EFFECT OF INCLINATION ANGLE ON HEAT TRANSFER FOR DIFFERENT GEOMETRY OF SAME HYDRAULIC DIAMETER IN NATURAL CONVECTION

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Abstract: In this we will compare the geometries (cylindrical & rectangular) for different inclination angle with same hydraulic diameter. Natural convection is a heat transport mechanism in which the fluid motion is by naturally means no external source is required, temperature gradient is occurring due to density difference. Forced convection is a heat transport mechanism in which fluid motion is by an externally. It is one of the most important heat transfer mechanism in which maximum amounts of heat energy can be transferred very efficiently. We compare by calculating average heat transfer coefficient and Nusselt number for both geometries, for inclination angle (i.e. $0°$, $15°$, $30°$, $45°$, $60°$, $75°$, $90°$). It is concluded that average Nusselt number, for angles ($15°$, $30°$, $60°$, $75°$, $90°$) shows maximum heat transfer rate for cylindrical test section and for angle (0^0, 45^0) shows maximum heat transfer rate for square test section and also we found that heat transfer coefficient rate increases with inclination angle in both cases.

IndexTerms - convection, geometry, inclination angle.

I. INTRODUCTION

A number of studies have been presented on natural convection for an enclosure because of the great importance in designing buildings, electronic devices, solar collectors, thermal storage devices, etc. In convection mechanism, two types of convection natural convection and forced convection. Convection is the heat transfer process occur in-between a solid surface and the fluid which is in motion.

Natural convection is a heat transport process, in which the fluid motion is generated by naturally, only due to density differences in the fluid and density differences are occur due to temperature gradients. Forced convection is heat transfer process in which fluid motion occur due to external devices. It is one of the important methods of heat transfer as maximum energy can be transported very easily. Consider a hot object kept in cold air. The temperature of the outside surface will drop as heat transfer with cold air, and temperature of adjacent air the object will increase. And, the object is surrounded with warm layer of air and then heat transfer from this layer to the outer layer the temperature layer adjacent to the hot object is greater, and it lowers the density. So heated air rises upward that process of movement of air is called the natural convection current. And due to absence of this process, heat would be transfer by only conduction and its rate will be much lower.

In gravitational field, a net force which pushes a light fluid which placed heavier fluid upward. This is called the buoyancy force. The magnitude of buoyancy force is the weight of the fluid displaced by the body Cool air. Convective heat transfer is more complicated because it involves fluid motion along with conduction. The fluid motion increases heat transfer rate (as higher the velocity, higher the heat transfer rate). The convective heat transfer coefficient which is denoted by h ,which is totally depend on the fluid properties as well as roughness of the surface of solid, and type of fluid flow which are laminar or turbulent. It is to be assumed that fluid velocity is zero at wall surface called no slip condition. As a result of this, heat transfer from solid surface to fluid layer adjacent to surface by conduction, when the fluid is motionless.

II. LITERATURE REVIEW

Yuichi Funawatashi et. Al [1] studied a natural convection in which heat transfer between concentric parallel pipes for low Rayleigh number Ra (L 3500) with aspect to ratio of inner parallel pipe of 2.0, 4.0, 6.0, and 8.0. In this flow pattern for high Rayleigh number in a space over inner parallel pipe are ring or rectangular role. And as a aspect ratio increases number of role. The flow pattern which is oblong in circulation in side space , which extends towards the bottom space. The local Nusselt number distribution at the top of the surface of the inner parallele pipe has peak at the stagnation points. The the Nusselt and Rayleigh numbers relation at the top surface is similar to that of the Rayleigh–Bernard convection obtained, and on the side and bottom of surface and the Nusselt number increase with Rayleigh number. Yuichi Funawatashi et. Al [2] conducted study on natural Convection in an enclosures, as represented by the Rayleigh–Bénard convection. It has so many applications including solar collectors, heat storage, and cooling of electrical devices.

