Enhancement of Performance of a Shell and Tube Heat Exchanger using Twisted Tape: A Review

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***Abstract*—Enhancing the heat transfer rate is an important factor in a heat exchanger. One of the most widely accepted way to enhance heat transfer rate is by using twisted tapes inside tubes. Many researches are done on twisted tapes by using full length, half length and reduced width twisted tapes of various twist ratios. It is found that lesser the twist ratio more is the heat transfer rate, but pressure drop also increases and hence reduced width tapes are mostly used in turbulent flows. From the various research studies it can be concluded that most of the studies are done for twist ratio greater than two and also half length tapes are preferred over full length tapes. No study is done on the effect of reduced width tapes instead of half length tapes in laminar flow which may reduce the pressure developed. This work focuses on performance enhancement of the heat exchanger experimental setup using reduced width twisted tapes over full as well as half length twisted tapes inside tubes having twist ratio equal to 1 for laminar flow.**

***Index Terms*—Shell and Tube Heat Exchanger, Heat Transfer Rate, Reduced Width Twisted Tape**

I. INTRODUCTION

The heat loss that takes place in the form of conduction, convection and radiation through various joints header, tube sheet and walls of the shell needs to be calculated to evaluate the performance of the heat exchanger. Parameters such as hot fluid inlet temperature and hot and cold fluid mass flow rate can be varied to get the experimental results to help formation of performance analysis model. To calculate the heat loss, there is a need to analyse the various regions through which the losses can take place. From the numerical model the heat losses can be studied by measuring the parameters experimentally at different conditions. Some amount of heat is lost during the process which affects the effectiveness and heat transfer rate of the heat exchanger.

Use of twisted tape is one of the most widely used methods for enhancing the performance of heat exchangers along with the presence of these loses. The reviewed literature reveals that researchers have limited their work with respect to the dimensions considered for twisted tapes, especially with respect to the width, twist ratio and thickness of the tape. It is also realized that the heat transfer rate is more at the cost of pressure drop when the twist ratio for a twisted tape is lesser. Varying the width of the tape reduces the increase in pressure drop. Work considering such modification was found lacking, which if done, can give more enhancements in the heat transfer rate. Such enhancement methods does not require any power input because it is related to just modifying the existing geometry by having insertion of tapes inside the tubes of heat exchanger thereby making them cost effective. Until now full width and half length twisted tapes of twist ratios more than 2 have been used by the researchers.

II. LITERATURE REVIEW

Heat transfer methods are often used to improve the thermo-hydraulic performance of the heat exchanger. Such methods can be classified into mainly three categories: [1]

i. Active methods: These methods require external power supply to make the desired flow happen in order to achieve increased flow rate. Hence these methods have limited application because of the external power required and its complexity from design point of view.

ii. Passive methods: These methods aims at changing the existing flow patterns by including modifications in the geometry such as insertions, extended surfaces coiled tubes. These methods lead to increase in heat transfer coefficient but leading to increase in the pressure drop.

iii. Compound methods: This method uses a combination of above mentioned techniques to further improve the performance of the heat exchanger. Some of these methods are rotating tube heat exchangers, jet impingement, fluid vibration, surface vibration, injection.

Among these three methods passive technique is considered to be better since it does not require any external power input unlike active and passive techniques. Some modification in the geometry will provide heat transfer enhancement in the heat exchanger without an additional external aid. For single phase heat exchangers, twisted tapes have proved to provide better thermo hydraulic performance.

Heat transfer coefficient is increased by twisted tapes with significant amount of increase in the pressure drop. They are widely used to generate turbulence in the flow because of their convenience in designing for any application. By using twisted tape the size can be made much compact giving better performance.

Many studies and researches are done on enhancement of heat transfer rate by twisted tape in laminar and turbulent flows. Different types of twisted tapes, like full-length twisted tape, full length twisted tape with varying twist ratio, reduced width twisted tape and regularly spaced twisted tape, have been studied widely by many researchers. [2]

Date [3] [4]reported that a deviation of 30% is found in friction and Nu for water flow in tube containing twisted tape as compared to plain tube.

Patil et al. [5] mentioned various types of heat transfer methods required to increase rate of heat transfer and concluded from his work that twisted tape insert leads to better mixing and thus gives better performance in laminar flow. It gives better results provided increase in pressure drop is not considered. Twisted tape is ineffective in turbulent flow, since it just blocks the flow and leads to unnecessary increase in pressure drop. It was also evident from the literature survey that the work on twisted tapes with minimum twist ratio which can give better heat transfer performance is limited.

