Review of Heat Transfer in a Pulsating Turbulent

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Abstract- There are many engineering practical situations where heat is being transferred under conditions of pulsating and reciprocating flows such as the operation of modern power producing facilities and industrial equipment used in metallurgy, aviation, chemical and food technology. The performance of this equipment in thermal engineering applications is affected by the pulsating flow parameters. The objective of the present work is to evaluate experimentally the heat transfer characteristics of pulsatile turbulent flow in a pipe. The effect of pulsation frequency, location of pulsation mechanism on the heat transfer characteristics in pulsatile flow has been evaluated. At the same time pulsating flow visualization with smoke generation has been done. The effect of flow pulsation on average and local heat transfer coefficient has been experimentally evaluated. The result shows that, the values of mean heat transfer coefficient are increases if pulsation is created in flow of air but the local heat transfer coefficient either increased or decreased with increasing the value of pulsation frequency. The values of mean Nusselt number are increases if pulsation is created in flow but local Nusselt number either increases or decreases with increasing the pulsation frequency. The effective way of increasing the average heat transfer coefficient is by locating the pulsation mechanism at the downstream. The maximum enhancement occurred in average Nusselt number is 38 % at pulsation frequency of 3.33 Hz as compared with plain tube.
Keywords: Heat transfer enhancement, pulsation, Turbulent flow, Pipe flow.

I. INTRODUCTION

Conventionally, uniform fluid flow system is used in many fluid flow and heat transfer systems in conventional size as well as micro channel systems. Thus, many studies do exist in literature that deals with such systems which helped to understand the thermo hydrodynamics of single phase as well as two-phase systems. Additionally, two more types of fluid flow that find application in many engineering systems (a) oscillating flow (or oscillatory flow), and (b) pulsating flow (or pulsatile flow). When there is no net mean velocity of the fluid in any direction and it is only oscillating back and forth about a fixed point with a superimposed frequency only then the flow is called oscillating flow. Where in case of pulsating flow, an oscillating velocity is superimposed with the one directional translational velocity. Therefore in pulsating flow time-average velocity is non-zero whereas in oscillating flow time-average velocity is zero over any particular period of cycle at any instant. This type of flow mainly characterized by two parameters namely (i) frequency of oscillation, f (or Womersley number, Wo), and (ii) amplitude of oscillation (A). Because of rapid motion, convective heat transfer may increase in such cases.

The effect of pulsations on heat transfer is an interesting problem for researchers due to its wide occurrences in many real time situations at macro as well as mini/micro level. 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. Pulsating flow which is defined as flow with periodic fluctuations of the bulk mass flow rate may have the same influence on enhancing the heat transfer coefficients.

II. LITERATURE SURVEY

Karamercan and Gaine [2021] experimentally investigated the effect of pulsation in a double-pipe heat exchanger and considered parameters of interest as Reynolds number, displacement amplitude, and pulsation frequency. Experiment was conducted by changing the displacement amplitude by five different values where for every flow rate the frequency of flow pulsation varied up to 300 cycles/minute. They concluded that heat transfer coefficient was increasing with pulsations, leading to higher heat transfer and the maximum enhancement was reported in the transition flow regime.

Mackley et al. [2020] carried out experiment in the double tube heat exchanger by inserting baffles in the heat exchanger. Lubricating at temperature of 60oC was passed on the tube side of heat exchanger which was subsequently cooled whereas shell side of the heat exchanger maintained at constant temperature by providing tap water at 11oC. Pulsating mechanism provided by the help of rotary motor which was driven by cam. Temperature at different locations at different time intervals in heat exchanger was recorded by thermocouples. By changing the rotary speed oscillatory parameters was changed.

Mackley et al. [2018] concluded that Nusselt number increases with a very reasonable manner as compared to the system where pulsation in the flow and baffles are not available.