M. Al-Arab et al [3] investigations available on heat transfer on vertical plate by natural convection. Only a limited number of investigations are, Investigations are, however, available on inclined plates and in only some of them were the investigation extended into the turbulent region. The plates used in most cases were of 'finite width' and the results suffered from the presence of side-edge effects. The present work is the result of experiments carried out to investigate local and average natural convection heat transfer from isothermal, vertical and inclined plate which facing upwards air in both laminar and the turbulent region. Kimura [4] reported on a differentially heated partial sector- shaped enclosure. As a series of our studies to discuss the effects on the enclosure shape on natural convection, a previous paper focused on natural convection in a vertical and inclined semicircular enclosure heated differentially, where flat surface was heated and radial surface was cooled. Yue-Tzu Yang et al [5] The present investigation shows that study of convective heat transfer from a horizontal circular cylinder under the effect of a solid plane wall. The full Navier-Stokes and energy equations for two- dimensional steady flow are solved by finite element method. It present the Variations in surface shear stress, local pressure and Nusselt number along the surface of cylinder as well as predicted average Nusselt number values, also shows the location of separation and some flow and temperature fields are presented. Wei Qi et. al [6]Experimental investigation shows natural convection heat transfer of air which is in layer in vertical annuli are presented. In these

experiment inner cylinder is maintained at a constant heat flux condition and the outer is cooled in the atmosphere. so to obtain the convective contribution, the overall heat transfer data are corrected for thermal radiation and axial conduction losses from the end plates in the annuli.

III. EXPERIMENTAL SETUP

Experimental setup consist of two test section, one is hollow cylindrical (with dimension, diameter 50mm, thickness 4mm and length 500mm.) and another hollow square with dimension (50 50 500mm) with thickness 4 mm. Material used for both test section are aluminium 19000 with thermal conductivity 210 W/mK, nichrome heater of 1 kW capacity is used for heating the test section, which is placed inside the test section. For cylindrical test section round shaped heater used and for square test section square heater is used. For temperature measurement, k type thermocouples are used. Thermocouples are connected by tapping it on outer surface of both geometries. Both test section attached to MS plate shown in fig. 1. Its one end is fixed and another is hinged. They are moving 0 to 90^0. The control panel placed on MS plate and it consists of Ammeter, voltmeter, dimmer stat and two temperature indicators. The heat supplied to heater is measured by Ammeter and voltmeter and it is varied by dimmer stat. Temperature at different sections on test section is indicateed on temperature indicator.
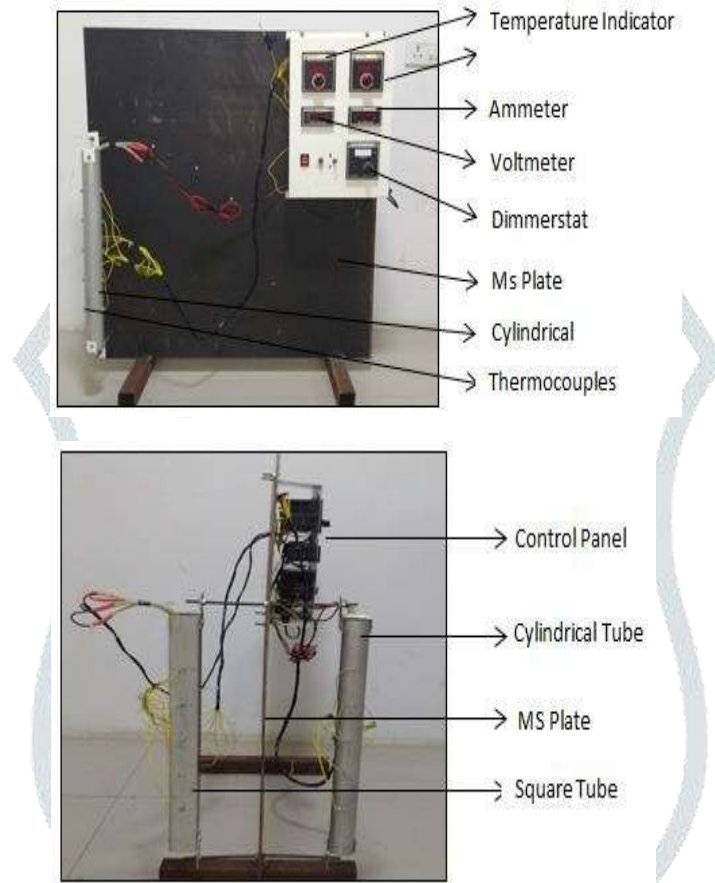

