Heat Transfer Enhancement in Double Pipe Heat Exchanger with Twisted Type Inserts In ANSYS Fluent

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***Abstract* - The study deals with CFD simulation of concentric tube heat exchanger and concentric tube heat exchanger with insert used for heating air using ANSYS FLUENT Software for steel. Nowadays, heat exchangers with twisted-tape inserts have widely been applied for enhancing the convective heat transfer in various industries such as thermal power plants, chemical processing plants, air conditioning equipment, refrigerators, petrochemical, biomedical and food processing plants. In general, twisted tape insert introduces swirl into the bulk flow which consequently disrupts a thermal boundary layer on the tube surface. In general, twisted tape insert introduces swirl into the bulk flow which consequently disrupts a thermal boundary layer on the tube surface. Design process for heat exchanger and insert has been carried out in solid works fluid domain is formed in ANSYS workbench, followed by meshing in default mesh tool of ANSYS and solution is developed using ANSYS Fluent software as Finite element tool and the results are compared between the two designs for parallel flow.**

***IndexTerms* - Double pipe heat exchanger, Insert, ANSYS Fluent, Twisted tape insert.**

I. INTRODUCTION

The analysis of heat exchanger is of great significance from engineering point of view due to various engineering applications and implications dealt with it. Considerable significance has been made on the development of various augmented heat transfer surfaces and devices, in recent years. Energy and material saving reconsideration, space considerations as well as economic incentives have led to the increased efforts aimed at producing more efficient and reliable heat exchanger equipment through the augmentation of heat transfer.

The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment.

The major challenge in designing a heat exchanger is to make the equipment compact and achieve a high heat transfer rate using minimum pumping power. Enhanced performance of heat exchanger enables the size of the heat exchanger to be decreased.

In tube heat exchanger design the tube often represents poor performance when handling viscous liquids in laminar flow because near the tube wall, there is thermally inefficient boundary layer with very little mixing.

A majority of heat exchangers used in thermal power plants, chemical processing plants, air conditioning equipment, and refrigerators, petrochemical, biomedical and food processing plants serve to heat and cool different types of fluids. Both the mass and overall dimensions of heat exchangers employed are continuously increasing with the unit power and the volume of production.

II. LITERATURE REVIEW

Cylindrical pipes are used very extensively in a lot of heat transfer and engineering applications. They have found extensive use in various types of Heat Exchangers, in Automobile, in thermal power plants. Recently many emphasize has been made to increase the heat transfer characteristics of concentric tube heat exchanger.

Heat transfer enhancement in double pipe heat exchanger using simple pattern of rectangular insert. They observed that the heat transfer coefficient varied from 1.9 times the smooth tube values.

Different techniques are employed to enhance the heat transfer rates, which are generally referred to as heat transfer enhancement, augmentation or intensification technique.

A. Heat Transfer Augmentation Techniques

Heat transfer augmentation techniques are generally classified into three categories namely:

- Active techniques,
- Passive techniques and
- Compound techniques.

Active Techniques: Active techniques involve some external power input for enhancement of heat transfer.
Example: Mechanical aids, Surface vibrations, Fluid vibrations and Jet impingement.

Passive Techniques: Passive techniques do not require any direct input of external power. They generally use geometrical or surface modifications to the flow channel by incorporating inserts or additional devices.
Example: Rough surfaces, Extended surfaces, Swirl flow devices and Coiled tubes.

Compound Techniques: Combination of active and passive techniques may be employed simultaneously to obtain enhancement in heat transfer that is greater than that produced by any of those techniques separately. This simultaneous utilization is termed compound enhancement.

B. Twisted Tape Inserts

To enhance the heat transfer rate, some kind of insert is placed in the flow passages and they also reduce the hydraulic diameter of the flow passages. Heat transfer enhancement in a tube flow is due to flow blockage, partitioning of the flow and secondary flow. Flow blockages increase the pressure drop and leads to viscous effects, because of a reduced free flow area. The selection of the twisted tape depends on performance and cost. The performance comparison for different tube inserts is a useful complement to the retrofit design of heat exchangers.

Twisted Tape in Laminar Flow: Manglik and Bergles developed the correlation for friction factor and Nusselt number for laminar flows including the swirl parameter, which defined the interaction between viscous, convective inertia and centrifugal forces.

