Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. **10(3),** 36-38, September **(2021)** *Res. J. Engineering Sci.*

Experimental analysis and investigation on twisted tube shell type heat exchanger

Kushal Desai, Priyeshnath Rathod, Pallav Bariya, Rohan Doshi and Abhishek Bagul
Dept. of Chemical Engineering, Parul Institute of Technology (PIT), Parul University, Vadodara, India
kushalsdesai2942@gmail.com

Available online at: www.isca.in, www.isca.me
Received 4th May 2021, revised 19th August 2021, accepted 15th September 2021

Abstract

A lot of heat exchangers which are employed in the oil refineries, petro-chemical, chemical, dairy, pharmaceutical industries are simple shell and tube heat exchanger. However, there are certain drawbacks related to the technology like inadequate using of shell area pressure drop, flow zones which are dead round the baffle like structure, vibration, collection of unreactive chemical materials and low heat transfer. Despite, plenty of information is available, there is a serious lack of thermal-hydraulic design guidelines. We would like to show a very new fresh concept and formation of totally new advanced technology, referred to as Twisted Tube Design, which would surpass the drawbacks that are associated with orthodox shell and tube heat exchanger. This paper describes the experimental testing and working of twisted tube heat exchanger which upsurge the level of mixing and enhance turbulence in low Reynolds number range. This analysis examines the working performance, thermal design, and development of helical Tube shell type heat exchange equipment.

Keywords: Twisted Helical Tube Geometry, Swirl flow parameter, Fouling factor, Reynolds number, Heat transfer coefficient, Pressure drop.

Introduction

A Heat Exchanger is equipment that is used to transfer heat between two or more fluids at varied temperatures and within thermal contact. It is anticipated and very well predicted that ameliorated equipment for transferring the heat; is a less expensive, verified and trusted remedy for varied existential necessity of exchanging heat. Nevertheless, certainly some drawbacks associated to this type of automation. The factors who are more likely to show the characteristics[1] of predominance, eventually play a prominent role such as less utilization of hollow part area, difference in pressure, and not indispensable part which leads to the path of baffle structure where detrimental of inner parts and rusting could definitely take place, and quivering of small tubes may eventually result as deterioration gradually. This research study depicts a recent innovation and formation of a newly design heat exchanger, known as Helical[2] type heat exchanger advancement, which possess the ability to subdue the beforehand demerits of old version. 'Twisted Tube Technology' is the new emerging innovation in the era of heat transfer equipment. Twisted tube Shell Type heat exchanger combats nearly all performance limitations in conventional heat exchangers. The concept and well proved theories of swirl[3] flow moment of fluid generates turbulence which experimentally enhances thermal-hydraulic performance of newly fabricated heat exchanging device. The moulded tube shell type heat exchanger device drastically surges the overall efficacy[4] of heat transfer. The merits of advanced heat exchanger over orthodox heat exchanger are on the account of performance.

The objective is to significantly raise the capacity, diminish operating cost, lower down shell side pressure drop[5] and low fouling near shell and tube heat exchanger. The hardships[6] faced are mostly in operating, maintaining and optimizing these type heat exchangers. In this research study we are differentiating the two heat exchanger (Simple Shell and Tube heat Exchanger and Twisted Tube Shell Type Heat Exchanger) using working process model of the same. We have performed an experiment of a working model on the basis of heat exchanger characteristics.

Twisted tube: It encompasses a set of bundle of tubes cemented inside a cylindrical[7] outer shell. The design differentiates from a usual (orthodox) shell-and-tube exchanger by having elliptical and helical tubes twisted along the longitudinal axis. The Twists in numbers per unit length can differ from one design to another design. The tube length[8] between each 360 degree. Manufacturing of each Twisted tube is done with round ends so that it can easily find its place into the tube sheets by some common methods. Each tube is retained in parallel position by series of points of contacts to the adjacent tubes. This task is comfortably accomplished by fixing each tube such that the cross sections are aligned perfectly so that this kind of adjusting techniques results in six contact points per each 360 degree twist. The bundle is firmly strapped with the help of metal belts after the installation of the tubes. Such tube configuration gives us a very strong bundle construction, which also have a great impact in performance. Manufacturing of unique twisted tube will be made out of full varieties of different materials involving stainless steels, carbon steels[9], copper, nickel alloys.