Fig.1. Experimental Setup (Front View)

Fig.2. Experimental Setup (Side View)

IV. RESULT AND DISCUSSION

Validation of experimental setup
For Cylindrical Test Section

In the beginning, results of the present cylindrical rod are validated with those obtained from the standard empirical correlation of Adam, Churchill and other two for heat transfer coefficient given below,

i.   Empirical correlation of Churchill:

$$N_u = 0.68 + \frac{0.67 R_a^{1/4}}{[1+(\frac{0.492}{P_r})^{9/16}]^{4/9}}$$

ii.   Empirical correlation of Adam

$$N_{u=0.59 \times R_a^{1/4}}$$

iii.   Empirical correlation

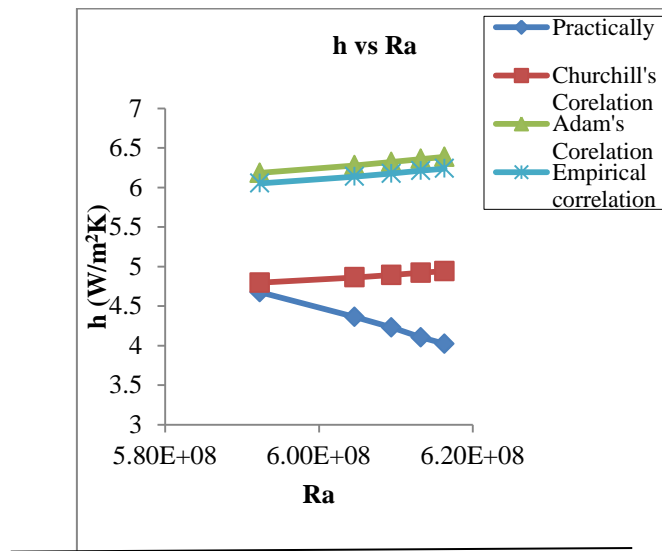$$N_{u=0.655 \times R_a^{0.25}}$$

Fig.3. Validation of Circular Test Section

The comparison of Nusselt number and coefficient of heat transfer for present cylindrical test section with existing correlation shown in fig.3. In this figure shows that validation experiment for heat transfers in terms of Nusselt number and heat transfer coefficient for cylindrical rod are in good arrangement with result obtained from all empirical correlation. It is found that the Nusselt number in the present cylindrical test section agree with those achieved from all empirical correlation within ± 10.470 shown in fig.

For Square Test Section

In the beginning, results of the present square rod are validated with those obtained from the standard empirical correlation of Adam, Churchill and other two for heat transfer coefficient given below
Nusselt number correlation:

      i.   Empirical correlation of Churchill and chu.

$$N_u = 0.68 + \frac{0.67 R_a^{1/4}}{[1+(\frac{0.492}{P_r})^{9/16}]^{4/9}}$$

      ii.   Empirical correlation of Adam

$$N_{u=0.59 \times R_a^{1/4}}$$

     iii. Empirical correlation
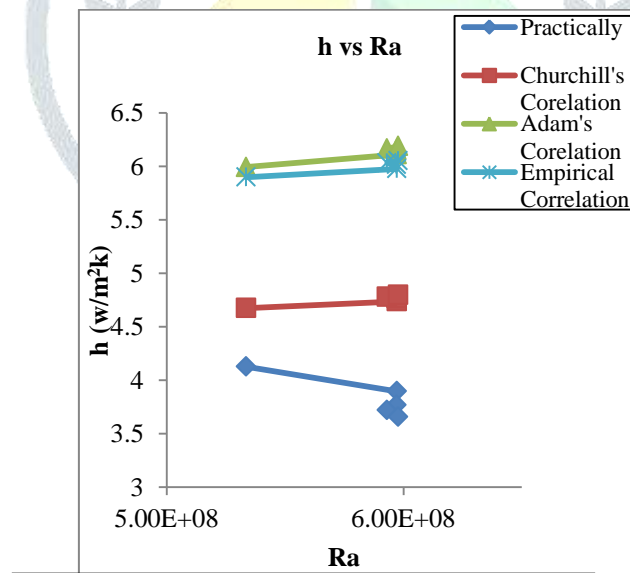
$$N_{u=0.655 \times R_a^{0.25}}$$