Royds [6] also reported that a tube with twisted tape gives better performance than plain tube. Higher the twist ratio better is the heat transfer rate for low Prandtl number fluid.

Watcharin Noothong et al. [7] did experimental studies on the effects of the twisted tape insertion on heat transfer and characteristics of flow friction in a double pipe heat exchanger. Pipes with different twist ratios like y = 5.0 and 7.0 was focused on in the experiment for the inner tube. For the conditions investigated with y = 5.0 and 7.0 it was found that the maximum Nusselt numbers are 188% and 159% respectively, higher than that of a normal plain tube.

Salam et al. [8] carried experimental investigation in a circular tube having a stainless steel twisted tape of twist ratio 5.3 as insertion which measured for a turbulent flow the tube side heat transfer coefficient of water. As compared to smooth tube, the ones with twisted tube showed an increase in Nusselt number by 2.9 to 4 times.

Dhamane et al. [9] carried experiments in a circular pipe having helical strips with regularly spaced cut sections. It was found that depending on the Reynolds number, helical tapes can increase the heat transfer rate to about 20%, at the cost of its efficiency since pumping power needs to be limited.

Salman et al. [10] carried out CFD analysis of circular tube with parabolic-cut twisted tape inserts having twist ratio of y = 2.93, 3.91 and 4.89. For each tape with the mentioned twist ratio, the cut depth for the tape was taken as w = 0.5, 1 and 1.5 cm. It was concluded from the analysis that Nusselt number and the friction factor in the tube with twisted tape insertion increases with decrease in twist ratios and cut depth.

Johar et al. [11] studied the effect of different types of twisted tapes like reduced width twisted tape, baffled reduced width twisted tape & baffled reduced width twisted tape with holes on heat transfer and friction factor. The experiment was carried in double pipe heat exchanger carrying water for which the Reynolds number ranged from 2500 - 30000. Three different twist ratio (y/w=3.69, y/w=4.39, y/w=5.25) were used and the results showed that the tapes with baffles and holes in the baffled tubes give better performance than the unbaffled reduced width tubes.

Al-fahed et al. [12] concluded that for a full length twisted tape, the performance depends upon tape width with twist ratio within a given range of Reynolds number.

Yadav [13] studied experimentally influence of using half length twisted tape on performance of heat transfer and pressure drop. A half length twisted tape was introduced in the inner pipe of a double pipe heat exchanger. The output showed an increase of 40% in the heat transfer coefficient for a half-length twisted tape inserts as compared to plain tube. For equal mass flow rate, half length twisted tube performs better and for unit pressure drop smooth tube performs better.

Smith et. al. [14] carried out analysis for heat transfer enhancement by insertion of single full length regularly spaced twisted tapes in round tube. It was found that lesser the tape width better is the heat transfer rate in turbulent flow under constant heat wall flux condition.

Naga Sarada et. al. [15] conducted experiments in a horizontal tube using air as the fluid. The experiment was carried for a turbulent flow. In order to reduce the increase in pressure drop due to full width tape in turbulent flow, reduced width twisted tapes (range of 10 - 22mm) was used without affecting much the heat transfer rate. Using reduced width twisted leads to reduction in material by 20 - 50 %. The Nusselt number for a 10mm width tape reduces by 8% as compared to 22mm width tape.

Meyer et al. [16] used Dittus - Boelter correlation to compare the experimental results of heat transfer coefficient with the CFD results obtained by using a tube in tube three dimensional.

Jae et al. [17] found k – Ɛ turbulent model to give better results for thermal performance of a shell and tube heat exchangers on comparing different turbulence models such as standard, RSM, k – ω, SST k- Ɛ used to carry out the CFD simulations.

Jian-Fei et al. [18] developed a model which simplified the existing model by considering single tube in place of multiple tubes in the shell and tube heat exchanger. This reduced the amount of time and computational power required for large geometry models. These simplified models gave good results which were in closer approximation to the experimental results.

III. COMPARATIVE STUDY

Friction factor and Nusselt number increases with twisted tape as compared to plain tube which hence increases the heat transfer rate.[3][5][6][7]Better heat transfer is achieved with twisted tape at the cost of increase in pressure drop.[4][5][6][12]Twisted tape insert is better in laminar flow as compared to turbulent flow because it blocks the flow and therefore pressure drop increases.[8]Studies are carried out only for twist ratio greater than 3. Lesser the twist ratio more will be the heat transfer rate.[4][6][7][9][10]Even by inserting any cuts in the twisted tapes to enhance the heat transfer rate, enhancement efficiency is limited by high Reynolds number.[8][9]Reduction in tape width enhances the thermal performance in turbulent flow. [10][11][13]Reduced width twisted tapes reduces the pressure with less reduction in heat transfer.

