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A ANALYSIS OF HEAT TRANSFER ENHANCEMENT IN PULSATING TURBULENT FLOW IN A PIPE

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ABSTRACT

Enhancement of heat transfer in a tube is a remarkable engineering achievement as it has the potential to reduce power consumptions of industrial heat exchangers significantly. Consequently, the power demand of industry would be reduced; lowering the need for excessive amounts of power and decreasing harmful emissions to the environment by power generators The enhancement and determination of pipe wall convective heat transfer characteristics has likely been one of the most interesting engineering aspects of heat transfer research. Different methods to enhance the heat transfer coefficient were developed. Thinking of such notion, one such technique that has been widely used in industry is the use of flow pulsation in the tube. Pulsating flows can be produced by reciprocating pump or by steady flow pump together with some mechanical pulsating devices. It may normally be expected that the heat transfer to or from the flow would be changed since the pulsation would alter the thickness of the boundary layer and hence the thermal resistance. In this paper effect of pulsation on heat transfer is studied and it is find out that pulsation does have positive influence on the heat transfer.

KEYWORDS: Heat transfer enhancement, pulsation, Turbulent flow, Pipe flow

INTRODUCTION

Heat exchangers are used in different processes ranging from conversion, utilization & recovery of thermal energy in various industrial, commercial & domestic applications. Some common examples include steam generation & condensation in power & cogeneration plants; sensible heating & cooling in thermal processing of chemical, pharmaceutical & agricultural products; fluid heating in manufacturing & waste heat recovery etc. Increase in Heat exchanger's performance can lead to more economical design of heat exchanger which can help to make energy, material & cost savings related to a heat exchange process. When pulsations are imposed on a flowing fluid it may normally be expected that heat transfer to or from it would be changed because the pulsation would alter the thickness of the boundary layer and hence the thermal resistance. In laminar region, this view is also supported by the fact that the velocity profile for pulsating flow is steeper near the wall than for steady flow. It follows from consideration of the Reynolds analogy that the heat transfer should increase under such conditions. A similar process might occur for turbulent flow. As the flow becomes turbulent at high Reynolds numbers, the influence of turbulence becomes significant.

RELEVANCE

The pulsating flow includes the steady and time-dependent velocity component. Typical and natural examples of pulsating flows are the arterial flows in the human body. Pulsating flow and heat transfer occur in many industrial applications, such as pulse combustor, pulse tube cry-cooler, cooling system of nuclear reactor, pulse-jet and compressors, electronic cooling, metallurgy, aviation, chemical, food technology and so on.

The pulsating flow parameters affect the performance of many thermal engineering applications. When pulsations are applied to the flow, then a change in heat transfer to or from it can be expected, because the pulsation would change the thickness of the boundary layer and thus the thermal resistance. From this perspective, an increase in the heat transfer due to the decreasing of the boundary layer thickness is expected. Therefore, recently, great interest is being evinced in studying the effects of pulsating flow on convective heat transfer.

EXPERIMENTAL INVESTIGATION

In order to achieve the stated objectives the experimental set up is designed which investigate the effect of pulsation on the convective heat transfer characteristics in pulsating turbulent flow in pipe. It is an open loop in which air as a working fluid is pumped and passed the test section to the atmosphere after being heated. The rig basically consists of three part; the air supply unit with necessary adoption and measuring devices, the test section and the pulsating mechanism. The air supply unit and its accessories consist of blower, flow control valves, orifice meter. The proposed pulsating mechanism consists of slotted disc connected to the motor which is further connected to the main supply through dimmer so that we can change the pulsation frequency. The whole mechanism is kept in front of the pipe outlet which repetitively opens and closes s the flow through slotted disc and thus imparts pulsation to the air.

Specifications of experimental set up:-

- **Test section :-** 25 mm (ID) Copper Tube, 400 mm length.
- **Centrifugal blower :-** 1.6 HP, 500 CFM, 50 mm WC
- **Band type heater :-** 500 W, Single Phase.
- **Orifice plate :-** 16 mm diameter
- **Pulsating mechanism :-** Slotted rotary disc

RESULTS AND DISCUSSIONS

Calculation of Mean Thermal Characteristics for upstream flow

Comparison between Experimental and Theoretical Heat transfer coefficient with and without Pulsation

Graphs showed that the value of heat transfer coefficient calculated by experimental and theoretical method is similar. From this graphs it is proved that experimental setup is validated.

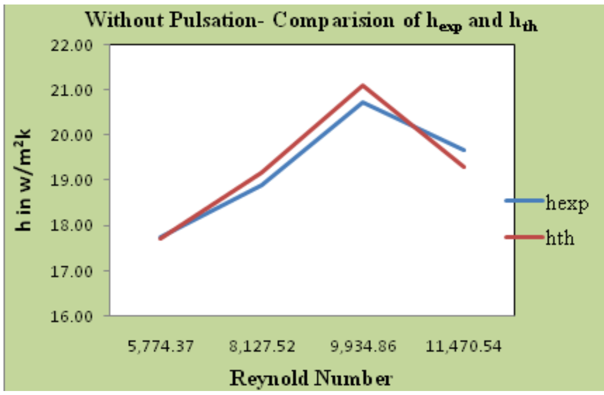

Figure 1 Comparison of heat transfer coefficient calculated experimentally and theoretically

Fig. 1 shows that the value of mean heat transfer coefficient either increased or decreased with increasing the value of Reynolds number.

