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A Review of Baffles based Shell and Tube Heat Exchanger using ANSYS Software

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ABSTRACT -

At present, shell and tube heat exchanger is the most common type of heat exchanger widely used in oil refineries and other large chemical processes because it adapts to high pressure application. The CFD solution process consists of modeling and meshing the basic shell and tube heat exchanger geometry using the ANSYS 18.0 CFD package. The objective of the project is to dimension a shell and tube heat exchanger with helical baffle and to study the flow and the temperature field inside the shell using the ANSYS software tools. There is wide application of coil heat exchanger in the field of industrial applications for its improved heat transfer characteristics and compact structure. Much research is being carried out to improve the heat transfer rate of helical coil heat exchanger. Here, in this work, an analysis was made for a tube-to-tube helical heat exchanger with constant heat transfer coefficient with parallel flow.

Keywords- Heat Exchanger, Mass Flow Rate, Baffles Spacing, Heat Transfer Coefficient, ANSYS Software and CFD.

1 INTRODUCTION

There are several factors present that can affect the heat transfer characteristics of the heat exchanger. The flow pattern on the shell side of the heat exchanger with continuous helical baffles was forced to be rotational and helical due to the geometry of the continuous helical baffles, which results in a significant increase in the heat transfer coefficient per unit pressure drop in the heat exchanger. The flow pattern on the shell side of the heat exchanger with continuous helical baffles was forced to be rotational and helical due to the geometry of the continuous helical baffles, which results in a significant increase in the heat transfer coefficient per unit pressure drop in the heat exchanger.

The design of shell and tube heat exchangers is usually based on correlations, among them, the Kern method and the Bell-Delaware method are the most commonly used correlations. Kern's method is mainly used for preliminary design and provides conservative results. Whereas, the Bell-Delaware method is the most accurate method and can provide detailed results. It can predict and estimate pressure drop and heat transfer coefficient with better accuracy. The Bell-Delaware method is actually the classification method and can suggest the weaknesses in the hull side design, but it cannot indicate where those weaknesses are. So, in order to discover these problems, the flow distribution must be understood. For this reason, several analytical, experimental and numerical studies have been carried out. Most of this research has focused on certain aspects of shell and tube heat exchanger design.

Experimental work shows higher Nusselt numbers and pressure drops in relation to theoretical correlation based on Bell's method. From this study it was concluded that combinatorial algorithms such as GA provide a significant improvement in optimal designs compared to traditional designs. The application of GA to determine the minimum overall heat exchanger cost is significantly faster and has an advantage over other methods in obtaining multiple solutions of the same quality.

All heat exchangers are built on the same principle, i.e. a hot fluid flowing over/around a colder fluid will transfer its heat (and therefore its energy) in the direction of the cold flow (to review their laws thermodynamics, check out our article on heat exchangers). Think about when you hold the steering wheel for the first time on a cold day: at first, the temperature difference between your hand and the steering wheel is large and you can feel how cold it is; however, if you continue to hold the wheel, some of the heat in your hand will be absorbed by the cold wheel and the wheel will “warm up”. This example is an intuitive way to understand the basic principles of any heat exchanger: bring two fluids with different temperatures together and allow them to “exchange” heat through some conductive barrier.

Shell and tube heat exchangers are, quite simply, a device that brings two working fluids into thermal contact using tubes housed within an outer cylindrical shell. These two integral paths are generally constructed with thermally conductive metals that allow easy heat transfer (steel, aluminum alloys, etc.). The tubes carry a fluid from their inlet to their outlet (the "tube-side" flow), while the shell passes a separate fluid over these tubes (the "shell-side flow"). The number of tubes, known as a tube bundle, will determine how much surface area is exposed to the shell side flow and therefore determines how much heat is transferred. These devices are among the most effective means of heat exchange as they are easy to build, maintain, compact and provide excellent heat transfer. They are widely distributed in industry, being useful for condensers, turbine coolers, evaporators, feedwater preheating, and much more.