IV. CONCLUSION

Based on the above conclusions, using twisted tape having smaller twist ratio of 1 and smaller tape width of 6mm and thickness 1mm for laminar as well as turbulent flow is recommended. Lesser tape width for laminar flow will reduce the increase in pressure drop as compared to full depth tape and also enhance heat transfer rate in turbulent flow. Decrease in the twist ratio will increase the heat transfer rate in both laminar and turbulent flow.

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REFERENCES

[1] B.Adrian and K. Allan D. Heat transfer enhancement. In Heat Transfer Handbook, Chapter 14, pg.1033, -1101, Wiley-interscience, 2003.

[2] Bergles, A.E. ―Techniques to augment heat transfer, Handbook of Heat Transfer Applications (Ed.W.M. Rosenhow), 1985, Ch.3 (McGraw-Hill, New York).

[3] Date, A.W. Prediction of fully developed flow in a tube containing a twisted tape, International Journal Heat Mass Transfer, 17, pp. 845-859, 1974

[4] Date A.W,.Flow in tube containing twisted tape Heat and vent Engr, Journal of Environmental Science,47, pp240-249,1973

[5] S.D.Patil et al. ―Analysis of Twisted Tape with Winglets to Improve the Thermo hydraulic Performance of Tube in Tube Heat Exchanger‖, International Journal of Advanced Engineering Research and Studies E-ISSN2249 – 8974

[6] Royds,.Heat transfer by radiation, convection and conduction, constable and camp ltd, pp190-201, 1921

[7] Watcharin Noothong et al. ―Effect of Twisted-Tape Inserts on Heat Transfer in A Tube‖, The 2nd Joint International Conference on ―Sustainable Energy and Environment (SEE), 21-23, 2006

[8] Bodius Salam et al. ―Heat Transfer Enhancement in A Tube Using Twisted Tape Insert‖, Proceedings of the 13th Asian Congress of Fluid Mechanics, 17-21 December 2010

[9] Prof. Naresh B. Dhamane et al. ―Heat Transfer Analysis Of Helical Strip Insert With Regularly Spaced Cut Sections Placed Inside A Circular Pipe International Journal of Modern Engineering Research (IJMER) Vol. 2, Issue. 5, pp-3711-3716, Sep.-Oct. 2012

[10] Sami D. Salman et al. ―CFD Analysis of Heat Transfer and Friction Factor Characteristics in a Circular Tube fitted With Parabolic-Cut Twisted Tape Inserts‖ Australian Journal of Basic and Applied Sciences, 7(7): 69-76, 2013

[11] Gaurav Johar et al. ―Experimental Studies On Heat Transfer Augmentation Using Modified Reduced Width Twisted Tapes As Inserts For Tube Side Flow Of Liquids

[12] Al-fahed et al. Effect of tube tape clearance for heat transfer for fully developed turbulent flow in horizontal isothermal tube, International journal of heat and fluid flow,17, pp173-178,1996

[13] Anil Singh Yadav et al. ―Effect Of Half Length Twisted -Tape Turbulators On Heat Transfer And Pressure Drop Characteristics Inside A Double Pipe U-Bend Heat Exchanger, Jordan Journal of Mechanical and Industrial Engineering, Volume 3, Number 1, ISSN 1995-6665, Pages 17- 22, March. 2009

[14] Smith et. al. ― Experimental investigation of heat transfer and flow friction in a circular tube fitted with regularly spaced twisted tape elements

[15] S. Naga Sarada et. al. ―Enhancement of heat transfer using varying width twisted tape inserts, International Journal of Engineering, Science and Technology Vol. 2, No. 6, pp. 107-118, 2010

[16] M. J. Van Der Vyver H et.al. ― Validation of a CFD model of a three dimensional tube in-tube heat exchanger, 2003.
[17] J. G. Jae-Young et al. ― Comparison of near-wall treatment methods for high Reynolds number backward-facing step flow, Int. J Computational Fluid Dynamics, vol. 19, 2005.
[18] Usman Ur Rehman, Heat Transfer Optimization of Shell-And-Tube Heat Exchanger through CFD Studies, Chalmers University of Technology, 2011.