Fig.4. Validation of Circular Test Section

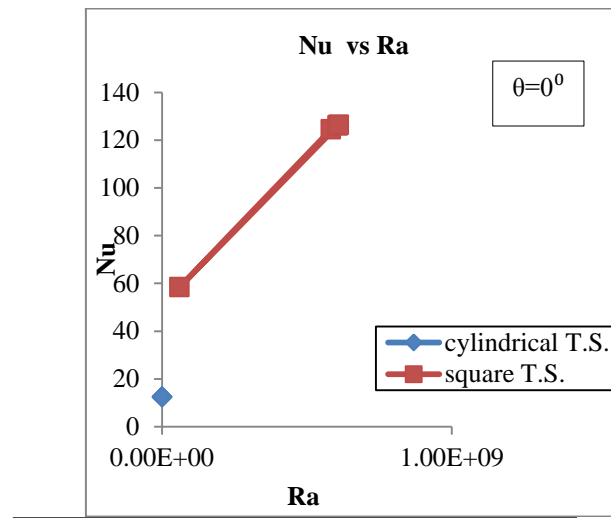*Effect of geometries on Average Nusselt number for different inclination angle:*

Fig.5. Effect of inclination angle ($\theta=0^0$)

The above fig.5 shows average Nu vs. Ra at $\theta=0^0$, in this case heat transfer rate in square test section is more than cylinderical test section.
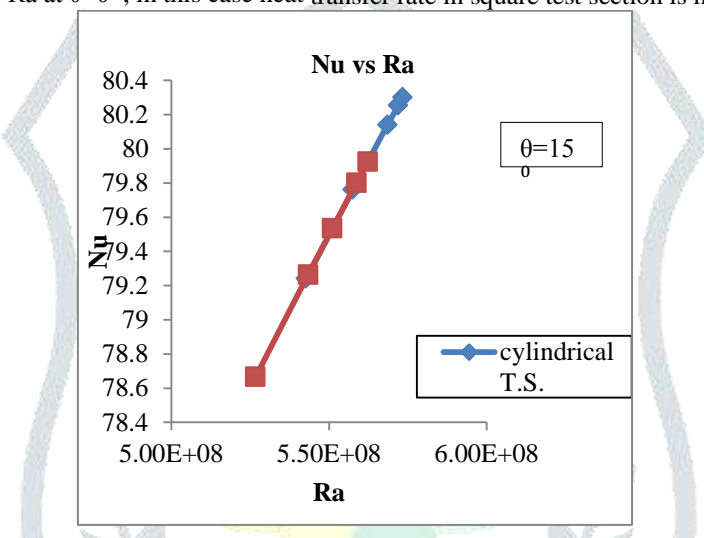

Fig.6. Effect of inclination angle ($\theta=15^0$)

The above fig.6 shows average Nu vs Ra at $\theta=15^0$, in this case heat transfer rate in cylindrical test section is more than square test section.
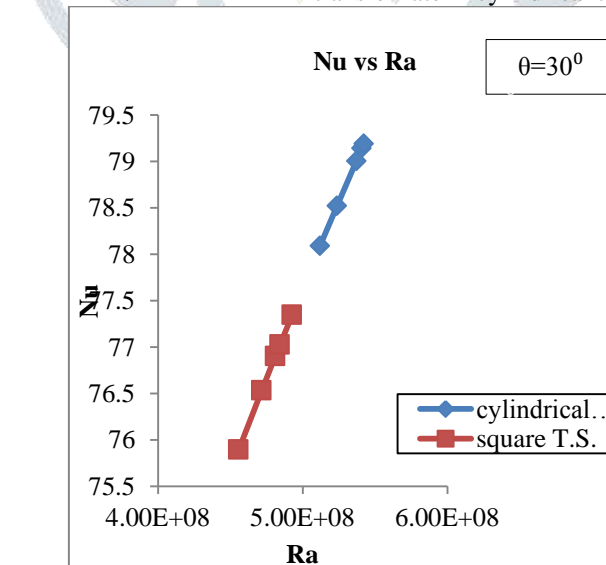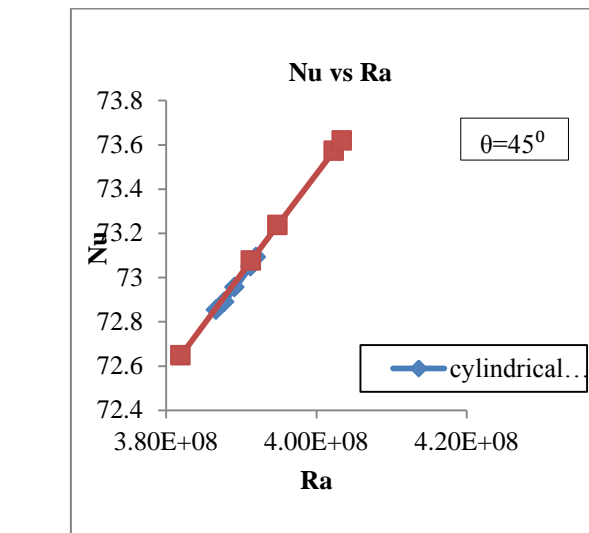

