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OPTIMIZATION OF HELICAL BAFFLE OF SHELL AND TUBE HEAT EXCHANGER USING CFD TOOLS

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Abstract:
A new type of baffle, called the helical baffle, provides further improvement. This use of continuous helical baffles reduces shell-side pressure drop and helps improve heat transfer performance of shell and tube heat exchanger. Properly designed continuous helical baffles can reduce fouling in the shell side and prevent the flow-induced vibration as well. The use of continuous helical baffles results in nearly 10% increase in heat transfer coefficient compared with that of conventional segmental baffles for the same shell-side pressure drop. Helical baffles are employed increasingly in shell-and-tube heat exchangers (helix changers) for their significant advantages in reducing pressure drop, vibration, and fouling while maintaining a higher heat transfer performance.

IndexTerms – Baffle, shell tube boiler, heat exchanger, CFD

I. INTRODUCTION

Baffles are flow-directing or obstructing vanes or panels used in some industrial process vessels (tanks), such as shell and tube heat exchangers, chemical reactors, and static mixers. Baffles are an integral part of the shell and tube heat exchanger design. A baffle is designed to support tube bundles and direct the flow of fluids for maximum efficiency. Baffle design and tolerances for heat exchangers are discussed in the standards of the Tubular Exchanger Manufacturers Association (TEMA).
Implementation of baffles is decided on the basis of size, cost and their ability to lend support to the tube bundles and direct flow.
Types of baffles

- Longitudinal Flow Baffles (used in a two-pass shell)
- Impingement Baffles (used for protecting bundle when entrance velocity is high)
- Orifice Baffles
- Single segmental
- Double segmental
- Support/Blanking baffles
- DE resonating (detuning) baffles used to reduce tube vibration Helical baffle

II. LITERATURE SURVEY

Usman Salahuddin et.al [1]: Heat transfer and pressure drop correction factors based on the Bell Delaware method have been compared for an optimized segmental baffle heat exchanger and a helical baffle heat exchanger.. The enhancement in heat transfer for helical baffles was reflected by the so-called turbulence enhancement correction factor, which accounted for the increase in heat transfer observed at a critical baffle inclination angle of 25[degree].As the baffle inclination angle was increased beyond this critical angle, the turbulence enhancement factor continued to increase and eventually produced a maximum heat transfer enhancement of 1.39 times that for ideal cross-flow conditions. The reduction in pressure drop due to the helical baffles was found to vary from 0.26 to 0.60 depending on the helical inclination angle.

Yong-GangLei et.al [2]: Numerical simulations were carried out to study the impacts of various baffle inclination angles on fluid flow and heat transfer of heat exchangers with helical baffles. The simulations were conducted for one period of seven baffle inclination angles by using periodic boundaries. The most desirable heat transfer coefficient of the highest order and pressure decline of the lowest order are the result generated in heat exchanger. Thus, the present study conclusively improved the performance of the heat exchanger by the use of helical baffle in place of segmental baffle from the numerical experimentation results.
Qiuwang wang et.al [3]: 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. In most cases, discontinuous, folded, sextant helical baffles, 40° baffle inclination angle as well as low baffle

spacing will give the best results when integrated in some combination, whereas continuous helical baffles eliminate dead regions. Moreover, sealing strips are more likely to improve the performance of shell and tube heat exchangers with continuous helical baffles.

Stehlik, P et.al [4]: The heat exchanger with a 40° helix angle shows the best comprehensive heat transfer performance in turbulent state, and the heat exchanger with a 50° helix angle shows better comprehensive heat transfer performance in laminar flow state. The leakage streams proportion of the helical baffles heat exchanger varies from 5.5% to 6.1%, compared with the leakage streams proportion changes from 16.6% to 21.0% in the segmental baffles heat exchanger. In both turbulent flow state and laminar flow state, with the rise of shell-side Reynolds number, the main spiral stream B proportion decreases and the leakage streams proportion increases in the segmental baffles heat exchanger, while the stream B proportion increases and the leakage streams proportion decreases in helical baffles heat exchanger.