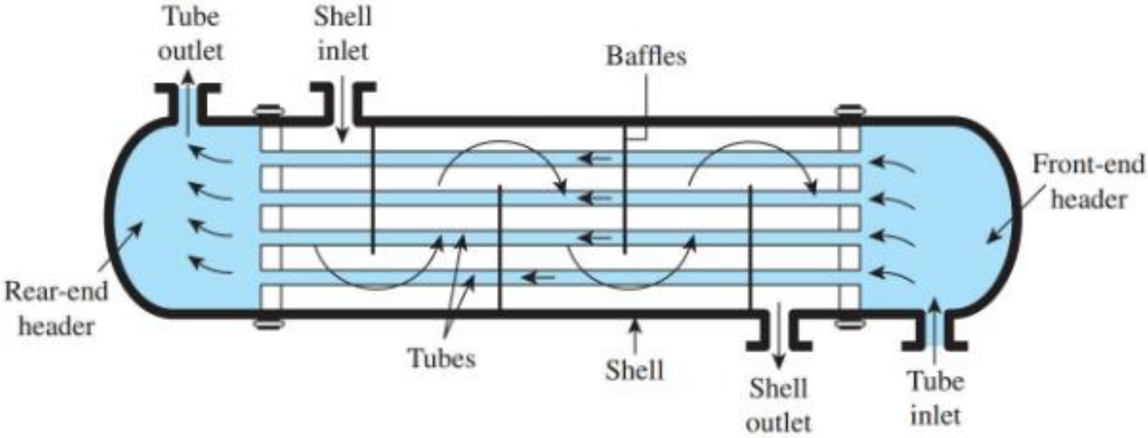

Figure 1: A diagram of shell and tube heat exchangers.

2 LITERATURE REVIEW

Heat is transferred from one fluid to the other through the walls of the tube, either from the tube side to the shell side or vice versa. Fluids can be liquids or gases on the shell or tube side. To transfer heat efficiently, a large heat transfer area is used, leading to the use of many tubes. This is an efficient way to use energy and avoid wasting thermal energy. BI. Master and others. in 2006 found that more than 30% of heat exchangers are used shell and tube type [1]. Shell and tube heat exchangers can be custom designed considering their operability, maintenance, flexibility and safety. This makes it very robust and serves as one of the main reasons it is widely used in industries [2]. For an efficient heat transfer process, the heat exchanger should have low pressure drop, high shell-side mass flow velocity, high heat transfer coefficient, and no or very low fouling, and so on. Heat transfer also depends on the amount of turbulence created on the hull side. This turbulence can be created using deflectors. Several types of deflectors are listed in the literature. Some of the commonly used ones are segmental, double segmental, triple segmental, donut type, helical type, double helical and flower type. When traditional segmental baffles are used in the shell and tube heat exchanger, a higher pumping power is usually required to compensate for the higher pressure drop under the same heat load. The SG-STHX problems mentioned above were improved or solved by helical baffles [3]. The discontinuous helical baffle shell and tube heat exchanger was initially proposed by Lutcha and Nemcansky [4] and produced commercially by numerical investigation to study the impact of various baffle inclination angles on fluid flow and shell heat transfer. and continuous helical tube heat exchangers using periodic model. From the computed results, it was observed that the best integrated performance occurs at approximately 45° of helix angle. The performance of the heat exchanger also depends on the pressure drop. Leakage can reduce the pressure drop and therefore the average heat transfer coefficient per compartment.

Gaddis and Gnielinsk [5] proposed a procedure to evaluate the pressure drop and its comparison with experimental data. Based on the flow arrangement, shell and heat exchangers are classified into parallel (co-current) and counter-current (concurrent). In a counterflow or countercurrent exchanger, the two fluids flow parallel to each other but in opposite directions inside the core (the temperature variation of the two fluids in such an exchanger can be idealized as one-dimensional). As shown later, the counterflow arrangement is thermodynamically superior to any other flow arrangement [6].

It is the most efficient flow arrangement, producing the greatest temperature change in each fluid compared to any other two fluid flow arrangements for a given overall thermal conductance (AU), fluid flow rates (actually capacity rates of fluid heat) and fluid inlet temperatures [7-9]. In addition, use of helical; The baffles proved better heat transfer efficiency than the original segmental tube and shell heat exchanger in the same shell structure and at the same mass flow rate. Wang et al. [10] proposed the maximum velocity design method for a continuous helical shell and tube heat exchanger

3 SHELL AND TUBE HEAT EXCHANGER

A typical heat exchanger, usually for higher temperatures, is the shell and tube heat exchanger. Shell and tube type heat exchanger, indirect contact type heat exchanger. It consists of a series of tubes through which one of the fluids passes. The bark is the container for the bark fluid. It is generally cylindrical in shape with a circular cross section, although differently shaped shells are used in specific applications. For this particular study, the shell is considered, which a one-pass shell is usually. A shell is most commonly used due to its low cost and simplicity and it has the highest log mean temperature difference (LMTD) correction factor. Although the tubes can have single or multiple passes, there is one pass on the hull side while the other fluid flows inside the hull over the tubes to be heated or cooled. Tube-side and shell-side fluids are separated by a sheet of tube. Baffles are used to support the tubes for structural rigidity, preventing tube vibration and sagging, and to divert flow through the bundle for greater heat.

