Review Report on Modeling for Shell-Side Heat Transfer Coefficient and Pressure Drop of Helical Baffle Heat Exchangers

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Abstract: In present day shell and tube heat exchanger is the most common type heat exchanger widely used in oil refinery and other large chemical process, because it suits high pressure application. Heat exchangers are important heat transfer apparatus in oil refining, chemical engineering, environmental protection, electric power generation etc. Shell-and-tube heat exchangers (STHXs) are widely used in many industrial areas, such as power plant, chemical engineering, petroleum refining, food processing, etc. The shell-side fluid pressure and temperature fields of the whole area are then presented. Finally the cycle average Nusselt number of different cycle in the heat exchanger are compared and it is found that within the accuracy allowed in engineering computation, periodic model for one cycle can be used to investigate the heat transfer and pressure drop characteristics for different heat exchanger to save computational source. This paper gives a review on Modeling for Shell-Side Heat Transfer Coefficient and Pressure Drop of Helical Baffle Heat Exchangers and related work.

***Index Terms* - Heat exchangers, Helical baffles, Numerical simulation, Turbulence Pressure drop, Heat transfer**

I. Introduction

Conventional heat exchangers with segmental baffles in shell side have some shortcomings resulting in the relatively low conversion of pressure drop into a useful heat transfer. Both hydrodynamic studies and testing of heat transfer and the pressure drop on research facilities and industrial equipment showed much better performance of helically baffled heat exchanger when compared with conventional ones. These results in relatively high value of shell side heat transfer coefficient, low pressure drop, and low shell side fouling [1]. Shell-and-tube heat exchangers (STHXs) are widely used in many industrial areas, such as power plant, chemical engineering, petroleum refining, food processing, etc. According to Master et al. [1] more than 35–40% of heat exchangers are of the shell-and-tube type due to their robust geometry construction, easy maintenance and possible upgrades. Baffle is an important shell-side component of STHXs. Besides supporting the tube bundles, the baffles form flow passage for the shell-side fluid in conjunction with the shell. The most commonly used baffle is the segmental baffle, which forces the shell-side fluid going through in a zigzag manner, hence improves the heat transfer with a large pressure drop penalty. This type of heat exchanger has been well-developed [2–5] and probably is still the most commonly used type of the shell-and-tube heat exchanger. The major drawbacks of the conventional shell-and tube heat exchangers with segmental baffles (STHXsSB) are threefold: first it causes a large shell-side pressure drop; second it results in a dead zone in each compartment between two adjacent segmental baffles, leading to an increase of fouling resistance; third the dramatic zigzag flow pattern also causes high risk of vibration failure on tube bundle. To overcome the above-mentioned drawbacks of the conventional segmental baffle, a number of improved structures were proposed for the purposes of higher heat transfer coefficient, low possibility of tube vibration, and reduced fouling factor with a mild increase in pumping power [5–10]. However, the principal shortcomings of the conventional segmental baffle still remain in the above-mentioned studies, even though the pressure drop across the heat exchangers has been reduced to some extent. The shell-side heat transfer and pressure drop calculations constitute the key part of the rating or design of a heat exchanger. In addition, beside the main cross flow stream through the tube bundle, the effect of various leakage streams and bypass streams must take into consideration in the shell-side calculations.

Heat exchangers are one of the mostly used equipment in the process industries. Heat exchangers are used to transfer heat between two process streams. One can realize their usage that any process which involve cooling, heating, condensation, boiling or evaporation will require a heat exchanger for these purpose. Process fluids, usually are heated or cooled before the process or undergo a phase change. Different heat exchangers are named according to their application. For example, heat exchangers being used to condense are known as condensers, similarly heat exchanger for boiling purposes are called boilers. Performance and efficiency of heat exchangers are measured through the amount of heat transfer using least area of heat transfer and pressure drop. A better presentation of its efficiency is done by calculating over all heat transfer coefficient. Pressure drop and area required for a certain amount of heat transfer, provides an insight about the capital cost and power requirements (Running cost) of a heat exchanger. Usually, there is lots of literature and theories to design a heat exchanger according to the requirements. Heat exchangers are of two types:-

- Where both media between which heat is exchanged are in direct contact with each other is Direct contact heat exchanger,
- Where both media are separated by a wall through which heat is transferred so that they never mix, indirect contact heat exchanger.

