Review of Computational Fluid Dynamic Analysis of Helical Coil Heat Exchanger

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Abstract: ANSYS CFX is used for calculating the temperature and analysis of the given data from experimental values. A computational study is used to determine the effects of heat transfer in the helical coiled heat exchangers. Comparison with experimental results and values obtained by CFD simulations shows that, by increasing velocity in helical coil heat exchanger and analysed a result which shows that as the velocity increase then heat transfer decreases. Many experimental and numerical studies on the helical coiled heat exchanger have been made, the physical behaviour of the heat transfer phenomenon. Several different hypotheses based on experimental analytical and numerical studies have been put forward to describe the optimization of heat transfer through helical coiled heat exchanger. Optimisation of the heat transfer by the use of helical coils are studied and researched by many researchers, because of the fluid dynamics inside the pipes of a helical coil heat exchanger has many advantages over the straight tube, shell and the tube type heat exchanger, in terms of better heat transfer and mass transfer coefficients. Various configurations of coil structure are possible, and the configuration in which there is a series of vertically stacked helically coiled tubes is the most common type while running the analysis.

Keywords: Helical coil Heat exchanger, CFD or computational fluid dynamics, Conjugate heat transfer, Heat transfer optimization ,Solid works 2009, ANSYS CFX 12.1

1. INTRODUCTION

A heat exchanger is a device built for efficient heat transfer from one medium to another medium. The media may be separated by a solid wall, so that they never mix, or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, cryogenics applications and sewage treatment. One common example of a heat exchanger is the radiator in a car, in which the heat source, being a hot engine-cooling fluid, water, transfers heat to air flowing through the radiator (i.e. the heat transfer medium).There are two primary classifications of heat exchangers according to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. he counter current design is most efficient, in that it can transfer the most heat from the heat (transfer) medium. For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger.

1.2 Types of Heat Exchangers

1.2.1 Shell and Tube Heat Exchanger

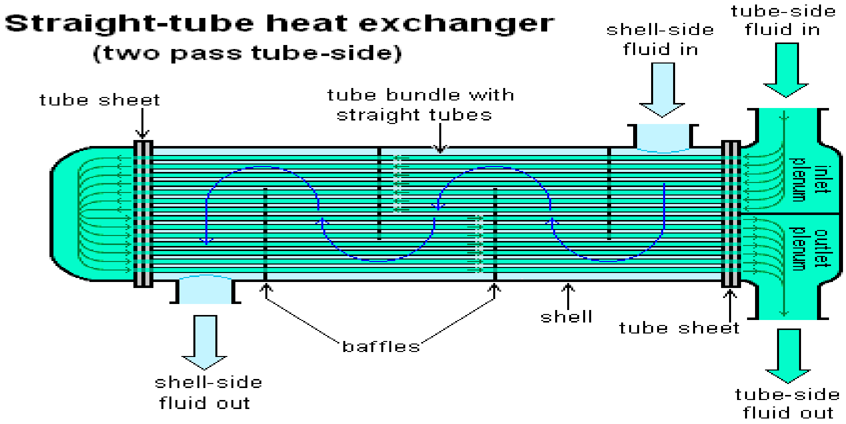

Fig: 1.2 Shell and Tube heat exchanger

Shell and tube heat exchangers consist of a series of tubes. One set of these tubes contains the fluid that must be either heated or cooled. The second fluid runs over the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat required. A set of tubes is called the tube bundle and can be made up of several types of tubes: plain, longitudinally finned, etc. Shell and tube heat exchangers are typically used for high-pressure applications. This is because the shell and tube heat exchangers are robust due to their shape.