Comparison between Experimental and Theoretical Nusselt Number with and without Pulsation

Fig. 2 shows that the values of mean Nusselt number are similar to each other without pulsation with increasing the value of Reynolds number.

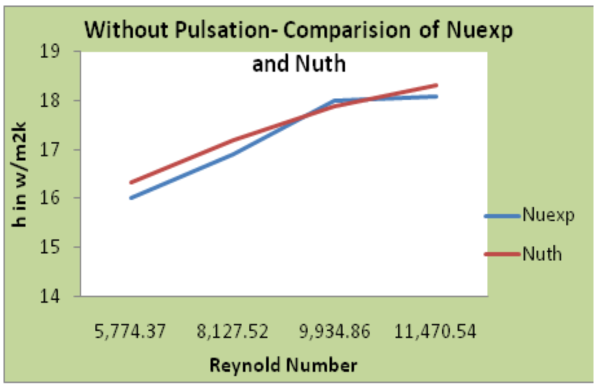

Figure 2 Comparison of Nusselt Number calculated experimentally and theoretically without Pulsation

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Comparison between Experimental and Theoretical Heat Transfer coefficient at Pulsation frequency is 3.33

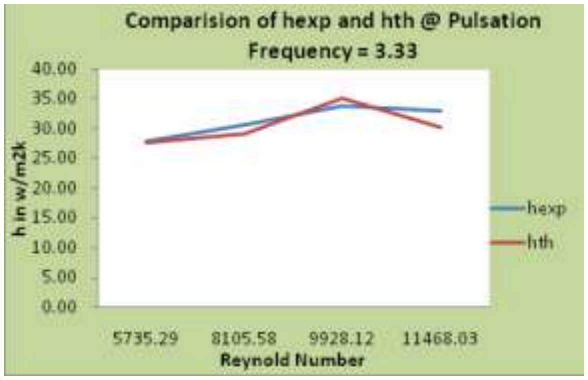

Figure 3 Comparison of Heat Transfer Coefficient experimental and theoretical when (f= 3.33 Hz)

Fig. 3 shows that the value of mean heat transfer coefficient calculated by experimentally and theoretically either increased or decreased with increasing the value of Reynolds number.

Comparison between Experimental and Theoretical Nusselt Number at Pulsation frequency is 3.33

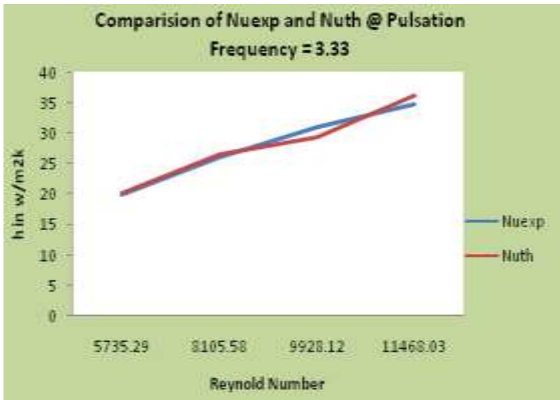

Figure 4 Comparison of Nusselt Number when frequency is 3.33 calculated experimentally and theoretically

Fig. 4 shows that the values of mean Nusselt number are similar to each other when pulsation frequency is 3.33 Hz with increasing the value of Reynolds number.

Variations in Heat Transfer Coefficient with Reynold Number at diff pulsation Frequencies

For increment in pulsation frequency, it can be seen from Fig. 14 that enhancement is found in mean heat transfer coefficient in comparison of with and without pulsation.

Fig. 5 shows that the values of mean heat transfer coefficient are either increases or decreases with increasing both the value of Reynolds number and pulsation frequencies.

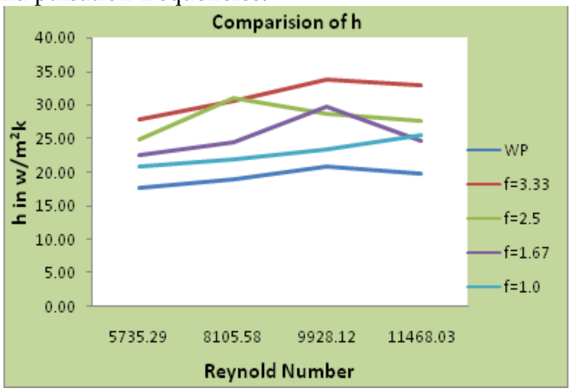

Figure 5 Variations in Heat Transfer Coefficient with Reynolds Number at various pulsation Frequencies

Variations in Nusselt Number with Reynolds Number at diff pulsation Frequencies
For increment in pulsation frequency, it can be seen from Fig. 6 that enhancement is found in mean Nusselt Number in comparison of with and without pulsation.
Fig. 15 shows that the values of mean Nusselt number are either increases or decreases with increasing both the value of Reynolds number and pulsation frequencies.