A typical heat exchanger, usually for higher pressure applications up to 552 bars, 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 runs. The shell is the container for the shell fluid. Generally, it is cylindrical in shape with a circular cross section, although shells of different shape are used in specific applications. For this particular study shell is considered, which one pass shell is generally.

II. LITERATURE SURVEY

Reza Tasouji Azar et. al. [1] "Modeling for shell-side heat transfer coefficient and pressure drop of helical baffle heat exchangers" In this study has suitably modified the existing heat transfer and pressure drop correction factors of the modified Bell Delaware method used for heat exchangers with segmental baffles, taking into consideration the helical baffle geometry. In order to calculate the shell-side heat transfer coefficient and pressure drop using the present method, a computational code has been developed by the authors. In this study, correction factors are proposed for the helical baffle geometry of heat exchangers using the model similar to the procedure for segmental baffles presented. In addition, in order to examine the validity, the results of code for a case study are compared with the results obtained from Express software and experimental formulas presented by Zhang. The results of comparison show that the proposed method is accurate and can be used by designers confidently.

Anas El Maakoul et. al. [2] "Numerical comparison of shell-side performance for shell and tube heat exchangers with trefoil-hole, helical and segmental baffles" In this paper, three-dimensional computational fluid dynamics (CFD) simulations, using the commercial software ANSYS FLUENT, have been performed to study and compare the shell-side flow distribution, heat transfer coefficient and the pressure drop between the recently developed trefoil-hole, helical baffles and the conventional segmental baffles, at low shell side flow rates. In this numerical comparison, the whole heat exchangers consisting of the shell, tubes, baffles and nozzles are modeled, the numerical model predicts the thermo-hydraulic performance with a considerably good accuracy, by comparing with experimental data for single segmental baffles. a numerical model is used to compute and compare the thermo-hydraulic performances of shell-and-tube heat exchangers with different baffle types: segmental, helical and trefoil-hole baffles. Flow analysis in shell side, showed that velocity distribution in helical baffles is more uniform and homogenous compared to segmental and trefoil-hole baffles. This leads to less dead zones and less fluid recirculation areas inside the shell.

Mehdi Bahiraei et. al. [3] "A novel application for energy efficiency improvement using nanofluid in shell and tube heat exchanger equipped with helical" Hydrothermal characteristics of the water-Al_2O_3 nanofluid are numerically evaluated in shell-and-tube heat exchanger equipped with helical baffles using the two-phase mixture model. Heat transfer and pressure drop increase by increasing nanoparticle concentration and baffle overlapping, and decreasing helix angle. At smaller helix angles, changing the overlapping is more effective on the convective heat transfer coefficient and the pressure drop. Neural network is used for modeling, and based on the test data, the model predicts the convective heat transfer coefficient and the pressure drop with MRE values of about 0.089% and 0.65%, respectively. The results obtained from optimization revealed that due to the greater effect of overlapping on the pressure drop in comparison with its effect on the heat transfer, using great overlapping values is suggested only when heat transfer improvement is significantly more important than the pressure drop reduction.

J.J. Liu et. al. [4] "3D numerical study on shell side heat transfer and flow characteristics of rod-baffle heat exchangers with spirally corrugated tubes" This article presents a numerical simulation of the shell side flow in rod-baffle heat exchangers with spirally corrugated tubes (RBHXsSCT). Results are compared with those in rod-baffle heat exchanger with plain tubes (RBHX). Simulation is conducted to improve the thermoe hydraulic performance in longitudinal flow heat exchangers and to obtain an understanding of the physical behavior of thermal and fluid flow in the RBHXsSCT with Reynolds number ranging from 6000 to 18,000. The velocity vector plots show that in RBHX, the vortices are generated when the fluid flows across the rods. However, in RBHXsSCT, little vortices are generated and the fluid is leaded by the spiral flow channels to flow against the tube walls. The different flow structures between the RBHXsSCT and RBHX result in different thermoe hydraulic performance in these heat exchangers.