Fig.7. Effect of inclination angle ($\theta=30^0$)

The above fig.7 shows average Nu vs. Ra at $\theta=30^0$, in this case heat transfer rate in cylindrical test section is more than square test section.

Fig.8. Effect of inclination angle ($\theta=45^0$)

The above fig.8 shows average Nu vs. Ra at $\theta=45^0$, in this case heat transfer rate in square test section is more than cylindrical test section.
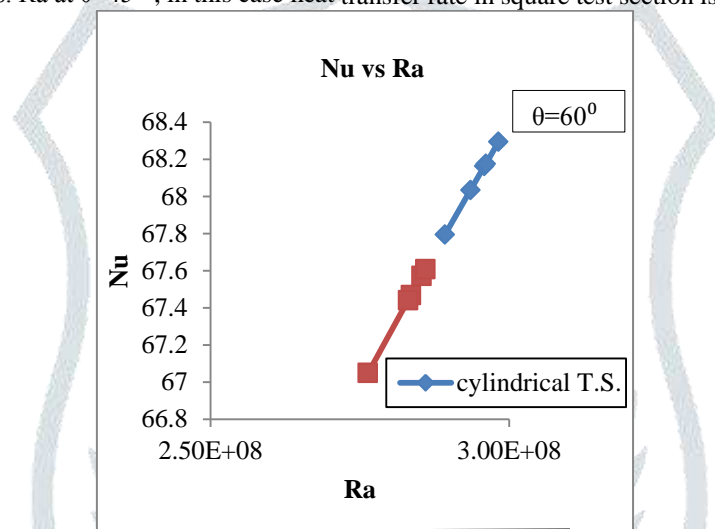

Fig.9. Effect of inclination angle ($\theta=60^0$)

The above fig.9 shows average Nu vs. Ra at $\theta=60^0$, in this case heat transfer rate in cylindrical test section is more than square test section.
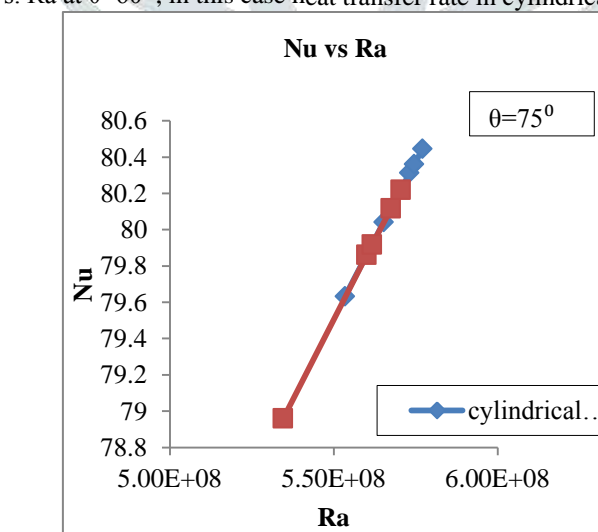

Fig.10. Effect of inclination angle ($\theta=75^0$)

