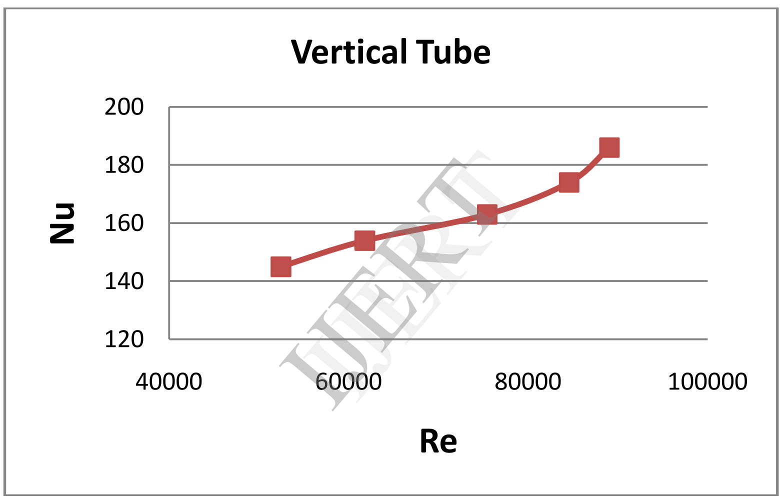

Figure 4: Variation of Reynolds number with Nusselt number when the tube is Vertical.

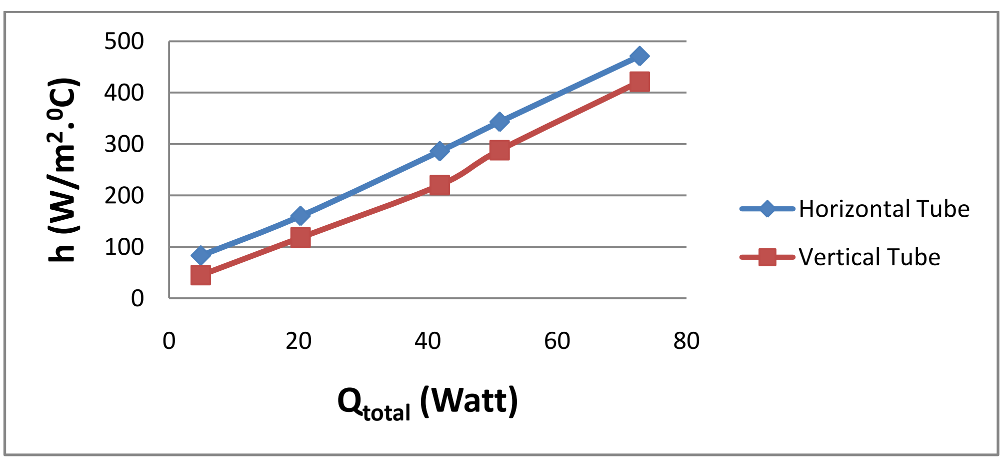

Figure 5: Variation of Heat transfer coefficient with total heat transfer at different Orientation Tube.

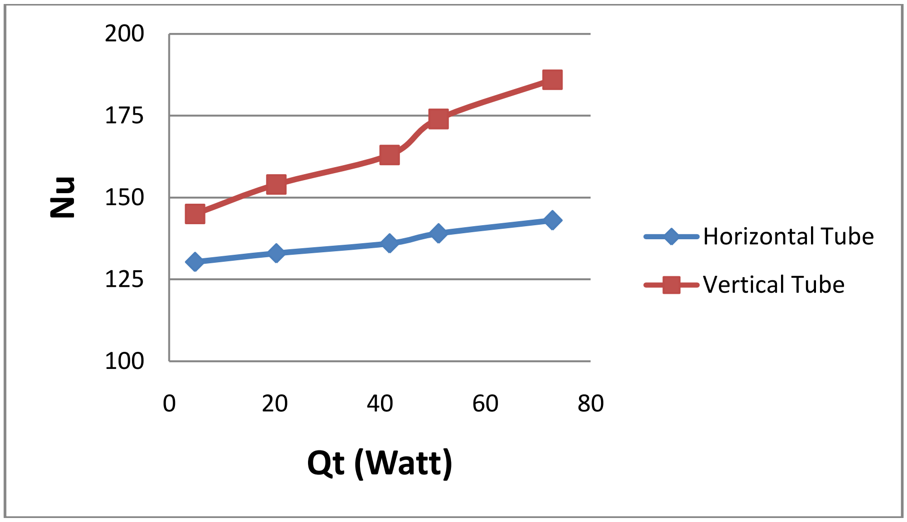

Figure 6: Variation of total heat transfer with Nusselt number at different Orientation Tube.

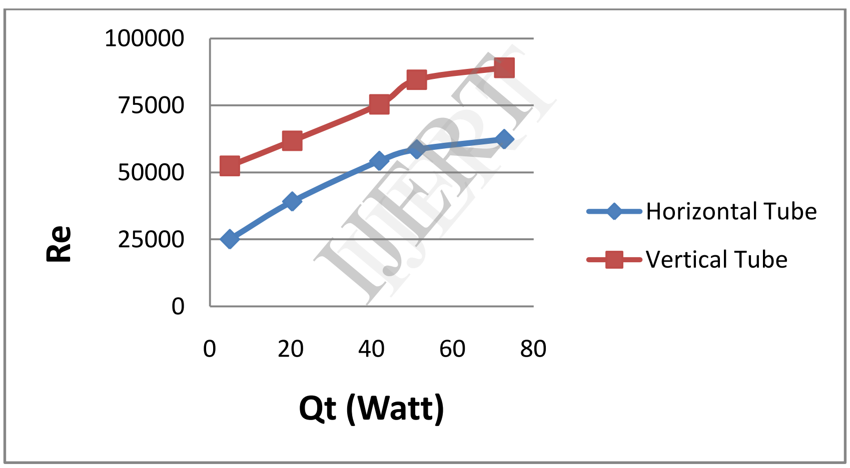

Figure 7: Variation of total heat transfer with Reynolds number at different Orientation Tube.

5. Conclusions

In this work, forced convection heat transfer from horizontal, vertical tubes heated cylinders configuration has been studied and tested in closed duct .The main conclusions which can be drawn from the results of the present work are:-

1. Average heat transfer coefficient increases by increasing the heat transfer of the Heater tube for different orientation.
2. Nusselt number (Nu_D) increases with increasing of Reynolds numbers for the different heat input at close system.
3. The air stream velocity was varied from (28 to 72) m/s to obtain the largest range of the Reynolds numbers given the experimental setup.
4. The experimental results for horizontal tubes are obtained for the range of Reynolds number (2.6×10^4 to 6.4×10^4), Nusselt number (37.75 – 226.98).
5. The experimental results for vertical tubes are obtained for the range of Reynolds number (4×10^4 to 6.9×10^4), Nusselt number (41.45 – 245.56).
6. The effect of Nusselt number (Nu) as the function of the (Re) at the different heat input can be represented by following relation.

$$Nu = C \Pr^n \mathrm{Re}^m$$

Form this test only air is used, so Prandtl number is assumed to be constant due to small change of the ambient temperature. We get these empirical equations

For horizontal Tube is $Nu = 8.283 \mathrm{Re}^{0.017}$

For Vertical Tube is $Nu = 7.806 \mathrm{Re}^{0.178}$

These two equations above shows that as the Reynolds numbers increase the nusselt number also increases.

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6. Acknowledgments

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