Usman Salahuddin et. al. [5] "A review of the advancements made in helical baffles used in shell and tube heat exchangers" This paper provides a review about the major work done on helical baffles to improve the performance of shell and tube heat exchangers. Some of the major factors affecting the performance of shell and tube heat exchanger are discussed. A comparison between segmental baffles and helical baffles is also presented to show that helical baffles are more advantageous than segmental baffles. The current study covers some of the important factors affecting the performance of STHE, and then a comparison of helical baffles with the traditional segmental baffles was made. It was evident from the comparison that helical baffles give better results than the segmental ones due to better heat transfer performance, less fouling and less fluid-induced vibrations.

Guo-Yan Zhou et. al. [6] "A numerical study on the shell-side turbulent heat transfer enhancement of shell-and-tube heat exchanger with trefoil hole baffles" Shell-and-tube heat exchangers with trefoil-hole baffles are new type heat transfer devices and widely used in nuclear power system due to their special advantages, with the fluid flowing longitudinally on the shell side. However, very few related academic literature are available. In order to obtain an understanding of the underlying mechanism of shell-side thermal augmentation, a CFD model including inlet and outlet nozzles is proposed in the present study. The numerical analysis of heat transfer and fluid flows in the shell sides of the shell-and-tube heat exchanger with trefoil-hole baffles is carried out, with the aim to improve the overall themo-hydraulic performance in longitudinal flow heat exchangers.

III. FEATURES OF HEAT EXCHANGERS:

In order to obtain maximum heat exchanger performance at the lowest possible operating and capital costs without comprising the reliability, the following features are required of an Exchanger:

(1) Higher heat transfer coefficient and larger heat transfer area.

(2) Lower pressure drop.

The objective of the present work is to determine the pressure drop and heat transfer on shell side of Helix changer analytically. A comprehensive experimental investigation on heat transfer and pressure drop on Helix changer is very expensive. The paper discusses developments in the Helix changer and its design and research aspects. Important geometrical parameters have been discussed while calculating the thermal parameters. For calculating the pressure drop and heat transfer on shell side of conventional as well as helical baffle heat exchanger, Bell Delaware method with suitable modification has been used. Results and discussions show that for all the helical baffle heat exchangers studied, the ratios of heat transfer coefficient to pressure drop are higher than those of a conventional segmental heat exchanger. This means that the heat exchangers with helical baffles will have a higher heat transfer coefficient, when consuming the same pumping power..

IV. DEVELOPMENTS IN SHELL AND TUBE EXCHANGER:

The developments for shell and tube exchangers center around better conversion of pressure drop into heat transfer by improving the conventional baffle designs. With single segmental baffles, a significant proportion of the overall pressure drop is wasted in changing the direction of flow. This baffle arrangement also leads to other undesirable effects such as dead spots or zones of recirculation which can cause increased fouling, high leakage flow and large cross flow. The cross flow not only reduces the mean temperature difference but can also cause potentially damaging tube vibration [12].