***Twisted tape in Turbulent Flow*:** Manglik and Bergles developed the correlation for friction factor and Nusselt number for turbulent flows.

Computational Fluid Dynamic: Fluid (gas and liquid) flows are governed by partial differential equations (PDE) which represent conservation laws for the mass, momentum and energy. Computational Fluid Dynamics (CFD) is used to replace such PDE systems by a set of algebraic equations which can be solved using digital computers. The basic principle behind CFD modeling method is that the simulated flow region is divided into small cells. Differential equations of mass, momentum and energy balance are discretized and represented in terms of the variables at any predetermined position within or at the center of cell. These equations are solved iteratively until the solution reaches the desired accuracy (ANSYS FLUENT 14.0). CFD provides a qualitative prediction of fluid flows by means of

- Mathematical modeling (partial differential equations)
- Numerical methods (discretization and solution techniques)
- Software tools (solvers, pre- and post-processing utilities)

Turbulence Modeling: Turbulent flows are characterized by fluctuating velocity fields. These fluctuations mix transported quantities such as momentum, energy, and species concentration, and cause the transported quantities to fluctuate as well. It is an unfortunate fact that no single turbulence model is universally accepted as being superior for all classes of problems. The choice of turbulence model will depend on considerations such as the physics encompassed in the flow, the established practice for a specific class of problem, the level of accuracy required, the available computational resources, and the amount of time available for the simulation.

Turbulence models are classified as,

i) k–ε model
  - Standard k–ε model
  - RNG k–ε model

ii) k- ω model
  - Standard k- ω model
  - shear-stress transport (SST) k-ω model

III. MATHEMATICAL FORMULATION

The system consists of concentric tube heat exchanger with and without insert for heating air through water. The geometric model of the heat exchanger were constructed using design software solid works.

In order to numerically establish the heat transfer coefficient of heat exchanger with insert the parameters were assumed to be same that of heat exchanger without insert. Tube diameter was considered to be 0.015 m and length considered was 2.5 m. The three dimensional computational domain is modeled using quad mesh for both models. The flow is assumed to be steady and turbulent. In this numerical investigation, the following hypotheses are adopted.

- Physical properties of water are constant.
- Profile of velocity is uniform at the inlet.
- The radiation heat transfer is negligible.

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- The flow is assumed to be steady.

IV. VALIDATION OF MODEL

In the present paper concentric tube heat exchanger with and without insert was modeled and simulated using computational fluid domain for heating cold air by applying fixed wall temperature boundary conditions. Simulation results were compared with analytical results using the correlations developed by different researchers.

The simulation results of the concentric tube heat exchanger without insert were compared with the results obtained for concentric tube

heat exchanger with insert of equal length and similar operating conditions in order to compare its performance related to heat transfer characteristics.

Schematic diagram of double pipe heat exchanger is as shown in Figure 1.

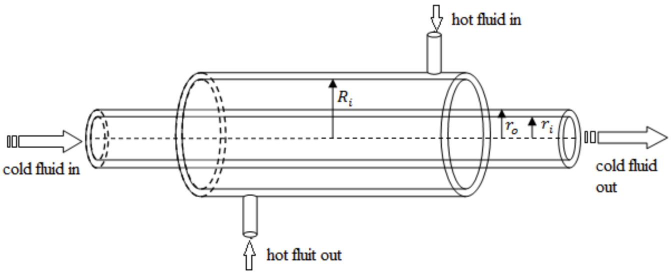

Figure 1. Plain double pipe heat exchanger

The copper tapes were first cut into 3 equal sizes. Holes were drilled at both ends of each tape so that the two ends could be clamped. Lathe was used to give the tapes the desired twist. One end was kept fixed on the tool part of the lathe while the other end was given a slow rotator motion by holding it on the tool part side to avoid its distortion, thus creating the required twist in the tapes.

Three tapes with varying twist ratios were fabricated as shown in Figure 2

Figure 2. Twisted tape inserts

V. RESULTS AND DISCUSSIONS

Parameters adopted for comparison are heat transfer coefficient, Nusselt number and friction factor. In order to validate the CFD results important factor like Nu was calculated by using the correlation for plain tube.