The above fig.10 shows average Nu_1 vs. Ra_1 at $\theta=75^0$, in this case heat transfer rate in cylindrical test section is more than square test section.
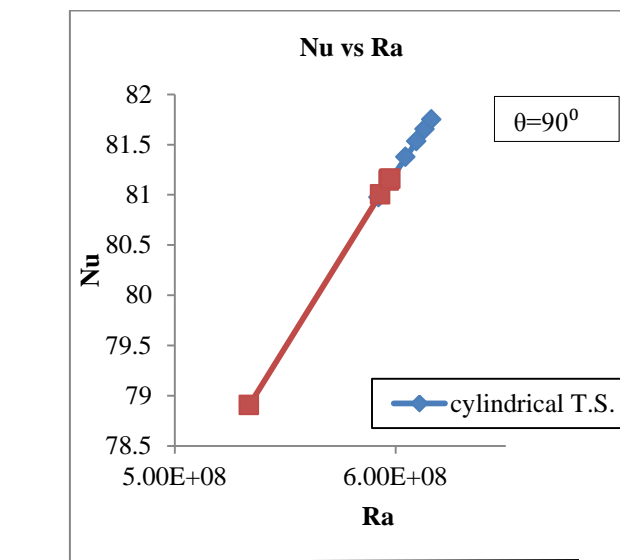
Fig.10. Effect of inclination angle ($\theta=90^0$)

The above fig. 10 shows average Nu vs. Ra at $\theta=90^0$, in this case heat transfer rate in cylindrical test section is more than square test section.

V. CONCLUSION

1. It is good agreement of results of heat transfer coefficient with empirical correlation for both cylindrical as well as square rest section.
2. Nusselt number, for angles 15^0, 30^0, 60^0, 75^0, 90^0 have maximum heat transfer rate for cylindrical test section and for angles 0^0 and 45^0, maximum heat transfer rate for square test section.
3. As the inclination angle increases also increase the heat transfer rate.

REFERENCES

[1] Yuichi Funawatashi and Tateyuki Suzuki, "Natural Convection Heat Transfer between Horizontal Concentric Rectangular Pipes", Heat Transfer-Japanese Research, 1998, 27 (4).
[2] Yuichi Funawatashi And Tateyuki Suzuki, "Natural Convection Heat Transfer Between Concentric Rectangular Parallelepiped", Heat Transfer-Asian Research, 2001, 30 (2).
[3] M. Al-Arabi and M. K. El-Riedyt, "Natural Convection Heat Transfer from Isothermal Horizontal Plates of Different Shapes", Int. Journal heat Transfer, 1976, Vol. 19, pp. 1399-1404.
[4] Teruo Kimura, Masanori Takeuchi, Niroh Nagai, and Makoto Hirano, "Natural Convection Heat Transfer in a Circular Enclosure", Heat Transfer-Asian Research, 1999, 28 (2).
[5] Yue-Tzu Yang, Cha'o-Kuang Chen and Chi-Fang Chiu, "Convective Heat Transfer from A Circular Cylinder under the Effect of A Solid Plane Wall", International Journal for Numerical Methods in Fluids, 1996, Vol. 23, 163-1 76.
[6] Wei Qi, Yang Shiming, "Experimental Study of Natural Convection Heat Transfer of Air Layers in Vertical Annuli under High Rayleigh Number Conditions," Heat Transfer—Asian Research, 1999, 28 (1).
[7] Shigeyuki Sasaki And Noriyuki Ashiwake, "Enhancement of Natural Convection Heat Transfer from an Inclined Heated Plate Using Rectangular Grids", Heat Transfer-Asian Research, 2002, 31 (5).
[8] Katsuo Komori, Shunsuke Kito, Terumi Inagaki, Norio Mizoguchi, "Natural Convection Heat Transfer Along a Vertical Flat Plate with a Projection in the Turbulent Region", Heat Transfer-Asian Research, 2001, 30 (3).
[9] Yusuke Sakai, Hisanobu Kawashima, Shigeaki Inada, "Suppression of Natural Convection Heat Transfer Along a Vertical Flat Plate with Concavities", Heat Transfer-Asian Research, 39 (5), 2010.
[10] Koki Takahashi, Takuya Morikawa, Yutaka Harada, Naozo Hattori, "Natural Convective Heat Transfer in Uniformly Heated Vertical Pipe Annuli", Heat Transfer-Asian Research, 2001, 30 (8).