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A Review on Heat Transfer Enhancement Due to Air Bubble Injection into a Double Pipe Heat Exchanger

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***Abstract*- In recent years, researchers have tried to reduce the size and weight of heat exchangers without reduction of heat transfer rate. Numerous methods have been presented to increase the heat transfer rate and performance of heat exchangers in the past decades. Air bubble injection is one such technique but passive one to enhance the heat transfer rate. Air bubbles are induced to any flowing fluid channels to maximize the heat transfer characteristics of the fluid. As per the different studies, the bubble dynamics creates much impact on the wall skin friction drag. Injecting bubbles in the flowing fluid reduces the density of the liquid that leads to the generation of baroclinic vorticity on larger scale.**

In present work attempts are made to enhance the heat transfer rate in double pipe heat exchangers by injecting air bubbles. For this a double pipe heat exchanger were used in which a tube is inserted with 12 no. of holes by which air bubbles are injected. Modelling is done using ANSYS.

Index terms- Heat exchanger, double pipe, Air bubble injection, Heat transfer, ANSYS 14.5, Overall heat transfer coefficient, Nusselt number.

1. INTRODUCTION

Heat exchangers are widely used in industries, and the improvement of their performances will raise the efficiency of energy utilization, and minimize the equipment. With the rapid growth of energy consumption in recent decades, improvement of heat exchanger becomes more important for energy conservation. Generally, to upgrade the thermal performance of heat exchangers, increasing the heat transfer coefficient is largely based on, and it is referred to as the technologies of the enhanced heat transfer.

1.1 Heat Exchanger

Heat exchangers are devices designed to transfer heat between two or more fluids i.e., liquids, vapours, or gases of different temperatures. Depending on the type of heat exchanger employed, the heat transferring process can be gas-to-gas, liquid-to-gas, or liquid-to-liquid and occur through a solid separator, which prevents mixing of the fluids, or direct fluid contact. These devices can be classified and categorized in several different ways based on their design characteristics. The main characteristics by which heat exchangers can be categorized include:

- Flow configuration
- Construction method
- Heat transfer mechanism

1.1.1 Flow Configuration

The flow configuration, also referred to as the flow arrangement, of a heat exchanger refers to the direction of movement of the fluids within the heat exchanger in relation to each other. There are four principal flow configurations employed by heat exchangers:

- Cocurrent flow
- Counter current flow
- Crossflow
- Hybrid flow

1.2 Heat Transfer Enhancement

As a result of the global energy crisis, which is one of the most crucial problems due to the large and continuous increase in the consumption and the increment shortage of energy resources as well as the high cost, many researchers have performed to increase the efficiency of thermal systems and reduction of the size and thus energy consumption rates.

Heat transfer enhancement is a process of increasing the heat transfer rate and thermohydraulic performance of a system using various methods. The methods of heat transfer enhancement are employed for developing the heat transfer without affecting the overall realization of the systems significantly, and it covers a wide range of areas where heat exchangers are used for such functions as air-conditioning, refrigeration, central heating systems, cooling automotive components, and many uses in the chemical industry.

Heat transfer enhancement techniques generally reduce the thermal resistance either by increasing the effective heat transfer surface area or by generating turbulence. Heat transfer enhancement techniques are classified as the - Passive Methods, Active Methods, and Compound Methods.

Active methods require external power to input the process; in contrast, passive methods do not require any additional energy to improve the thermohydraulic performance of the system. Also, two or more passive and active techniques can be used together and that is called compound technique, which is employed to produce a higher augmentation than using one passive or active technique independently

Passive techniques

In the passive techniques, any external power is not required; rather, geometry or surface of the flow channel is modified to increase the thermohydraulic performance of the systems. The inserts, ribs, and rough surfaces are utilized to promote fluid mixing and the turbulence in the flow, which results in an increment of the overall heat transfer rate. Passive techniques have also some advantages in relation to the other heat transfer enhancement techniques such as low cost, easy production, and installation.

Active techniques

Active techniques are more complex than the passive techniques in the expression of design and application because of the necessity of external energy to adjust the flow of fluid so as to obtain an improvement in thermal efficiency. Providing external energy in most applications is not easy; for this reason, the use of active techniques in scientific fields is limited.

Compound techniques

A compound technique consists of the combination of more than one heat transfer enhancement method (active and/or passive) to increase the thermohydraulic performance of heat exchangers. It can be employed simultaneously to generate an augmentation that promotes the performance of the system either of the techniques operating independently. Preliminary studies on compound passive augmentation technique of this kind are quite encouraging.

Nowadays, a significant number of thermal engineering researchers are seeking for new enhancing heat transfer methods between surfaces and the surrounding fluid. To the best knowledge of the authors, the mechanisms of heat transfer enhancement can be at least one of the following.

1. Use of a secondary heat transfer surface.
2. Disruption of the unenhanced fluid velocity.
3. Disruption of the laminar sublayer in the turbulent boundary layer.
4. Introducing secondary flows.
5. Promoting boundary-layer separation
6. Promoting flow attachment/reattachment.
7. Enhancing effective thermal conductivity of the fluid under static conditions.
8. Enhancing effective thermal conductivity of the fluid under dynamic conditions.
9. Delaying the boundary layer development.
10. Thermal dispersion.
11. Increasing the order of the fluid molecules.
12. Redistribution of the flow.
13. Modification of radiative property of the convective medium.
14. Increasing the difference between the surface and fluid temperatures.
15. Increasing fluid flow rate passively.
16. Increasing the thermal conductivity of the solid phase using special nanotechnology fabrications.

