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Study of Shell and Tube Heat Exchanger with the Effect of Types of Baffles

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Abstract

For evaluation of shell and tube heat exchanger, thermal performance and pressure drop are considered as major factors. Both, thermal performance and pressure drop are dependent on the path of fluid flow and types of baffles in different orientations respectively. Increasing the complexity of baffles enhances heat transfer which also results in higher pressure drop which means higher pumping power is required. This reduces the system efficiency. This paper presents the numerical simulations carried out on different baffles i.e. single segmental, double segmental and helical baffles. This shows the effect of baffles on pressure drop in shell and tube heat exchanger. Single segmental baffles show the formation of dead zones where heat transfer cannot take place effectively. Double segmental baffles reduce the vibrational damage as compared to single segmental baffles. The use of helical baffles shows a decrease in pressure drop due to the elimination of dead zones. The less dead zones result in better heat transfer. The lower pressure drop results in lower pumping power, which in turn increases the overall system efficiency. The comparative results show that helical baffles are more advantageous than other two baffles.

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Keywords: *Shell and tube heat exchanger, CFD, baffle types, pressure drop, mass flow rate.*

1. Introduction

Heat exchangers are used for transferring thermal energy between two or more fluids, or solid particulates and a fluid, at different temperature and in thermal contact. The essential principle of a heat exchanger is that it transfers the heat without transferring the fluid that carries the heat. In heat exchangers, there are no external thermal energy and work interactions. The heat transfer occurs mainly due to conduction and convection. The heat exchangers are classified according to transfer processes, number of fluids, and degree of surface compactness, construction features, flow arrangements, and heat transfer mechanisms [1]. Heat exchangers are extensively used in many engineering

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applications such as chemical engineering processes, power generation, petroleum refining, refrigeration, air conditioning, food industry and so on. Among different types of heat exchangers, shell and tube heat exchangers are relatively easy to manufacture and have multipurpose application possibilities for gaseous as well as liquid media in large temperature and pressure ranges [2].

In shell and tube heat exchanger, two fluids of different temperature flow through the heat exchanger. One flows through the tubes (the tube side) and other flows outside the tubes but inside the shell (the shell side). Heat is transferred from one fluid to the other through the tube walls, either from tube side to shell side or vice versa. The fluids can either be liquids or gases on either the shell or the tube side. In order 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 wastage of thermal energy.

B.I. Master et al. in 2006 found that more than 30% heat exchangers are used of shell and tube type [3]. Shell and tube heat exchangers can be custom designed by considering its operability, maintainability, flexibility and safety. This makes it very robust and serves major reason to be used widely in industries [4]. For efficient heat transfer process, 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 in shell side. This turbulence can be created by using baffles. Various types of baffles are enlisted in literature. Some of the commonly used are segmental, double segmental, triple segmental, doughnut type, helical type, double helical and flower type. When traditional segmental baffles are used in shell and tube heat exchanger, higher pumping power is often needed to offset higher pressure drop under same heat load. The problems of SG-STHX mentioned above were improved or solved by helical baffles. The shell and tube heat exchanger with discontinuous helical baffle was firstly proposed by Lutcha and Nemcansky [5] and commercially produced by ABB Lummus [6] heat transfer. Lei et al. [7] carried out a numerical investigation to study the impact of various baffle inclination angles on fluid flow and heat transfer of continuous helical shell and tube heat exchangers by using periodic model. From the results computed, it was observed that the best-integrated performance occurs approximately 45° helix angle. Performance of heat exchanger also depends on pressure drop. Leakage can reduce pressure drop and thus per compartment average heat transfer coefficient. Gaddis and Gnielinsk [8] proposed a procedure to evaluate pressure drop and its comparison with experimental data. Based on flow arrangement, shell and heat exchangers are classified into parallel (co-current) and counter (concurrent). In a counter-flow or counter-current exchanger, the two fluids flow parallel to each other but in opposite directions within the core (The temperature variation of the two fluids in such an exchanger may be idealized as one dimensional). As shown later, the counter-flow arrangement is thermodynamically superior to any other flow arrangement. It is the most efficient flow arrangement, producing the highest temperature change in each fluid compared to any other two fluid flow arrangements for a given overall thermal conductance (UA), fluid flow rates (actually, fluid heat capacity rates), and fluid inlet temperatures. Moreover, use of helical; baffles has proved better heat transfer efficiency than original segmental shell and tube heat exchanger in same shell structure and same mass flow rate. Wang et al. [9] proposed maximal velocity design method for continuous helical shell and tube heat exchanger.

The objective of the present work is to reduce the pressure drop of fluid in shell side of shell and tube heat exchanger by variation and application of different types of baffles i.e. segmental (SG-STHX), double segmental (DSG-STHX) and continuous helical (CH-STHX) baffles for changed mass flow rate for heat exchanger with same dimensional parameters.

2. CFD as a tool:

2.1. Mathematical modelling

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