Figure 3 shows the CFD simulated heat transfer coefficient vs. mass flow rate plot for two cases.

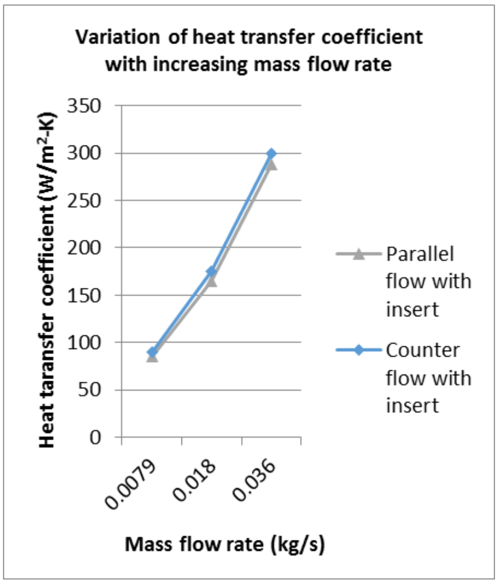

Figure 3. Variation of heat transfer coefficient with increasing mass flow rate

Heat transfer coefficient corresponding to the counter flow is higher than that for parallel flow. This is because of the better mixing of fluid particles provided by insert and increase in contact time. In rectangular insert, it was observed that the heat transfer coefficient varied from 1.15 to 1.4 times for parallel flow and 1.2 to 1.5times for counter flow that of the plain tube.

Figure 4 shows the CFD simulated Nusselt number vs. mass flow rate plot for two cases.

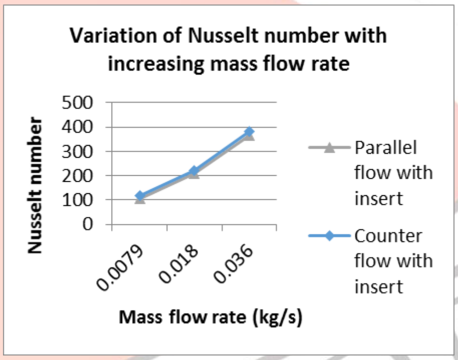

Figure 4. Variation of Nusselt number with increasing mass flow rate

The results have shown a good agreement. Friction factor for tubes with insert is found to be more than that of plain tube for all mass flow rates.

Figure 5 shows the comparison of friction factor for two cases with plain tube.

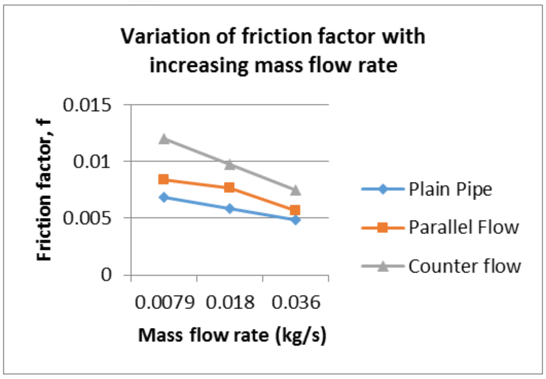

Figure 5. Variation of Friction Factor with increasing mass flow rate

VI. CONCLUSION

The results showed a trend of increase in heat transfer with the provision of insert on the heat exchanger. The heat transfer was found to increase as the Reynolds number was varied over the range. The results obtained show that the effect of insert on the enhancement of heat transfer depends on both the pattern of insert and the Reynolds number of the flow.

The analytical results obtained by the ANSYS fluent software, are presented to analyze the heat transfer enhancement. Based on the CFD analysis the following conclusions can be drawn.

- The heat transfer enhancement effect is primarily due to induced turbulence which gives higher heat transfer rates.
- At higher Reynolds number more temperature increment can be attained.
- By using such kind of insert length of Heat exchanger can be minimized, for high Reynolds number applications.
- The inner convective heat transfer coefficient for rectangular insert of this kind is approximately 25% higher than for plain tube.

Whenever higher heat transfer rate is required irrespective of pressure drop then the twisted tape with smaller twist ratio can be used for that operation. For lower pressure drop and moderate heat transfer rate the twisted tape with higher twist ratio can be used, therefore based on the requirement, the twisted tape inserts will be selected.

VII. ACKNOWLEDGEMENT

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