2. LITERATURE REVIEW

In the past decade, several studies on passive and active techniques of heat transfer augmentation have been reported. Literature review on active and passive techniques of heat transfer augmentation is given in the following sections.

D.Han et al. (2017) studied heat transfer enhancement using nanofluid in double tube heat exchanger. Study aims at experimentally investigating the effect of Al2O3 /water nanofluids on the heat transfer enhancement inside the double tube heat exchanger at variable inlet temperature. Al2O3 nanoparticle with concentration of 0.25% and 0.5% by volume concentration has been used at different inlet temperature. The experimental setup consisted of double tube heat exchanger with nanofluids on the cold side was used in turbulent regime with Reynolds number ranging from 20000 to 60000. Results from the study shows that the heat transfer increases with the increase in temperature and volume concentration of nano-particles. Significant improvement over the water is seen with maximum Nusselt number increase up to 24.5% at 50℃ inlet temperature.

Khorasani et al. (2017) studied experimentally the effects of air bubble injection on the performance of a horizontal helical shell and coiled tube heat exchanger. The variations of number of thermal units (NTU), exergy loss and effectiveness due to the air bubbles injection with different air flow rates are evaluated. A new procedure for injecting the air bubbles into the shell side flow of the heat exchanger is proposed. The results exhibited a significant increase in the effectiveness and NTU of the heat exchanger as the air bubbles were injected. It is suggested that the disturbance and perhaps the turbulence intensity of the shell side flow are increased due to the motion of air bubbles resulting in an increment in the value of NTU and exergy loss. In addition, the mixing effect of the bubbles and the interaction with the thermal boundary layer can increase the velocity (hence the Reynolds number) of the shell side flow.

Andrew et al. (2016) studied due to their compact design, ease of manufacture and enhanced heat transfer and fluid mixing properties, helically coiled tubes are widely used in a variety of industries and applications.

Dizaji et al. (2015) studied experimentally the effects of flow, thermodynamic and `geometrical characteristics on exergy loss in vertical shell and coiled tubes heat exchangers. Pressure drop and heat transfer characteristics in shell and coiled tube heat exchangers have been widely studied in the resent years. However, the effects of flow, thermodynamic and geometrical parameters on energetic characteristics have not been explicitly and experimentally studied. Hence, the main scope of the present work is to clarify the effect of shell and coil side flow rates, inlet temperatures, coil pitch and coil diameter on exergy loss in shell and coiled tube heat exchangers. Both of the total exergy loss and dimensionless exergy loss are studied.

Samaroo et al. (2014) performed an experiment on the turbulent flow characteristics in an annulus under air bubble injection and sub cooled flow boiling conditions with water as the working fluid. Their findings indicated that, in the laminar flow case, the coalescence of two bubbles successively injected is seen, and in turbulent flow, the bubble departure frequency increases and no coalescence are observed.

Saffari et al. (2013) investigated the effect of bubble injection on pressure drop reduction in helical coil. The experimental results indicated that the maximum reduction of friction drag is 25%, which occurs at low Reynolds numbers.

From the above literature review introduction of Injecting air bubbles in a fluid flow path is one of the promising techniques to increase the turbulence in the flow. The air can either be injected at the entrance of the fluid in the channel or tube so that it can properly mixed before entering or throughout the channel or tube so that there would be a reduction in the skin friction. This also increases the turbulence and thus enhances the different parameters such as heat transfer rate, efficiency etc. Studies have been done on different conditions with air bubble injection and results show a considerable enhancement in the different parameters such as heat transfer performance, turbulence etc.

3. RESEARCH OBJECTIVES

It can be observed that the problem describes on the previous chapter can be dissolving by the improvement in the double pipe heat exchanger by applying various techniques which causes the result in the enhancement of heat transfer rate in the heat exchanger. The effort make to enhancement of heat transfer in heat exchanger are as fallows

- To develop model of double pipe heat exchanger, injecting air bubbles in it.
- Develop a proper Heat Exchanger for maximum heat transfer rate.
- Provide the turbulence in the fluid flow of the heat exchanger.

4. METHODOLOGY

The geometrical model of double pipe heat exchanger has generated in the design modular by using ANSYS 14.5 as shown in figure. The design model will mesh in the ICEM CFD and the meshed model will be imported to Fluent. The desired boundary condition will be applied and model will be analysed and the result will be compared on the basis of previous study.

5. CONCLUSION

If an air flow is injected into a liquid fluid, many ambulant air bubbles are formed inside the fluid. Air bubbles move inside the liquid fluid because of the buoyancy force, and the mobility of these air bubbles makes sizable commixture and turbulence inside the fluid. This mechanism has employed to enhance the heat transfer rate of a horizontal double pipe heat exchanger in this paper. However it can be used in any other type of heat exchanger. Especially, this method can be expanded as a promising heat transfer improvement technique in automotive cooling system, for instance in radiator which contains of water or other liquid fluid. Bubbles were injected via a special method. All the study will based on the CFD simulation of double pipe heat exchanger.

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