Most research nowadays is carried out on helical baffles, which offer better performance than single segmental baffles, but involve high manufacturing cost, installation cost and maintenance cost. Efficiency and cost are two important parameters in the design of heat exchangers. Thus, in order to improve the thermal performance at a reasonable cost of the shell and tube heat exchanger, the baffles in the present study are provided with some slope to maintain a reasonable pressure drop across the exchanger. The complexity of experimental techniques involves the quantitative description of flow phenomena using measurements that deal with one quantity at a time for a limited range of problems and operating conditions. Computational Fluid Dynamics is now an established industrial design tool, offering obvious advantages. In this study, a complete 360° CFD model of a shell and tube heat exchanger is considered. By modeling the geometry as accurately as possible, the flow structure and temperature distribution inside the shell are obtained.

4 PRINCIPLE

A shell and tube heat exchanger is a class of heat exchanger designs. It is the most common type of heat exchanger in oil refineries and other large chemical processes and is suitable for high pressure applications. As the name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside. One fluid runs through the tubes and another fluid. flows over the tubes (through the shell) to transfer heat between the two fluids. The set of tubes is called a tube bundle, and can be composed of several types of tubes: smooth, longitudinally finned, etc.

Baffle:

Baffles are placed inside the heat exchanger shell firstly to support the tubes, preventing tube vibration and sagging and secondly to direct the flow to have higher heat transfer coefficient. The distance between two baffles is the baffle spacing.

Baffles Serve Two Purposes:

- Divert (direct) the flow across the bundle to obtain a higher heat transfer coefficient.
- Support the tubes for structural rigidity, preventing tube vibration and sagging.

Type of Baffles:

Baffles are used to support the tubes, allow a desirable velocity to be maintained for the shell-side fluid, and prevent tube failure due to flow-induced vibration. There are two types of deflectors: plate and rod. Plate baffles can be single segment, double segment or triple segment.

5 CFD AS A TOOL

5.1 MATHEMATICAL MODELLING

Any physical problem can be converted into a mathematical domain which is now solved using a CAE based solver like Fluent. It is basically based on numerical methods that are solved iteratively or using some empirical relations. In this way, this complex system is modeled in simplified numerical equations and solved accordingly. Computational Fluid Dynamics (CFD) is the analysis of the system involving fluid flow, heat transfer and associated phenomena such as chemical reactions through computer-based simulations. CFD is used to visualize how the fluid flows and how the fluid behaves under certain circumstances.

5.2 COMPUTATIONAL FLUID DYNAMICS

Computational Fluid Dynamics is based on the Navier-Stokes equation, which is given in general format as: Computational domain, mesh and boundary conditions The heat exchanger is modeled using three different types of baffles. In these models, only the shell-side fluid domain is modeled and blended using a tetrahedral grid type. Meshes are generated using the ANSYS Meshing tool. Element quality and asymmetry are checked to keep them within limits. Three grids with a total cell count of ~2.1 million, ~3.7 million, and ~4.3 million are computed. The pressure drop for all three cases is monitored and the difference between ~3.7 million and ~4.3 million is found to be less than 0.5%. Taking into account the accuracy of the solution and computation time, a grid of ~3.7 million was chosen.

The flow in the shell and tube heat exchanger is highly turbulent. Due to the merits of the k-ε turbulence model, it is preferred for modeling turbulence in shell-and-tube heat exchangers. This simulation uses a realizable k-ε turbulence model with a scalable wall function. The scalable wall functions allow for solutions on arbitrarily thin near-wall grids, which is a significant improvement over the standard wall functions. The k-ε realizable model is often used to capture somewhat coarsely mesh contour effects. Solid walls are defined with no-slip moment boundary condition. The inlet to the enclosure is defined as a mass flow inlet. Mass flow rates range from 0.0104 kg/s to 0.032 kg/s. The outlet of the enclosure is said to be a pressure outlet with pressure such that the inlet pressure is equal to the pressure drop. All governing equations are solved to second order accuracy and the residual limit is set to 10-4. The SIMPLE algorithm was used to solve the pressure-related equations.

Figure 2 : Types of baffles (a) Segmental baffles, (b) Double segmental baffles, (c) Helical baffles

6 CONCLUSIONS

Heat transfers and flow distribution are discussed in detail and the proposed model is compared with increasing the angle of inclination of the deflector. The model predicts heat transfer and pressure drop with an average error of 20%. Thus, the model can be improved. The guess worked well in this geometry and the mesh expects the output and input region where rapid mixing and change in flow direction occurs. So, an improvement is expected if the helical baffle used in the model has full contact with the hull surface, this will help in more turbulence on the hull sides and the heat transfer rate will be increased. If a different flow rate is taken, it may be useful to get better heat transfer and get a better temperature difference between inlet and outlet. The heat transfer rate is poor because most of the fluid passes without interacting with the baffles. Thus, the design can be modified for better heat transfer in two ways: decreasing the diameter of the housing so that there is proper contact with the helical baffle, or enlarging the baffle so that the baffles are in proper contact with the housing.

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