1.4.1 Helical baffle Heat Exchanger or Helix changer: .

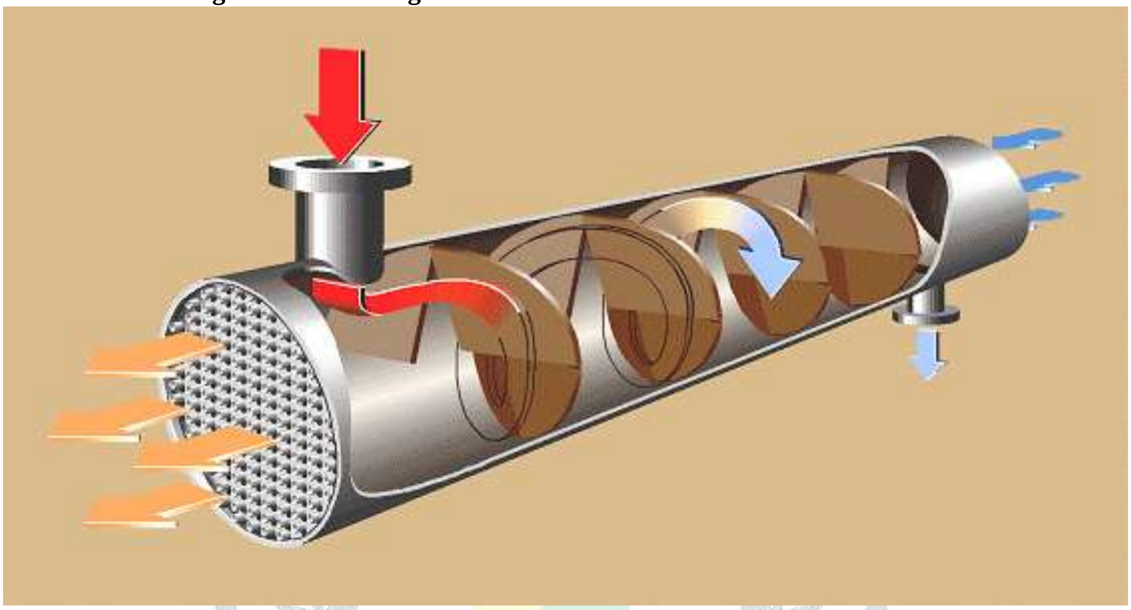

Figure 1: Helical baffle heat exchanger [12]

The baffles are of primary importance in improving mixing levels and consequently enhancing heat transfer of shell-and-tube heat exchangers. However, the segmental baffles have some adverse effects such as large back mixing, fouling, high leakage flow and large cross flow [12].

Compared to the conventional segmental baffled shell and tube exchanger Helix changer offers the following general advantages [14].

_ Increased heat transfer rate/ pressure drop ratio.
_ Reduced bypass effects.
_ Reduced shell side fouling.
_ Prevention of flow induced vibration.
_ Reduced maintenance.

1.4.2 Research aspects

Research on the Helix changer has forced on two principle areas.

• Hydrodynamic studies on the shell side and
• Heat transfer and pressure drop studies on small scale and full industrial scale equipment.

1.4.3 Design aspects:

An optimally designed helical baffle arrangement depends largely on the heat exchanger operating conditions and can be accomplished by appropriate design of helix angle, baffle overlapping and tube layout. In the original method for conventional shell and tube Heat exchanger, an ideal shell-side heat transfer coefficient is multiplied by various correction factors for flow distribution and the non-idealities such as leakage streams, bypass stream etc. are taken into consideration. For Helical baffle geometry it is suggested that some correction factor are not required and suitable modification is done in the Bell Delaware method [14].

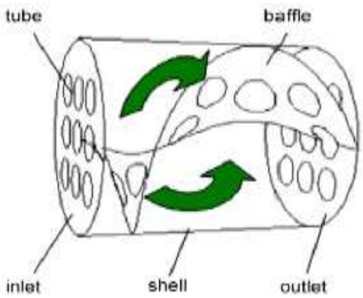

Figure 2: Helix changer pitch

V. CONCLUSION

In this paper gives a review on Modeling for Shell-Side Heat Transfer Coefficient and Pressure Drop of Helical Baffle Heat Exchangers and related work. In [1] correction factors are proposed for the helical baffle geometry of heat exchangers using the model similar to the procedure for segmental baffles presented. In addition, in order to examine the validity, the results of code for a case study are compared with the results obtained from Express software and experimental formulas presented by Zhang. In [2] . The results indicate that, compared to the conventional segmental baffles, the use of helical baffles provide a good balance between heat transfer and pressure drop characteristics. While trefoil-hole baffles enhance considerably the heat transfers, this enhancement is done at the expense of a large pressure drop. In [3] results obtained from optimization revealed that due to the greater effect of overlapping on the pressure drop in comparison with its effect on the heat transfer, using great overlapping values is suggested only when heat transfer improvement is significantly more important than the pressure drop reduction.

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