Volume 5, Special Issue, June 2018 ISSN: 2348-8565 (Online)
International Journal of Modern Engineering and Research Technology
Website: http://www.ijmert.org Email: editor.ijmert@gmail.com

National Conference on
Advances in Mechanical Engineering and Nanotechnology (AMENT2018)
29-30 June, 2018
Organized by
Department of Mechanical Engineering, University College of Engineering (A), Osmania University, Hyderabad, TS, India

Numerical Investigation on Heat Transfer of Helical Baffles Shell and Tube Heat Exchanger

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ABSTRACT

Heat exchangers are playing major role in heat and mass exchange apparatus like electrical power generation plants, oil refining, environmental protection and chemical engineering processes. Helical baffles with 400 helix angle are used in shell and tube heat exchanger to enhance the heat transfer and reduce the pressure drop. New geometries have been introduced to performance enhancement and to improve reliability of heat exchangers. In this present study, shell and tube heat exchanger has been designed based on TEMA standard and thermal characteristics are observed based on different Reynolds number in shell side (ranging from 2,500 to 16,500) as well as tube side (3,000 to 22,000). The heat transfer coefficient, friction factor and overall heat transfer coefficient have been estimated for different Reynolds numbers and noticed that the heat transfer coefficient, overall heat transfer coefficients are increasing along the increase of Reynolds number and friction factor reduces by increasing Reynolds number.

I. INTRODUCTION

Heat exchangers are playing major role in heat and mass exchange apparatus like electrical power generation plants, oil refining, environmental protection and chemical engineering processes. Among different types of heat exchangers shell and tube heat exchangers have been commonly used in Indus tries, due to the robust construction geometry as well as easy maintenance and possible upgrades. The heat transfer effectiveness can be improved by using baffles in shell and tube heat exchangers. Segmental baffles are mostly used one to support tubes and change the direction of fluid flow.

Higher pumping power is needed to offset the higher pressure drop when the segmental baffles are used in shell and tube heat exchangers under the same load. Therefore it is essential to develop a novel shell and tube heat exchanger using different baffles to have higher heat transfer efficiency and lower pressure drop. Shell and tube heat exchanger with helical baffles introduced by Lutcha and Nemcansky in May, 1990. Helical baffles serve as guide vanes for shell side flow when compared to segmental baffles. The use of continuous helical baffles in shell and tube heat exchangers can improve the performance. However, very few research works are done on shell and tube heat exchangers using continuous helical baffles. The pioneering work published is given in literature.

II. Literature Review

Master B.I et al (2006) gave the importance of heat exchangers along the worldwide applications of it. Bin Gao et al (2015) has experimentally studied on flow resistance and heat transfer of several shell and tube heat exchangers with discontinuous helical baffles of helix angles 8°, 12°, 20°, 30° and 40°. Their results provide the s hell and tube heat exchanger with 40° helix angles is the best comprehensive performance among 8°, 12°, 20°, 30° and 40° helix angles. Cong Dong et al (2016) experimentally studied on circumferential overlap trisection helical baffles shell and tube heat exchanger with folded baffles, their results shows the heat transfer performance and comprehensive performance evaluation indexes of the circumferential overlap trisection helical baffles are much better than the segmental baffle heat exchanger.

Jian Fei Zhang et al (2009) experimentally studied the flow and heat transfer characteristics on several shell and tube heat exchangers, one with segmental baffles and helical baffles of four different helix angles like 20°, 30°, 40° and 50°. They found that the shell and tube heat exchanger with 40° helix angle shows the best performance under the same volume flow rate. Jian Fei Zhang et al (2009) carried 3D numerical simulation on shell and tube heat exchangers with three different helix angles like 30°, 40° and 50° and found that the 40° helix angles shell and tube heat exchanger given best performance among all the three helix angles.

The heat exchanger has 2000 mm length and 114.3 mm, 102.10 mm of shell outer and inner diameters are chosen with 4 numbers of tubes with outer diameters are 25.4 mm, arranged in an angle of 45° rotating square arrangement. From literature the optimum helix angle (β) is 40° and same has been considered for the present work and thickness of the baffle is 3 mm. Hot fluid is considered in shell side at temperature of 343.15 K and cold fluid is considered in tube side at temperature of 298.15 K. In this study shell side flow rate (Q_s) and tube side flow rates (Q_t) are considered as 20 lpm to 60 lpm and 10 lpm to 30 lpm.)