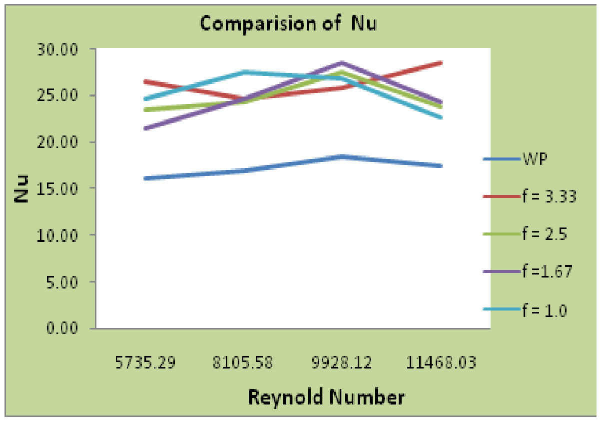

Figure 6 Variations in Nusselt Number with Reynolds Number at various pulsation Frequencies

Calculation of Local Thermal Characteristics for upstream flow
When Tube length is 50mm
Variations in Heat Transfer Coefficient with Reynold Number at diff pulsation Frequencies when L=50mm

For increment in pulsation frequency, it can be seen from Fig. 16 that enhancement is found in mean heat transfer coefficient in comparison of with and without pulsation when tube length is considered is 50mm. Fig. 7 shows that the values of mean heat transfer coefficient are either increases or decreases with increasing both the value of Reynolds number and pulsation frequencies.

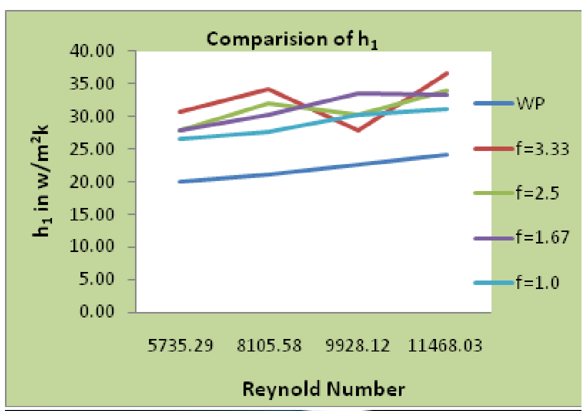

Figure 7 Variations in Heat Transfer Coefficient with Reynold Number at various pulsation Frequencies when tube length is 50mm

Variations in Nusselt Number with Reynolds Number at diff pulsation Frequencies when L=50mm
For increment in pulsation frequency, it can be seen from Fig. 8 that enhancement is found in mean Nusselt Number in comparison of with and without pulsation.
Fig. 8 shows that the values of mean Nusselt number are either increases or decreases with increasing both the value of Reynolds number and pulsation frequencies.

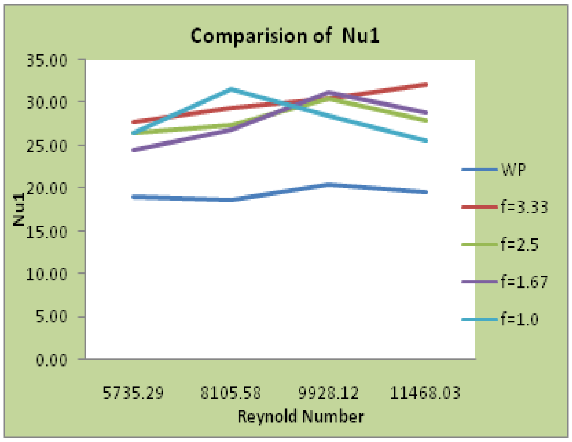

Figure 8 Variations in Nusselt number with Reynolds Number at various pulsation Frequencies when Tube length is 50mm

CONCLUSIONS

The experimental investigation was carried out on two types of pulsating flow upstream and Downstream. The effect of pulsation frequency and mass flow rate of air on heat transfer coefficient and Nusselt number of upstream and downstream air is experimentally investigated. The heat input to band air heater is kept constant 80 W and cold air stream flow rate varied in such way that its orifice manometer shows difference of water column 10 mm to 40 mm. The findings of this work are: The values of mean heat transfer coefficient are increases if pulsation is generated in air flow. It can be concluded that pulsation does have a positive effect of heat transfer enhancement. The value of local Heat transfer coefficient either increased or decreased with increasing the value of Reynolds number and pulsation frequency. The values of mean Nusselt number are increases if pulsation is created in flow of air.

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