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Shell and Tube Heat Exchanger with Segmental and Helical Baffle-A Review

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The shell and tube heat exchangers are widely used in engineering applications due to simple in manufacture, possibilities of applications and withstanding at high temperature and pressure limits. In this research paper, the recent development are reviewed on shell side heat transfer enhancement for shell and tube heat exchangers with segmental baffle and helical baffles and concluded that the shell and tube heat exchanger with helical baffle is superior when compared with segmental baffle. In this type produced low shell side pressure drop generated and will be having higher heat transfer coefficient.

***Keywords*:** Baffles, Mass flow rate, Heat Transfer Coefficient, Pressure Drop, Heat Transfer Coefficient per Unit, Shell and Tube Heat Exchanger.

Introduction

Over the years heat exchangers have been the most used equipment in many engineering applications like power plants, food processing, chemical engineering, oil refining, refrigeration etc. Shell and tube heat exchangers are the most widely used basic one among all types of heat exchangers, because of their robust construction, easy maintenance and large amount of heat transfer per unit volume, able to work under high pressure and temperature conditions, possible up-gradation. The flow in the shell side of a shell and tube heat exchanger with segmental baffle shown in figure: 1 is very complex, the baffle leads to a stream inside the shell part of the fluid flows parallel and part of the fluid flow perpendicular to the tube bank.

Pressure drop is the one of major issue while design of shell and tube heat exchangers, because pumping power cost is highly depend on shell side pressure drop. It means lower pressure drop leads lower operating costs and higher pressure leads higher operating costs. Over the years, different kinds of shell and tube heat exchangers are developed those are shown in figure 1 to figure 9, studied and better understanding has been achieved by many scientist, academicians and researchers.

Baffles are playing major role in shell and tube heat exchangers to enhance the performance of it. Several investigations have carried out to improve the performance, pressure drop, service life of a shell and tube heat exchangers using different types of baffles like segmental baffle, helical baffle (continuous, discontinuous and overlapped), disk and doughnut baffle, rod baffle etc. The major issues with the conventional segmental baffles are: high pressure drop on shell side, low heat transfer coefficient, low mass flow rate in shell side, low service period, more vibration [1, 10-13]. To avoid the problems caused by shell and tube heat exchangers with segmental baffles and upgrade the design.

A fresh look is needed towards baffle arrangement, while producing a high enough heat transfer rate. Since 1991, Lutcha and Nemcasky [3, 10-13] introduced a new type of baffles arrangement known as helical baffles shown in figure 2 is developed in the Czech Republic [14], then same investigation done by Norwegian group [14]. Guidong Chen et al (2008) listed out the advantages of helical baffle shell and tube heat exchangers with helical baffles [3] those are: enhancement of shell side heat transfer, reduction in pressure drop, reduction in fouling, controlling of induced vibration due to flow [3].

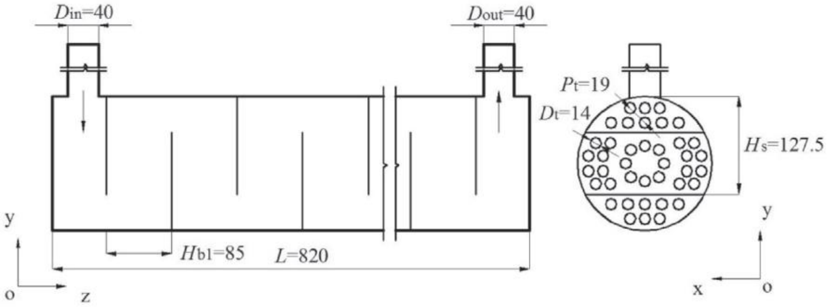

Fig 1: Shell and Tube Heat Exchanger with Segmental Baffles [7]