Tubes can be arranged either in a triangular or a rectangular pitch and the tube cross-section can be changed. A colossal[10] deformation will give a minute cross-section on the tube side area in compare to the shell side area, while a major change will give the opposite result. Variations in tube cross section provides reliability in the design to gain the specific use. Usual kind of heat exchanger is indeed completely equipped with a number of baffles. Baffles[11] play an essential role which are made of metal sheets covering the cross-sectional area of the shell and also enhances the efficiency along the longitudinal axis. Spherical[12] holes are made in the sheets for the tubes and a fixed cut-off opening for the shell side area fluid flow.

Precisely two functions are performed by Baffles. Firstly, it specifically directs the flow perpendicular to the tubes so to enhance heat transfer rate along with heat transfer coefficient. Secondly, the baffle helps to maintain the support for the tubes in order to avert the shaking. As a matter of fact, the helically tube and shell type unique pattern provides a firm and complacent whole group of tube in contrast to the common heat exchanger concept. Every tube is in continuous physical contact with the surrounding tubes.

Methodology

$Q = f_t * U * A * \Delta T_{lm}$ (1)

$d_h = d_{max} * d_{min} / \{3(d_{max}+d_{min})[(3d_{max}+d_{min})(d_{max}+3d_{min})]0.5$ (2)

$Nu = -hdh/k$
$Re = \rho * v * dh / \mu$
$Pr = C_p * \mu / k$
$Fr = S^2 / d_{max} * d_h$ (3)

Tube side coefficient: $Nu = 0.21 * Re0.8Pr0.4 * [1 + 3.74 (s/dmax) - 1](Twt/Tbt)^n$ (4)

Shell side coefficient: $Nu = 0.521 * Re^{0.8} * Pr^{0.4} *$

$(Tws / Tbs)^{-0.55}$ (5)

Overall heat transfer coefficient: $U = (1/hi + L/kc + Rf + 1/ho)$ (6)

Total pressure drop $\Delta P_{Total} = \Delta P_{entrance} + \Delta P_{core} + \Delta P_{exit}$ (7)

Tube side friction coefficient: $f_D = 0.92 * (s/dh)^{-0.55} * Re^{-0.18}$ (8)

Shell side friction coefficient: $fD = 10.5 Fr^{-1.6181+2.263 \log FR}$ (9)

Core pressure drop $\Delta P_{core} = f_D * L / 2dh\rho v^2$ (10)

Nusselt number = f(Re, Pr, Fr)

Darcy friction factor = f(Re, Fr)

Results and discussion

Percentage Difference between two exchanger is given as follows: Percentage = (U of Twisted tube shell type HE – U of conventional shell type HE)* 100/ U of Twisted tube shell type HE.
= 937.674−652.143/937.674
= 30.46%

So, it is well observed from the calculations and above experimental study, eventually we can conclude that the twisted tube shell type heat exchanger is perfect and ideal replacement for simple exchanger. The helical shaped tube shell type heat exchanger has ability to inculcate fewer tubes, less shell diameter and provides more heat transfer for the same mass flow of fluids.

Component/ Property	STHE	TTHE
No. of Tubes	12	8
Over all (U) Heat Transfer Co-efficient (W/m2C)	652.143	937.674
Shell Area Heat transfer Co-efficient (W/m2C**)**	4357.355	7772.595
Tube Area Heat transfer Co-efficient (W/m2C)	3883.124	5919.904

Based on my examinations it is very lucid that; i. The performance in thermal aspects is exceptionally well than conventional heat exchanger. ii. Due to uniform and evenly distributed flow, the dead spots are eliminated as well as the fouling is reduced. iii. The Firmness[14] and strength of tube bundle enables the heat exchanger to be free of baffles. iv. Fouling is declined due to the newly design of twisted tube in twisted tube heat exchanger. v. The gained heat transfer is far more than the increase in pressure drop.