Cho and Hyun [2015] numerically studied thermo-hydrodynamics of pulsating flow in a pipe. They numerically solved unsteady laminar boundary-layer equation for wide ranges of frequency and the amplitude of oscillation. From the solution it was concluded that, Nusselt number may increase/decrease, depending on pulsating frequency but deviation of Nusselt number is very less from the steady flow.

Kim et al. [2015] numerically studied hydro dynamically developed, thermally developing fluid flow in a channel with isothermal wall. Simulation was performed at Re = 50, Pr = 0.7, where the pulsation amplitude (A) and nondimensional pulsation frequency (M) taken in a wide range. From the simulation it is confirmed that when M was low, no deviation found in steady and unsteady velocity profiles. But for larger value of M, the effects of pulsation confined to a very limited area nearer to the walls. And at the same moment, for small and moderate pulsation frequency the effect of pulsation on Nusselt number noticeable but at higher frequency the effect is negligible. The effect of pulsation on Nusselt number mainly observed in the entrance region, whereas the fully developed downstream location effect is less. Also, pressure gradient increases with frequency and at very high frequencies, flow reversal takes place for some part of pulsating phase.

Guo and Sung [2014] had tested different versions of Nusselt number to clarify the conflicting results and purposed an improved version of Nusselt number which was closely matches with measurement. They found that for lower range of amplitudes, heat transfer may enhanced or reduced within a certain band of operating frequency but at higher amplitudes, heat transfer was always augmented irrespective of frequency.

Moschandreou and Zamir [2013] analytically studied heat transfer characteristics in a tube subjected to constant heat flux boundary condition and observed that flow pulsation enhance the heat transfer corresponding to moderate values of frequency ranging from 5-25. The augmentations were more frequently observed at higher Prandtl number.

III. DISCUSSION

The performances of equipment are mostly affected by the pulsating flow parameters subjected to thermal engineering applications. The convection heat transfer rate is highly dependent on the flow pulsation. The effect of pulsating flow on heat transfer is an interesting as well as challenging problem for researchers considering that this type of fluid flow occurs in natural as well as and in many engineering applications ranging from conventional to mini/micro size channels. A detail literature review regarding pulsatile flow and its effect on heat transfer is presented in next chapter. Though many studies on the effect of pulsation on heat transfer do exist in literature, they provide contradictory results. Secondly, no studies do exist in open literature that deals with study of conjugate heat transfer in pulsating flow microchannel systems. Motivation for the present work starts from the review in order to fill the gap in the literature. Hence by considering such huge application of pulsatile flow in the engineering field and gap in the literature, a dedicated study must be needed to understand the thermo-hydrodynamics of pulsating flow in order to increase the efficiency and for better thermal design of such systems.

With developments in micro-manufacturing technology, many applications of fluid flow and heat transfer in mini/microchannels has emerged. Typical applications include cooling of miniaturized devices, Bio-fluidic systems etc. to name a few. Micro heat exchangers play a vital role in the thermal management of many engineering devices. Axial wall conduction play crucial role in thermal performance of micro heat exchangers. Axial wall conduction is not a new concept and is not confined to microchannels only. Axial wall conduction also exists in conventional channels but in most cases its magnitude is negligible, due to the smaller wall thickness as compared to inner radius. Therefore, the whole attention is focused on recent studies in this field.

IV. CONCLUSIONS

The pulsation mechanism is designed by using variation in pulsation motor speed. Conclusions from studied experiment are as follows,

a) Higher values of the local heat transfer coefficient occurred in the entrance of the tested tube. The variation is more pronounced in the entrance region than that in the downstream fully developed region.

b) Value of heat transfer coefficient calculated by

experimental and theoretical method is similar. From this experimental setup is validated.
c) The values of mean heat transfer coefficient are increases if pulsation is created in flow of air.
d) The value of local Heat transfer coefficient either increased or decreased with increasing the value of Reynolds number and pulsation frequency.
e) The values of mean Nusselt number are increases if pulsation is created in flow of air.
f) The value of local Nusselt number either increased or decreased with increasing the value of Reynolds number and pulsation frequency.

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