Unnat Prajapati et.al [5]: To minimize the abrasion of sharp-corners of holes of inclined baffles manufactured by 2D laser beam cutting machine on the tubes, the application of axial separation with small inclined angle helical baffles is a simple alternate, which creates greater helix pitch for suitable cross section area. Numerical simulation on the flow and thermal performances were conducted on three axial separation helical baffle electric heaters with equivalent angles 15°, 20° and 25° using 10° inclined baffles, three normal helical baffle ones and two segment baffle ones spanned respectively 200 and 250 mm. Each electric heater comprises 27 U-tubes on equilateral triangle layout with nine one-plus-two units. The secondary flow imposed plug flow pattern and leakage flow were demonstrated for helical schemes.

Minhua Zhanget.al [6]: Shell-and-tube heat exchanger with helical baffles is superior to that with segmental baffles in reducing pressure drop, eliminating dead zone and lowering the risks of vibration of tube bundle. This paper focused on the small-angle helical baffles that have been merely reported in open literature. These baffles are noncontinuous helical baffles with a helix angle of 10° to 30°, and their shapes are 1/4 ellipse, 1/4 sector and 1/3 sector. To assess the integrative performance, $\alpha/\Delta p$ is employed, and the calculated results show that among the three baffle shapes the heat exchangers with a 1/4 sector helical baffle have the lowest pressure drop. For the study of helix angles, we found that 30° has the best integrative performance at low mass flow rate, almost the same as 20° at high mass flow rate.

Haseler, L.E. et.al [7]: When the helix angle was varied from 0 to 20 for the heat exchanger containing 7 tubes of outer diameter 20 mm and a 600 mm long shell of inner diameter 90 mm, the simulation shows how the pressure vary in shell due to different helix angle and flow rate. The heat transfer coefficient when recorded showed a very high value when the pressure inside the heat exchanger registered a decline value and this incremental hike was found to be highly significant in the present study. This might be due to the rotational and helical nature of flow pattern following the geometry change by the introduction of continuous helical baffles in the shell side of the heat exchanger. The simulation results obtained with Computational fluid dynamics tools for the baffle cut given to the modified heat exchanger are utilized for the calculation of various parameters like the pressure decline, desired baffle inclination angle and mass flow rate, outlet temperature at the shell side and recirculation at baffle side for the particular geometry of the heat exchanger.

Jian-Fei Zhang, et.al [8]: In the present study, a 3D numerical simulation of a whole heat exchanger with middle-overlapped helical baffles is carried out. At first, the computational model and numerical method of the whole heat exchanger with middle-overlapped helical baffles is presented in detail, and parallel computation mode is adopted for the simulation of a whole heat exchanger with six cycles of the middle-overlapped helical baffles of 40° helical angle on a grid system of 13.5-million cells; second, the validation of the computational model is performed by comparing the total pressure drop and average Nusselt number of the whole heat exchanger with experimental data. Reasonably good agreement is obtained, and the reasons causing to the discrepancy are analyzed. The shell-side fluid pressure and temperature fields of the whole area are then presented.

Khairun Hasmadi Othman et.al [9]: Computational Fluid Dynamic (CFD) is a useful tool in solving and analyzing problems that involve fluid flows, while shell and tube heat exchanger is the most common type of heat exchanger and widely use in oil refinery .Then, the boundary condition will be set before been simulate in Fluent 6.2 based on the experimental parameters. Parameter that had been used was the same parameter of experimental at constant mass flow rate of cold water and varies with mass flow rate at 0.0151 kg/s, 0.0161 kg/s and 0.0168 kg/s of hot water.

Sunilkumar Shinde et.al [10]: The results obtained give us a clear idea that the ratio of heat transfer coefficient per unit pressure drop is maximum in helical baffle heat exchanger, as compared to segmental baffle heat exchanger. The Helical baffle heat exchanger eliminates principle shortcomings in Conventional Heat Exchangers due to shell side zigzag flow, induced by Segmental baffle arrangement. The flow pattern in the shell side of the continuous helical baffle heat exchanger is rotational & helical due to the geometry of continuous helical baffles. This flow pattern results in significant increase in heat transfer coefficient, however the pressure drop reduces significantly in the helical baffle heat exchanger.