1.2.2 Helical Pipe (Coil) Heat Exchanger

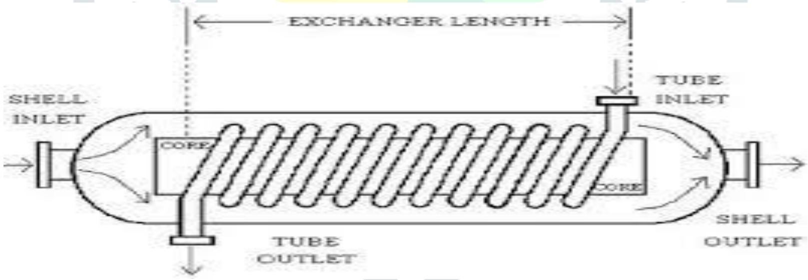

Fig: 1.2 Helical Pipe Heat Exchanger

Helically coiled tubes can be found in many applications including food processing, nuclear reactors, compact heat exchangers, heat recovery systems, chemical processing. Due to the extensive use of helical coils in these applications, knowledge about the pressure drop, flow patterns, and heat transfer characteristics are very important. Pressure drop characteristics are required for evaluating pump power required to overcome pressure drops to provide the necessary flow rates. These pressure drops are also functions of the curvature of the tube. The curvature induces secondary flow patterns perpendicular to the main axial flow direction.

2. LITERATURE REVIEW

Different analyses with CFD software were performed for the heat transfer enhancement in Helical Coil Type Heat Exchanger and comparison with other types of heat exchanger and factors or parameters affecting the performance of helical coil.Some of the relevant studied papers are shown as below:

M. M. ABO ELAZM [1], In this paper, the concept of helical cone coils and their Enhanced heat transfer characteristics compared to the ordinary helical coils. Helical and spiral coils are known to have better heat and mass transfer than straight tubes, which is attributed to the generation of a vortex at the helical coil known as Dean Vortex. The Dean number which is a dimensionless number used to describe the Dean vortex is a function of Reynolds number and the square root of the curvature ratio, so varying the curvature ratio for the same coil would vary the Dean number. Two scenarios were adopted to study the effect of changing the taper angle (curvature ratio) on the heat transfer characteristics of the coil; the commercial software

FLUENT was used in the investigation. It was found that Nusselt number increased with increasing the taper angle. A MATLAB code was built based on empirical correlation of Manlapaz and Churchill for ordinary helical coils to calculate the Nusselt number at each coil turn, and then calculate the average Nusselt number for the entire coil turns, the CFD simulation results were found acceptable when compared with the MATLAB results.

Pramod S. Purandare [2], Heat exchangers are the important engineering systems with wide variety of applications including power plants, nuclear reactors, refrigeration and air-conditioning systems, heat recovery systems, chemical processing and food industries. Helical coil configuration is very effective for heat exchangers and chemical reactors because they can accommodate a large heat transfer area in a small space, with high heat transfer coefficients. This paper deals with the parametric analysis of the helical coiled heat exchanger with various correlations given by different researchers for specific conditions. The parametric analysis of these various correlations with specific data is presented in this paper.

Ashok B. Korane [3], In present study, comparative analysis made on two different geometries of the helical coils for heat transfer analysis. Square and circular coiled patterned geometries were tested under counter flow configuration. The tube side and shell side flow rates were varied and both side input output temperatures measured using suitable temperature sensors. The tube and shell side mass flow rates are controlled by using flow meters and varied by using flow control valve. Overall heat transfer coefficients were calculated for both the coil. Inner heat transfer coefficients were calculated by using Wilson plot method. Tube side Nusselt number calculated for various mass flow rates. The new tube side Nusselt number correlations were developed for both the coil geometries and compared with the available existing correlations.

P.C. Mukesh Kumar [4], In this work, heat transfer coefficients of shell and helically coiled tube heat exchanger using Al_2O_3 / water nanofluid were studied. This study was done by changing the parallel flow configuration into counter flow configuration under laminar flow regime. The Al_2O_3 / water nanofluid at 0.4% and 0.8% particle volume concentration were prepared by using two step methods. The nanoparticles were characterized by X-Ray diffraction (XRD) and Scanning Electron Microscope (SEM). It is found that the overall heat transfer coefficient of counter flow was 4-8% higher than that of parallel flow at 0.4% nanofluid. The overall heat transfer coefficient was found to be 5-9% higher than that of parallel flow at 0.8% nanofluid. It is studied that there is no considerable effect on heat transfer coefficient on changing flow configuration. This is because of helically coiled tube flow and shell flows are perpendicular direction both in parallel and counter flow configuration. It is also studied the thermal performance of 0.8% nanofluid is higher than 0.4% nanofluid.