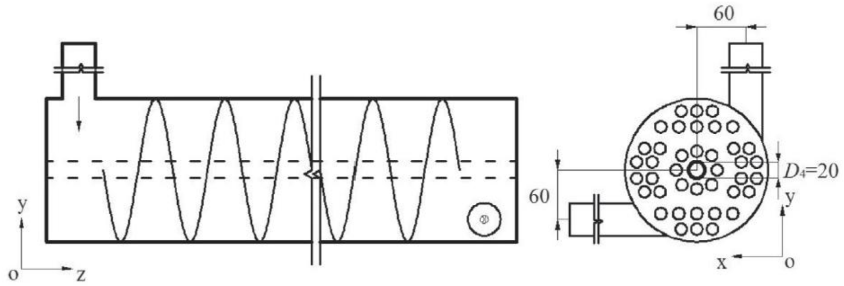

Fig 2: Shell and Tube Heat Exchanger with Continuous Helical Baffles [7]

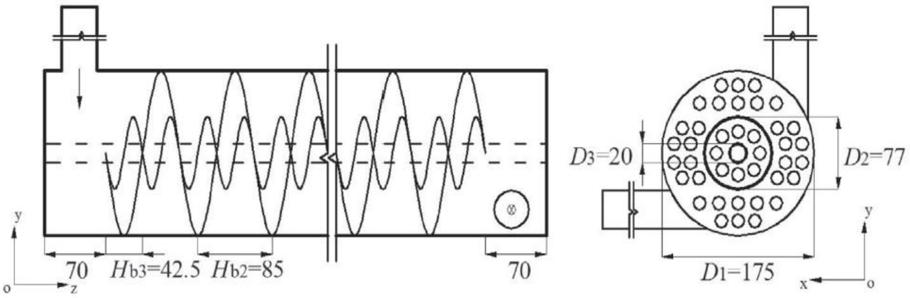

Fig 3: Shell and Tube Heat Exchanger with Combined Single shell pass Helical Baffles [7]

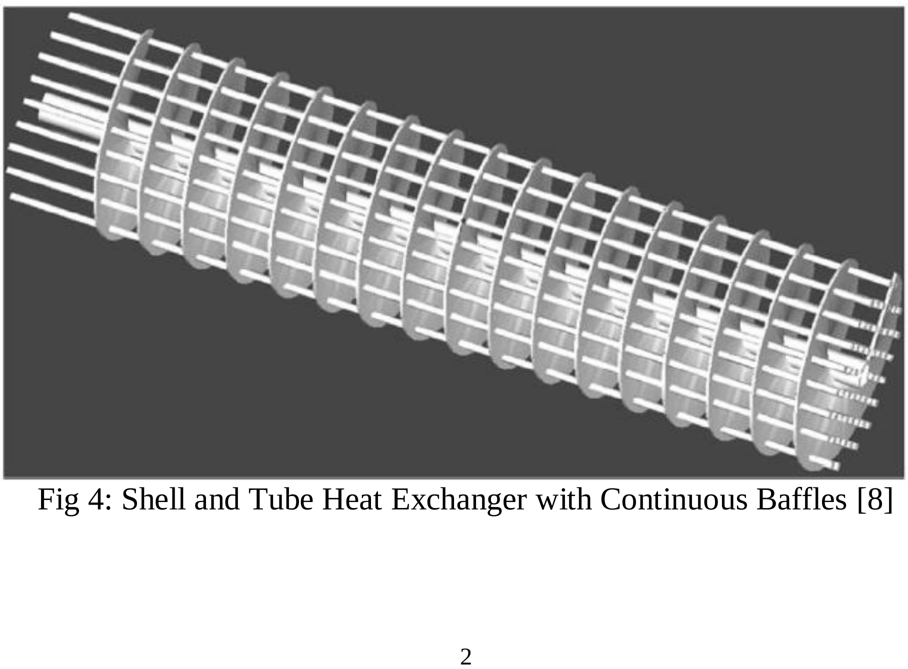

Fig 4: Shell and Tube Heat Exchanger with Continuous Baffles [8]