III. METHODOLOGY

- Problem Definition
- Geometric Modelling of Helical Baffle(10deg,20deg)
- Creation Of CFD Model
- Applying Boundary Conditions
- Results Comparison

IV. **STEPS INVOLVED**

- Problem Description
- Computational Model
- Geometry and Mesh
- Grid Generation
- Meshing
- Problem Setup

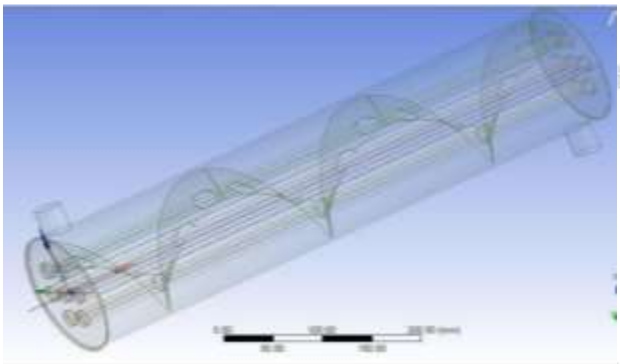

Fig 1. Isometric view of arrangement of tube and baffles in shell and tube heat exchanger with baffle inclination

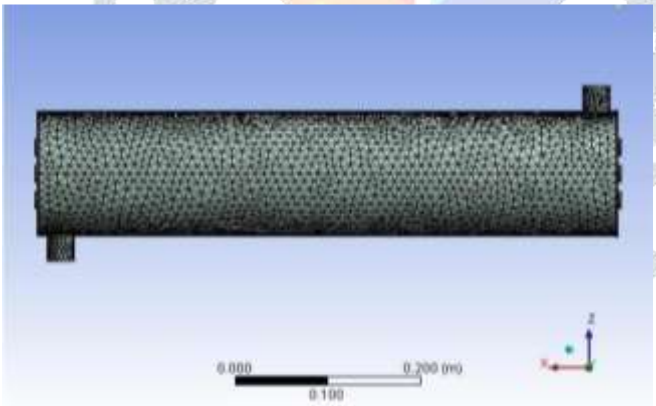

Fig 2 Meshing Figure of shell and tube heat exchanger

IV. RESULTS AND DISCUSSION

Case 1 SIMULATION FOR 10 DEGREE BAFFLE INCLINATION

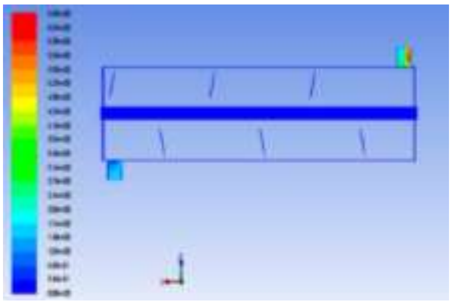

Fig 3. Temperature distribution

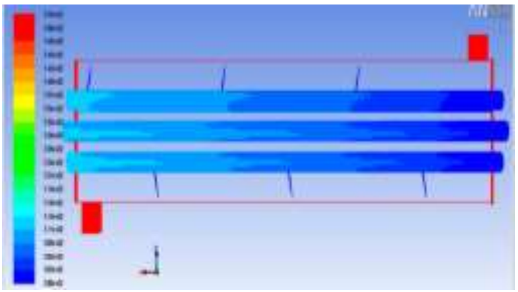

Fig.4 Pressure drop distribution

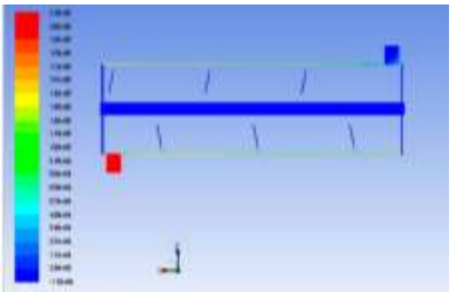

Fig.5 Velocity distribution

Case 2 SIMULATION FOR 10 DEGREE BAFFLE INCLINATION

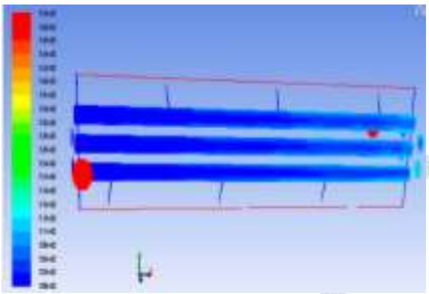

Fig 6 Temperature distribution

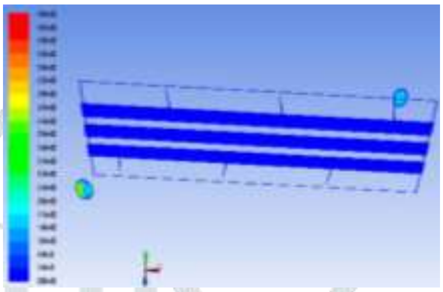

Fig 7. Velocity distribution

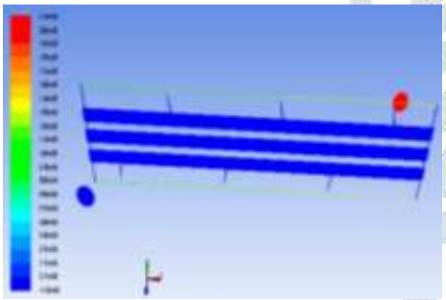