Baffle spacing (S) = 0.2 × D_i or 51mm. (Whichever is greater). (1)

Tube outer diameter (D_0) = 25.4mm from Table RCB-4.52 (2)

$$p = 1.25 \times d_0 \tag{3}$$

$$B_{helical} = \sqrt{2} D_i \tan(\beta) \tag{4}$$

$$m = Q_s \times P_s \tag{5}$$

Shell Side Calculation

$$A_s = 0.25\,\pi\left(D_i^2 - \left(N \times d_0^2\right)\right) \quad (6)$$

$$V_s = \frac{m_s}{\rho_s A_s} \quad (7)$$

$$D_e = \frac{4\left(P_t^2 - \left(0.25\,\pi - d_0^2\right)\right)}{\pi d_0} \quad (8)$$

Equivalent/Effective diameter varies with the flow arrangements.

$$\mathrm{Re}_S = \frac{V_S \times D_e}{\nu} \quad (9)$$

$$\mathrm{Pr}_S = \frac{\mu C_p}{k_{ShellFluid}} \quad (10)$$

For turbulent flow, Dittus -Boelter correlation is used

$$h_S = 0.023 \times \left(\frac{k_{ShellFluid}}{D_e}\right) \times (\mathrm{Re})^{0.8} \times (\mathrm{Pr})^{0.3} \quad (11)$$

$$Nu_S = \frac{h_S \times D_e}{k_{ShellFluid}} \quad (12)$$

$$f_S = 0.184 \times (\mathrm{Re})^{-0.2} \quad (13)$$

$$\Delta p_S = \frac{\rho \times f_S \times L_S \times V_S^2}{2 \times B} \quad (14)$$

$$Q_s = mC_{p,s}\left(T_{s,in} - T_{s,out}\right) \quad (15)$$

Tube side calculation

$$m_t = Q_t \times P_t \quad (16)$$

$$A_t = N \times A_0 \quad (17)$$

$$V_t = \frac{m_t}{\rho_t \times A_t} \quad (18)$$

$$\mathrm{Re}_t = \frac{V_t \times d_i}{\nu} \quad (19)$$

For turbulent fluid flow, from Dittus-Boelter correlation,

$$\mathrm{Pr}_t = \frac{\mu C_p}{k_{tubefluid}} \quad (20)$$

$$h_t = 0.023 \times \left(\frac{k_{tubefluid}}{d_i}\right) \times (\mathrm{Re})^{0.8} \times (\mathrm{Pr})^{0.4} \quad (21)$$

The heat transfer coefficient can be calculated by the Nusselt number equation.

$$Nu_t = \frac{h_t \times d_i}{k_{tubefluid}} \quad (22)$$

$$f_t = 0.184 \times (\mathrm{Re})^{-0.2} \quad (23)$$

$$\Delta p_t = \frac{\rho \times f_t \times L \times V_t^2}{2 \times d_i} \quad (24)$$

$$Q_t = mC_{p,t}\left(T_{t,in} - T_{t,out}\right) \quad (25)$$

$$Q = \frac{Q_s + Q_t}{2} \quad (26)$$

$$\Delta T_{\max} = T_{s,in} - T_{t,out} \quad (27)$$

$$\Delta T_{\min} = T_{s,out} - T_{t,in} \quad (28)$$

$$\Delta T_{LM} = \frac{\left(\Delta T_{\max} - \Delta T_{\min}\right)}{\ln\left(\frac{\Delta T_{\max}}{\Delta T_{\min}}\right)} \quad (29)$$

$$A_0 = N.\pi d_0.l_{tb} \quad (30)$$

$$U = \frac{Q}{A_0 \times \Delta T_{LM}} \quad (31)$$

Number and size of tie rods: No fewer than four tie rods and not less than 9.5mm of diameter. Any baffle segment requires a minimum of three points of supports.

III. Research Methodology

The heat exchangers are devices which transfers heat between two fluids which are at different temperatures. A shell and tub heat exchanger consists of a bundle of tubes enclosed within a cylindrical shell. One fluid flows through the shell and another fluid flowing through the tubes. The fluid flow and heat transfer processes are turbulent flow and steady state. The shell and tube heat exchanger consider in the present study with helical baffles is shown in figure 1.