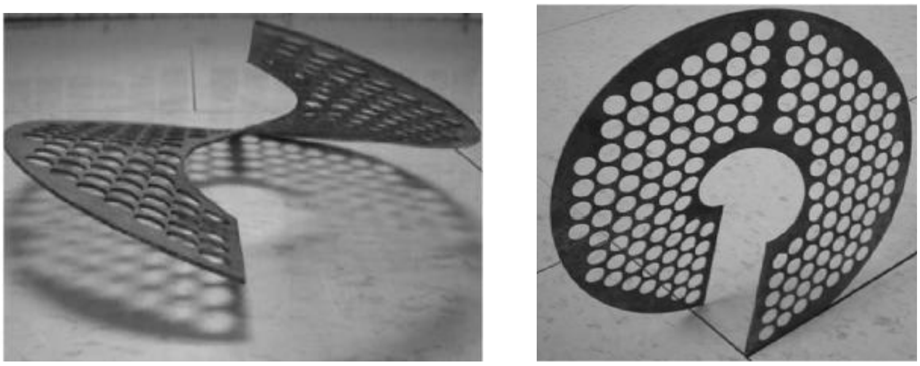

Fig 5: One Helical Cycle of Helical Baffles

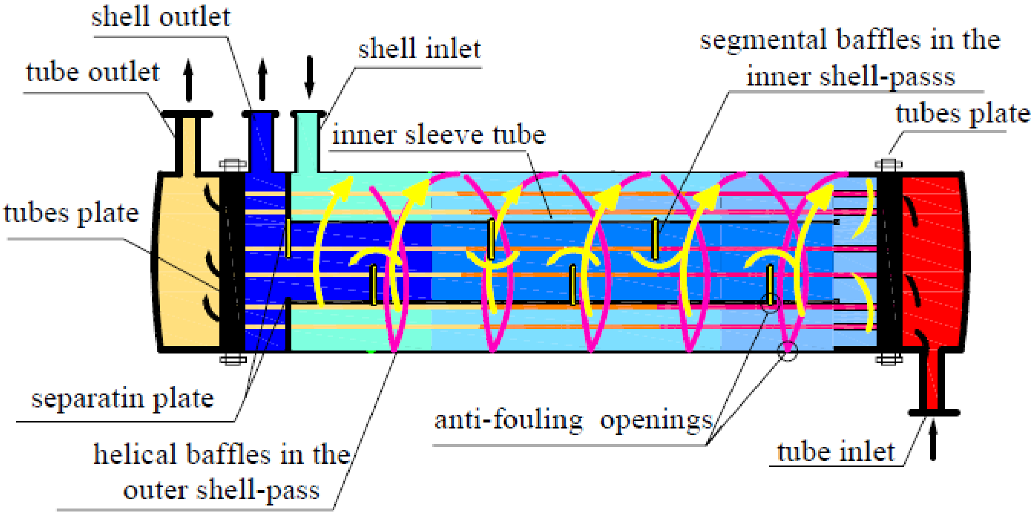

Fig 6: Combined Multiple Shell and Tube Heat Exchanger with Continuous Helical Baffles [3]

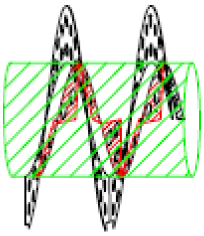

Fig 7: Inner Discontinuous Helical Baffles [3, 9]

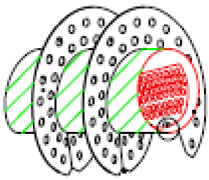

Fig 8: Inner Segmental Baffles [3, 9]

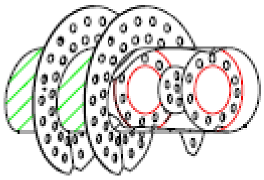

Fig 9: Inner disk and doughnut baffles [3, 9]

Literature

Asif Ahmed et al (2017) conducted numerical simulation on two shell and tube heat exchangers with conventional segmental baffles as well as continuous helical baffles by varying shell side fluid as engine oil with a mass flow rate of 0.5 kg/s to 2 kg/s at a temperature of 100^0C and tube side water as fluid with a mass flow rate of 1 kg/s at a temperature of 25^0C. They found that the shell and tube heat exchanger with helical baffle has 72 to 127% higher heat transfer coefficient per unit pressure drop, shell side heat transfer coefficient is 16-28% lower and shell side pressure drop is 59-63% higher when compared with segmental baffle shell and tube heat exchanger at same mass flow rate. They concluded that for the same geometric structure, the shell and tube heat exchanger with continuous helical baffle is more suitable when compared with the conventional segmental baffles.