Fig 8 Pressure drop

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Graphs

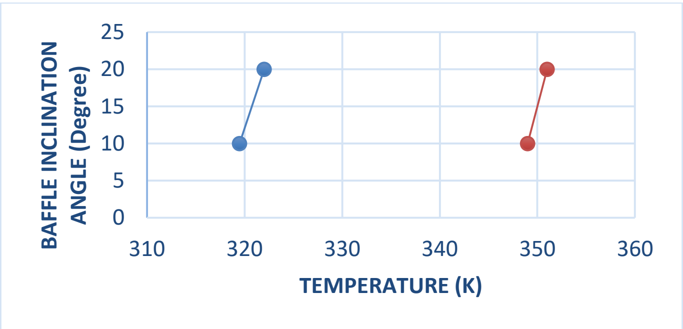

Fig-9: Plot of Outlet Temperature of shell and tube side Vs Baffle inclination angle

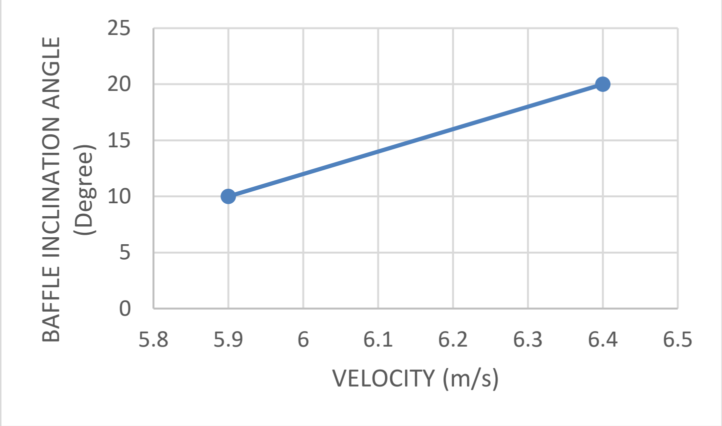

Fig:10- Plot of Velocity Vs Baffle inclination angle

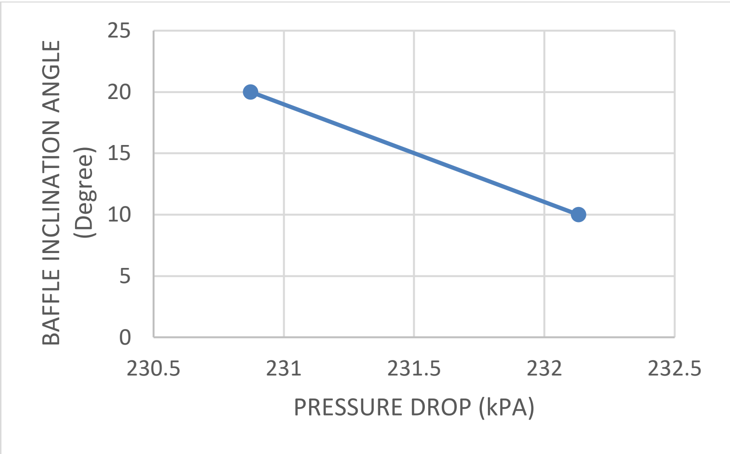

Fig:11- Plot of Pressure Drop Vs Baffle inclination angle

V CONCLUSION.

Following conclusion were made

1. When the baffle inclination angle is 10 the outlet temperature of shell side and tube side are 349K and 319.5K respectively and when the baffle inclination angle is 20 the outlet temperature of shell side and tube side are 351K and 322K respectively.
2. The velocity inside the shell at 10 is 5.9 m/s and at 20 is 6.4m/s.
3. The pressure drop inside shell at 10 is 232.132kpa and at 20 is 230.873kpa.

Since the temperature, velocity and pressure is more in 20 baffle inclination angle. Therefore, the baffle which is inclined at 20 is better as compare to 10.

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