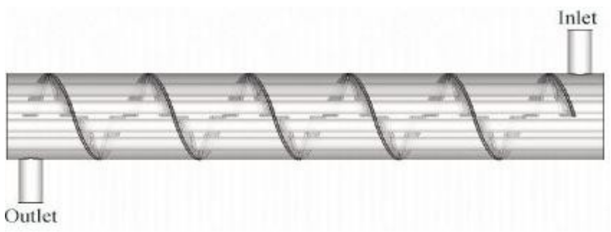

Figure 1: Shell and Tube Heat Exchanger with Helical Baffle

IV. Results and Discussion

Numerical analysis of shell and tube heat exchangers using 40° helical baffles are conducted in MAT Lab and results are discussing here.

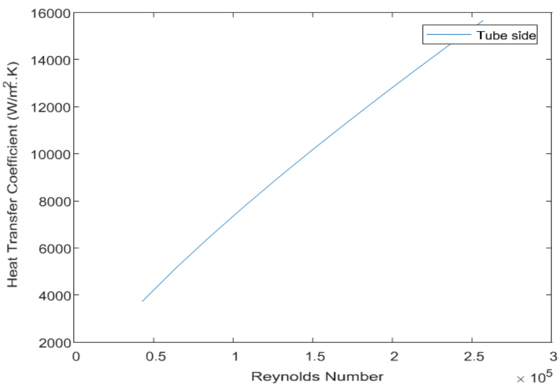

Figure 2: Reynolds number Vs Heat Transfer Coefficient (Shell side and Tube side)

Figure 2 shows the increase of heat transfer coefficient along the Reynolds number in shell side as well as tube side, due to the increase in flow rates.

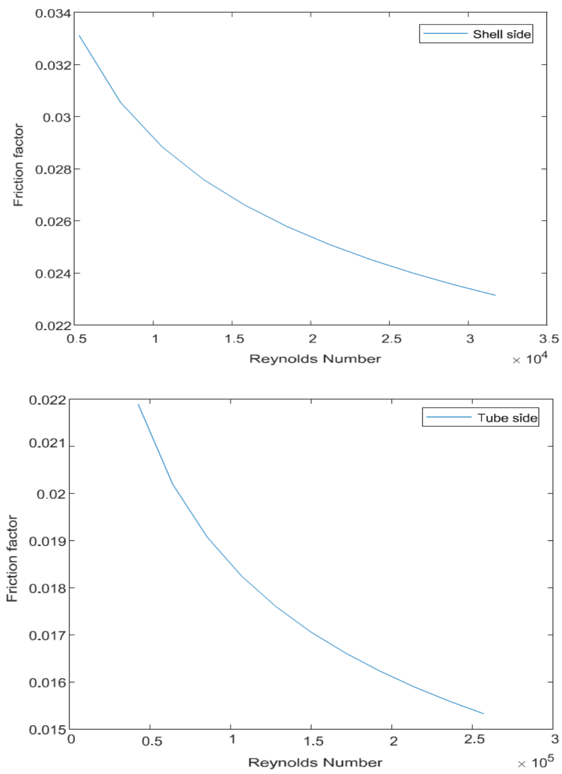

Figure 3: Reynolds number Vs Friction factor (Shell side and Tube side)

Figure 3 predicts the friction factor decreases along the increasing of Reynolds number in shell side and tube side for a helical baffled shell and tube heat exchanger. This is due to increase of mass flow rates.

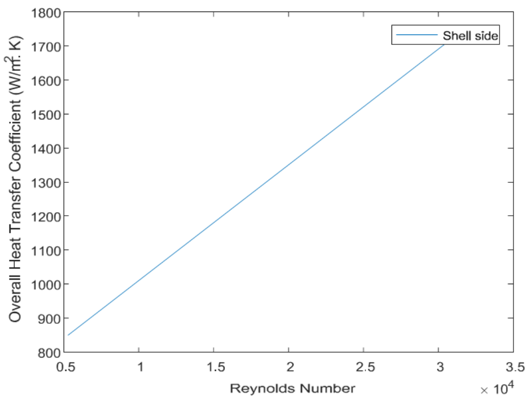

Figure 4: Reynolds number Vs Overall Heat Transfer Coefficient (Shell side)