Anuruddha Bhattacharjee et al (2017) conducted numerical simulations of shell and tube heat exchangers with different geometric configurations of continuous helical baffles of same dimensions with different helix angles (25.52^0, 17.66^0 and 10.81^0) by using finite element methods and water as tube side fluid at a temperature of 25^0C with mass flow rate of 2kg/s and engine oil as shell side fluid by varying mass flow rates from 2 kg/s to 10 kg/s at a temperature of 100^0C. They found that the poor heat transfer performance at helix angle of 25.52^0C. Shell and tube heat exchangers with 10.81^0 helix angle have highest heat transfer coefficient and 25.25^0 have the lowest heat transfer coefficient when comparing the all geometrical helical baffles heat exchangers.

Guidong Chen et al (2008) numerically studied to enhance the heat transfer performance using combined multiple shell pass shell and tube heat exchanger with continuous helical baffles of helix angle 25^0 and water as working fluid. They found that the overall heat transfer rate, overall pressure drop of the combined multiple shell and tube heat exchanger with discontinuous helical baffles or segmental baffles in the inner shell pass is 12-13% lower than the segmental baffle shell and tube heat exchanger under the same mass flow rate.

Jian Fei Zhang et al (2009) experimentally studied on shell and tube heat exchangers with different helix angles (20^0, 30^0, 40^0 and 50^0) and compared with segmental baffle shell and tube heat exchanger. They noticed that the pressure drop of the shell and tube heat exchanger with helical baffle of helix angle 20^0, 30^0 are 45-65% and 55-75% lower than the shell and tube heat exchanger with segmental baffle, the shell side heat transfer coefficients of the shell and tube heat exchanger with segmental baffle under the same inside diameter and mass flow rate. The heat transfer coefficients per unit pressure drop of the shell and tube heat exchangers with helical baffle of helix angle 20^0 and 30^0 are increases by 30-65% and 120-162% over the segmental baffle. They concluded that the shell and tube heat exchanger with 40^0 helix angle helical baffle one is best when compared with other shell and tube heat exchangers.

Jian Feng Yang et al (2015) numerically investigated on three different heat exchangers which are shell and tube heat exchanger with segmental baffles, shell and tube heat exchanger with continuous helical baffles and combined single shell pass shell and tube heat exchanger with two layer continuous helical baffles. They found that the pressure drop of the combined single shell pass shell and tube heat exchanger with two layer continuous helical baffles is 25% and shell and tube heat exchanger with continuous helical baffles is 14% lower than that of the shell and tube heat exchanger with segmental baffle, combined single shell pass shell and tube heat exchanger with two layer continuous helical baffles is 13% lower pressure drop than the shell and tube heat exchanger with continuous helical baffles. The heat transfer rate and heat transfer coefficient of the combined single shell pass shell and tube heat exchanger with two layer continuous helical baffles are 2.4% and 4.2% and the heat transfer rate and heat transfer coefficients of shell and tube heat exchanger with continuous helical baffle are 4.5% and 7.9% higher than the shell and tube heat exchanger with segmental baffle.

Jian Fei Zhang et al (2009) studied the numerical model of a heat exchanger with middle overlapped helical baffles of helix angle 40^0. They found that the difference of Nusselt number in the fifth cycle and second cycle is 2% and fourth cycle and fifth cycle is 0.5% among the six cycles. Jian Fei Zhang et al (2009) studied the numerical model of a heat exchanger with middle overlapped helical baffles of helix angles 30^0, 40^0 and 50^0. They found that the helix angle 40^0 of helical baffle shell and tube heat exchanger is optimum in case of heat transfer coefficient per unit pressure drop.

Peng B et al (2007) experimentally studied on shell and tube heat exchangers by using continuous helical baffles instead of conventional segmental baffles. They found that the heat transfer coefficient of the heat exchanger with the side in side out shell design is 2% higher than the middle-in-middle-out shell design at a high shell side fluid flow rate and the heat transfer coefficient of the continuous helical heat exchanger with side-in-side-out shell design is 10% higher than the conventional segmental heat exchanger.