Muhammad Mahmood Aslam Bhutta [5], This literature review focuses on the applications of Computational Fluid Dynamics (CFD) in the field of heat exchangers. It has been found that CFD has been employed for the following areas of study in various types of heat exchangers: fluid flow maldistribution, fouling, pressure drop and thermal analysis in the design and optimization phase. Different turbulence models available in general purpose commercial CFD tools i.e. standard, realizable and RNG k _ ε RSM, and SST k _ ε in conjunction with velocity-pressure coupling schemes such as SIMPLE, SIMPLEC, PISO and etc. have been adopted to carry out the simulations. The quality of the solutions obtained from these simulations are largely within the acceptable range proving that CFD is an effective tool for predicting the behavior and performance of a wide variety of heat exchangers.

Ahmed M. Elsayed [6], Nanofluids have been reported to enhance heat transfer performance in heat exchangers. Additionally, the use of helical coils has shown to be another passive heat transfer enhancement technique. This work presents a CFD modeling study to investigate the laminar heat transfer through helical tubes with nanofluids. The developed CFD models were validated against published experimental results and empirical correlations in the literature. The effects of particles concentration and Reynolds number on heat transfer coefficient were numerically investigated. Results have shown that Al2O3 dispersed in water increases the heat transfer coefficient in helical coils by up to 4.5 times that of pure water in straight tubes at same Reynolds number. For concentrations larger than 2%, Al2O3 is more suitable for thermal systems of small thermal loads where the pumping power is not critical.

Mandhapati Raju [7], Hydrogen refueling in a metal hydride based automotive hydrogen storage system is an exothermic reaction and therefore an efficient heat exchanger is required to remove the heat for fast refueling. In this paper a helical coil heat exchanger embedded in a sodium alanate bed is modeled using COMSOL. Sodium alanate is present in the shell and the coolant flows through the helical tube. A three-dimensional COMSOL model is developed to simulate the exothermic chemical reactions and heat transfer. Due to memory limitations, only a few turns of the coil are included in the computational domain. Practical difficulties encountered in modelling such three dimensional geometries as well as suitable approximations made to overcome such difficulties are discussed. The distribution of temperature and hydrogen absorbed in the bed for a sample case is presented. A parametric study is conducted using COMSOL-Matlab interface to determine the optimal bed diameter, helical radius and helical pitch for maximum gravimetric capacity.

Rahul Kharat [8], The present study deals with developing a Correlation for heat transfer coefficient for flow between concentric helical coils. Existing Correlation is found to result in large discrepancies with the increase in gap between the concentric coils when compared with the experimental results. In the present study experimental data and CFD simulations using Fluent 6.3.26 are used to develop improved heat transfer coefficient correlation for the flue gas side of heat exchanger. Mathematical model is developed to analyze the data obtained from CFD and experimental results to account for the effects of different functional dependent variables such as gap between the concentric coil, tube diameter and coil diameter which affects the heat transfer. Optimization is done using Numerical Technique and it is found that the new correlation for heat transfer coefficient developed in this investigation provides an accurate fit to the experimental results within an error band of 3–4%.

Vijay P Desai [9], Present work experimentally investigates the hydrodynamic and heat transfer analysis of three different geometries of the tube in tube helical coil. This study was conducted over a range of Reynolds numbers from 2500 to 6700 using cold water in annulus side. The experiments were carried out in counter flow configuration with hot water in tube side and cold water in annulus side. Each patterned coils were fabricated by bending 3.5 m straight mild steel tube having 10 mm ID and 12 mm OD, and stainless steel tube having 23 mm ID and 25 mm OD in four active helical turns having zero pitch with coil diameter 270mm. The mild steel wires of 1.5 mm were wound on outer side of inner tube having 6 mm and 10 mm pitch distance. The annulus side Nusselt number and friction factor were determined. The pressure drop and overall heat transfer coefficient is calculated at annulus side for different rate conditions. The results show that the 6 mm wire wound tube in tube helical coil have more overall heat transfer coefficient than that of 10 mm and plain tube helical coil.