Conclusion

The formation and development, thermal-hydraulic[15] characteristics, working process and comparison of DNA resembling structure tube shell type heat exchanger has been studied. All the observations gives anindication that the twisted tube shell type heat exchange describes a substantial amount of advantages which overweigh the uncommon shell[16] and tube exchangers. Generally the initial cost is high than the simple exchangers; however the payback time is very less so eventually it is beneficial.

Nomenclature: d_h- hydraulic diameter. S –Twisted pitchin tube bundle, Fr - dimensionless swirl number[17]. T_{ws}, T_{bs}- Temperature of wall and bulk flow on shell side. T_{wt}, T_{bt}- Temperature of wall and bulk flow on tube side. F_d-Darcy friction factor. $\Delta \boldsymbol{T}_{lm}$= logarithmic temperature difference. F_t= correction factor for log mean temperature difference[18].

References

1. Morgan, R. D. (2001). Twisted tube heat exchanger technology. In Corrosion Solutions International Conference (pp. 75-82).

2. Rajput R. K. (2008). Heat and Mass Transfer books. 7th Edition, pp 574.

3. Kothandaraman C.P. and Subramanyan S. (2006). Heat and Mass Transfer Data Book. 5th Edition, pp 115.

4. Bartlett, D. A. (1996). The fundamentals of heat exchangers. *The Industrial Physicist*, 2(4), 18.

5. Singh, G., & Kumar, H. (2014). Computational fluid dynamics analysis of shell and tube heat exchanger. *Journal of Civil Engineering and Environmental Technology*, 1(3), 66-70.

6. Wang, Q., Chen, G., Xu, J., and Ji, Y. (2010). Second-Law Thermodynamic Comparison and Maximal Velocity Ratio Design of Shell-and-Tube Heat Exchangers With Continuous Helical Baffles. ASME. *J. Heat Transfer*., 132(10), 101801.

7. Sinnott R. K. (2005). Chemical Engineering Design. 4th Ed", Elsevier Butterworth Hienemann, NY. ISBN 0-7506-6538-6

8. Andre L.H costa and M. Queiroz, (2008). Design optimization of shell and tube heat exchanger. *Apllied Thermal, Engineering*, 28, 1798-1805.

9. Butterworth, D., Guy, A. R., & Welkey, J. J. (1996). Design and application of twisted tube heat exchangers. *Advances in industrial Heat Transfer*, IChemE.

10. Wang, S., Wen, J., & Li, Y. (2009). An experimental investigation of heat transfer enhancement for a shell-and-tube heat exchanger. *Applied Thermal Engineering*, 29(11-12), 2433-2438.

11. Devarakonda, A., Xiong, D., & Beach, D. E. (2005). Intermediate temperature water heat pipe tests. In AIP Conference Proceedings, American Institute of Physics. 746(1), 158-163.

12. Lunsford, K. M. (1998). Increasing heat exchanger performance. *Hydrocarbon engineering*, 77, 786-793.

13. Jahanmir, G. S., & Farhadi, F. (2012). Twisted bundle heat exchangers performance evaluation by CFD (CJ12/5054). *International communications in heat and mass transfer*, 39(10), 1654-1660.

14. Cengel, Y. A. (2004). Heat Transfer A Practical Approach in SI Units. 2nd Edition, Tata Mcgraw Hill.

15. Mukherjee, R. (1998). Effectively design shell-and-tube heat exchangers. *Chemical Engineering Progress*, 94(2), 21-37.

16. Sriharsha, K., Mamilla, V. R., & Mallikarjun, M. V. (2012). Strength Analysis of Tube to Tube Sheet Joint in Shell and Tube Heat Exchanger. *International Journal of Science, Engineering and Technology Research*, 1(4), 43.

17. Eiamsa-Ard, S., & Promvonge, P. (2010). Performance assessment in a heat exchanger tube with alternate clockwise and counter-clockwise twisted-tape inserts. *International Journal of Heat and Mass Transfer*, 53(7-8), 1364-1372.

18. Danielsen, S. O. (2009). Investigation of a twisted-tube type shell-and-tube heat exchanger. Master's thesis, Institute for energi-og prosessteknikk.