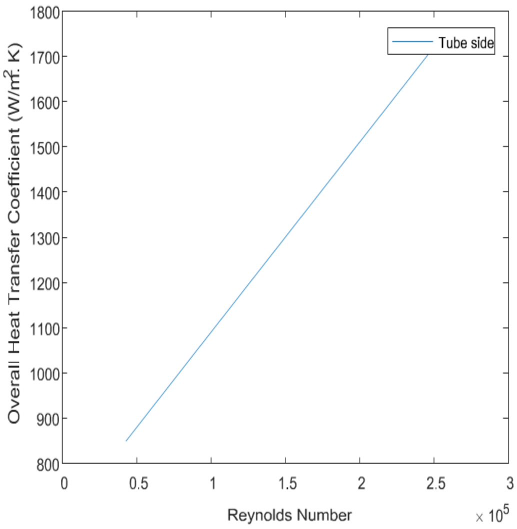

Figure 5: Reynolds number Vs Overall Heat Transfer Coefficient (Tube side)

Figure 4 indicates the Reynolds number Vs Overall heat transfer coefficient. Overall heat transfer coefficient increases with the increasing of Reynolds number. This is happen, due to increasing of flow rates .

V. CONCLUSIONS

The research on shell and tube heat exchangers with helical baffles is done by many researchers and it was proved that pres sure drop decreases and increases the heat transfer. For many years, various types of baffles have been used in shell and tube heat exchangers to improve the heat transfer while maintaining a reasonable pres sure drop. Helical baffles are proved the suitable type of baffles for enhancing the heat transfer and reducing the pressure drop in shell and tube heat exchangers . From the pioneering work, the great significant in the improvement of heat exchangers with helical baffles and the heat transfer increases with the decreasing the helix angles and become mild after the helix angle 40° for larger flow rates and 12° for smaller flow rates. The friction factor decreases with the increase of Reynolds number in shell and tube heat exchangers. Heat transfer coefficient increases with the increasing of Reynolds number.

REFERENCES:

[1] Bin Gao, Qincheng Bi, Zesen Nie and Jiangbo Wu, “Experimental study of effects of baffle helix angle on shell side performance of shell and tube heat exchangers with discontinuous helical baffles”, Experimental Thermal and Fluid Science 68(2015), pp: 48 -57.

[2] Cong Dong, Dongshuang Li, Youqu Zheng, Guuoneng Li, Yange Suo and Yaping Chen, “An efficient and low resistant circumferential overlap trisection helical baffle heat exchanger with folded baffles”, Energy Conversion and Management 113 (2016), pp: 143 -152.

[3] Jian Fei Zhang, Bin Li, Wen Jiang Huang, Yong Gang Lei, Ya Ling He and Wen Quan Tao, “Experimental performance comparison of shel side heat transfer for shell and tube heat exchangers with middle overlapped helical baffles and segmental baffles”, Chemical Engineering Science 64(2009), pp: 1643 -1653.

[4] Jian Fei Zhang, Ya Ling He and Wen Quan Tao, “3D numerical simulation on shell and tube heat exchangers with middle overlapped helical baffles and continuous baffles-Part II: Simulation results of periodic model and comparison between continuous and non-continuous helical baffles”, International Journal of Heat and Mass Transfer 52 (2009), pp: 5381 -5389.

[5] Jian Wen, Huizhu Yang, Simin Wang, Yulan Xue and Xin Tong, “Experimental investigation on

performance comparison for shell and tube heat exchangers with different baffles", International Journal of Heat and Mass Transfer 84 (2015), pp: 990 -997.

[6] Lutcha J and Nemcansky J, "Performance improvement of tubular heat exchangers by helical baffles", Chem. Eng. Res. Des, 68 (1990), pp: 263 -270.

[7] Master B.I, Chunangad K.S, Boxma A.J, Kral D and Stehlik P, "Most Frequently Used Heat Exchangers from Pioneering Research to Worldwide Applications", Heat Transfer Engineering, 27(6), pp: 4 - 11, 2006.

[8] Peng B, Wang Q.W, Zhang C, Xie G.N, Luo L.Q, Chen Q. Y and Zeng M, "An Experimental Study of Shell and Tube Heat Exchangers With Continuous Helical Baffles", Journal of Heat Transfer, October 2 007, Vol.: 129, pp: 1425-1431.

[9] Ravi Gugulothu, Narsimhulu Sanke and A.V.S.S.K.S Gupta, "Numerical Study of flow characteristics in shell and tube heat exchangers", Proceedings of the International Conference on Numerical Heat Transfer and Fluid Flow (NHTFF-2018).

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