3. PROBLEM FORMULATION

3.1 Circuit Diagram of Nuclear Cooling

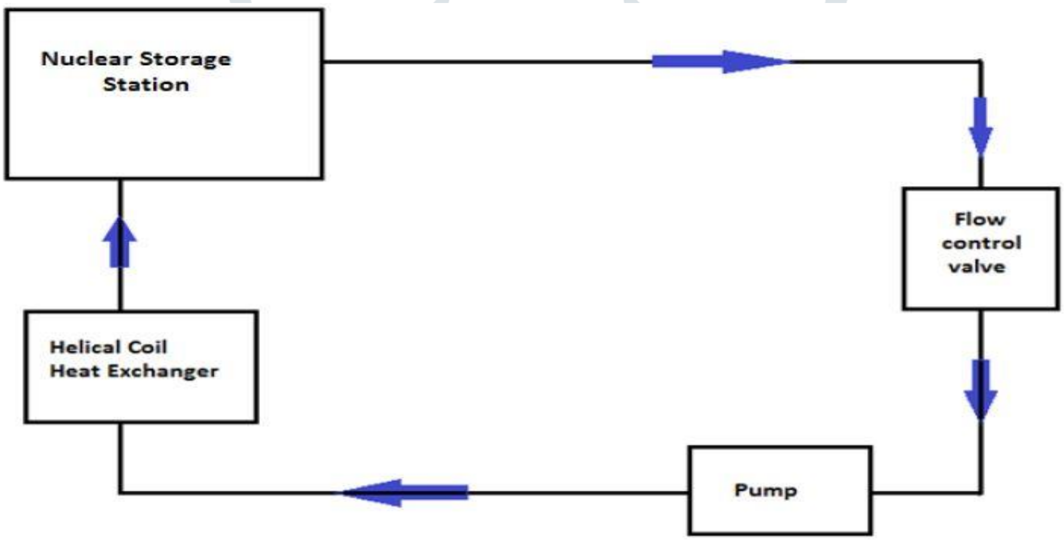

Fig.: 3.1 Circuit Diagram of Nuclear Cooling.

3.2 Working

Nuclear Radioactive stored in the nuclear storage tank at cryogenic temperature. If the temperatures of the radioactive exceed some desired temperature it emits its radioactivity which is very dangerous for that purpose above circuit is used. Liquid nitrogen is circulating in the circuit for cooling purpose.

3.3 Objective

Capacity of nuclear storage station will be increased without significant change in the circuit is possible only one way by increasing flow of liquid nitrogen in the nuclear storage tank but if we increase the flow in the Helical Coil Heat Exchanger, heat transfer characteristics goes down which could be balanced by decreasing pitch of Helical Coil Heat Exchanger.

3.4. Experimental Procedure

Measurements are taken only after the temperatures attain steady values. Experiments are conducted for six different flow rates through the coil and for three different values of temperature at the inlet of the helical pipe. During the course of each set of experiments, the flow rate through the shell side is kept constant, which ensures a constant heat transfer coefficient on the shell side. The experiment is carried out by changing the flow rate through the tube. Once a steady state is attained, values of flow rates of the hot and cold fluids, temperatures at the inlet and exit of the hot and cold fluid, and the power input to the heater and the pump are noted.

4. CONCLUSION

From the above review, ANSYS CFX is used for calculating the temperature and analysis of the given data from experimental values. A computational study is used to determine the effects of heat transfer in the helical coiled heat exchangers. Comparison with experimental results and values obtained by CFD simulations shows that, by increasing velocity in helical coil heat exchanger and analysed a result which shows that as the velocity increase then heat transfer decreases.

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