Qiuwang Wang et al (2010) reviewed the previous research articles of shell and tube heat exchangers with continuous helical baffles, combined single and combined multiple shell pass heat exchangers. They concluded that the heat exchanger with continuous helical baffles is superior than the segmental baffle or overlapped helical baffles, the combined helical baffled shell and tube heat exchanger in single shell pass have higher heat transfer coefficient than the segmental baffles, the combined multiple shell pass heat exchangers with helical baffles can enhance the comprehensive heat transfer performance when compared with the segmental baffles.

Ravi Gugulothu et al (2016, 2018) reviewed the previous researcher's journals and concluded that the helical baffle shell and tube heat exchanger is reducing the pressure drop and producing high rate of heat transfer when compared with conventional segmental baffles. Among different types of helical baffles, 40^0 helix angle baffles is optimum to design shell and tube heat exchanger to overcome the drawback with conventional segmental baffle. Based on the above review they designed a shell and tube heat exchanger with 40^0 helix angle and done a numerical study on it. Ravi et al conducted numerical studies on shell and tube heat exchanger with helical baffle of 40^0 helix angle [12] are calculated heat transfer coefficient, pressure drop and overall heat transfer coefficient on both (shell side as well as tube side) side of shell and tube heat exchanger.

Stehlik P et al (1994) designed and studied the heat transfer and pressure drop correction factors for segmental as well as helical baffle heat exchangers based on the Bell Delaware method. They found that the decrease in pressure drop ranged from 0.26 to 0.6 at an increase of helix angle from 5^0 to 45^0. They concluded that the 45^0 helix angled shell and tube heat exchanger is optimum for helical baffle shell and tube heat exchanger.

Tasouji Azar R et al (2010) numerically studied the performance of two shell and tube heat exchangers using CFD method at same parameters other than baffle geometries. One is shell and tube heat exchanger of segmental baffles and another one is shell and tube heat exchanger of single middle overlapped helical baffles with helix angle of 40^0. The conductive-320 oil as shell side fluid with mass flow rate of 3.54 kg/s to 12 kg/s. They found that the pressure drop with shell and tube heat exchanger with helical baffle is 90% lower than the segmental baffle under the same mass flow rate, the heat transfer coefficient of helical baffle is about 34-50% lower than segmental baffle. They concluded that the shell and tube heat exchanger with helical baffle given significant results when compared with the segmental baffle.

Xiaoming Xiao et al (2013) numerically studied the helical baffles heat exchanger at different Prandtl number and different helix angles from 0^0 to 50^0 with different shell side fluids (water and glycerin). They found that the 40^0 helical baffle shell and tube heat exchanger contained shell side fluid as water is having the best heat transfer performance at smaller the Prandtl number.

Conclusion

From the above literature review shell and tube heat exchangers with helical baffle is more suitable when compared with the conventional segmental baffle shell and tube heat exchanger. Because of less flow induced vibrations and fouling factor in shell side. It will increase the service life of the equipment, reducing the operating costs, operational time and more energy savings. It indicates that baffles are playing major role in shell and tube heat exchangers. The flow becomes more uniform with the decreasing of helix angle, baffle pitch and maximum velocity of flow is occurring at smaller helix angle in continuous helical baffle shell and tube heat exchanger, this will be helpful for better mixing of fluid flow and higher turbulence will be generated. Heat transfer performance increases with the decreasing of helix angle. Maximum shell and tube heat exchangers are made up of steel material. Lower pressure drop leads to the lower operating cost. Shell side heat transfer coefficient of shell and tube heat exchangers with helical baffle is lower than the shell and tube heat exchanger with segmental baffle. The overall pressure drop decreases with the increasing of helix angle. For the same mass flow rate, the shell and tube heat exchanger with helical baffle has a much higher heat transfer coefficient per unit pressure drop or pumping power and the shell and tube heat exchanger with helical baffle of helix angle 40^0 shows the best performance or optimum helix angle among the different helix angles. The pressure drop increases with the increase of volume flow rate and the heat transfer coefficient increases significantly with the increase in the overall pressure drop.

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