PERFORMANCE ANALYSIS OF HEAT TRANSFER PARAMETERS IN SHELL AND TUBE HEAT EXCHANGER WITH CIRCUMFERENTIAL TURBULATOR

Raghunath D1, Robin Britto Antony A2, Veeramanikandan S3, Vignesh C4, Vijaya kumar G5

1Assistant professor, 2,3,4,5 UG Students, K. Ramakrishnan College of Technology, Trichy, Tamilnadu, India.

Abstract

Performance of heat exchanger is evaluated by the value of heat transfer coefficients, Reynolds number, Nusselt number, temperature distribution along the length, residence time and pressure drop. Improving these parameters for better performance is the main focus in designing the heat exchanger. In that view, helical coil gives more turbulence to the fluid flowing through it that leads to improved tube side heat transfer coefficient. For increasing the turbulence in cold flow, turbulators can be used in the circumferential area between helical coil and shell. In this work, heat transfer rate of shell and helical coil heat exchanger is improved by using circumferential turbulators. For the same mass flow rate of cold fluid different hot fluid mass flow rates (0.03 kg/s, 0.06 kg/s, 0.09 kg/s and 0.12 kg/s) were fixed for taking readings and the improvement is obtained by calculation of performance parameters. The temperature distribution along the length of the heat exchanger is plotted for different flow rates. Results show that, increasing the mass flow rate of cold fluid above the mass flow rate of hot fluid decreases the performance.

KEYWORDS: Shell and helical coil heat exchanger; Turbulator; overall heat transfer coefficient; heat transfer enhancement.

1. Introduction

Transferring heat from one part to another part is major concern in many industries. For transferring heat between liquids, heat exchangers can be used. Based on the area of application any one type of heat exchanger can be chosen. Selecting a particular type of heat exchanger is more important to make the heat transfer process more effectively. Helical coils have more advantages in heat transfer applications because of its circular pathway. It creates more turbulence comparing with straight tubes which is desirable in the heat exchangers. It is important that the heat transfer coefficient in the shell side should be high to absorb heat from the hot fluid. In that view, turbulator is given in the shell side between helical coil and shell. That helps to increase the turbulence and reduce the residence time of cold water in the shell. Corrugated tube
can be used to improve heat transfer in tube side. Deep corrugations making disturbance improving the heat transfer of the shell side [1]. Realizable K model was adopted for a shell and tube heat exchanger to run numerical simulations were investigated [2]. Thermal and exergy behaviour of air -water non boiling two phase flow at a horizontal flow start helically corrugated tube. The corrugated tube was put under constant heat flux. The improvement of gas and liquid superficial Reynolds number cause increment in pressure drop, heat transfer coefficient and exergy destruction [3]. To improve thermal performance in a typical set heat exchanger for exhaust heat recover, effects of the numbers and heat transfer and flow characteristics of MTT is inserted in SRT heat exchanger which is numerically investigated and compared with those of typical SIT and SRT [4]. Demonstration has been done for hydrothermal behaviour to depict the impact of variable magnetic field on Nanofluid transportation with square perforated twisted tape [5]. Numerical simulation on the Drift flux model is formed to investigate the process parameters of Shell and-tube waste heat boiler that can be used in industry exhaust recovery. [6]. One fluid flows inside cylindrical shell of shell and tube heat exchangers, transferring between fluids without mixing. The optimal value of heat transfer and pressure drop in a STHX is a major need in the industrial applications. CFD analysis has been performed to investigate the effect of baffle cut and inclination angle. [7]. The investigations were conducted for a triangular wire inserts in a circular tube for Reynolds numbers 2731 to 27,732 resulted that entropy generation increases with increasing of Reynolds number [8]. The influence of PR; k and Rea for water to air heat exchanger on hydrothermal behaviour are studied. [9]. Techniques for developing the heat transfer in systems which need a high thermal efficiency in heat transfer applications. Perforated baffles were used with pores axis ratios of 0.190, 0.425 or 0.660. The obtained results by varying Reynolds number result that the vortex flows made by baffles help to stabilize the stagnant flow in the region of downstream baffles leading to enhance the heat transfer in the channel [10]. The overall heat transfer coefficient and heat transfer rate for different mass flow rates results in increased performance with minimum amount for mass flow rate 0.86kg/s whereas it is increases with maximum amount if the mass flow rate is 1.71kg/s. [11]. Performance of shell and tube heat exchanger and helical coil heat exchanger with counter flow arrangement, helical coil heat exchanger was more effective than shell and tube heat exchanger. The Overall heat transfer coefficient increases with increase in mass flow rate of hot water. As the curvature radius is increased, the centrifugal forces lowers which results in reduction of heat transfer coefficient and pressure drop. [12]

The convective heat transfer coefficients of a helical coil heat exchanger, in his study three helical coils with different curvature ratio and pitch are investigated in a shell and are tested for counter flow arrangement. His results shows that maximum heat transfer characteristics was exhibited by the helical coil with 18 turns and curvature radius of 90 mm and pitch ratio of 0.13 with Characteristic Shell length of 0.5m and Shell Diameter of 15.24cm [13]. The forced laminar fluid flow in rectangular coil pipes with circular cross section and characterized by pipe straightness, curvature
and torsion. Calculations were done on the performance parameters for forced laminar fluid flow in rectangular coil pipe for four rectangular coiled pipes at different Reynolds's number. The deviation obtained in maximum velocity area occurs simultaneously from outer wall through the straight tubes [14]. The performance and pressure drop of the helical coil heat exchanger with and without helical crimped fins. The experimental are done at the cold and hot water mass flow rates ranging between 0.10 and 0.22kg/s and between 0.02 and 0.12kg/s, respectively. The result is due to the heat transferred from the hot water increases with increasing its mass flow rate [15].

2. Experimental Setup

Shell and helical coil heat exchanger with circumferential turbulator is used to analyze the heat transfer performance in this work. Figure 2.1 shows the shell of the heat exchanger where the cold fluid is passed. Inside the shell, helical coil and turbulator are fixed. Specifications of shell dimensions are tabulated in Table 1. Helical coil made of copper tube is used to pass hot water at different flow rates. Helical coil is shown in Figure 2.2. For increasing the turbulence in the cold flow, circumferential turbulator is placed between the shell and helical coil, shown in Figure 2.3. Final experimental setup is arranged for counter flow configuration with pressure gauges.

![Figure 2.1 Shell](image1)

![Figure 2.2 Helical coil](image2)
3. Experimental procedure

Experiment on shell and helical coil heat exchanger fitted with turbulator is experimented for effectiveness and overall heat transfer coefficient. Starting from hot fluid flow rate of 0.03 kg/s to 0.12 kg/s is fixed for the four different cold fluid flow rates. Totally sixteen type of flow rate combination were used and temperature distribution of hot fluid, inlet and outlet temperature of cold fluid, pressure at inlet and outlet of hot fluid were taken.

4. Result and discussion

Comparison between the shell and tube heat exchanger with helical coil and shell and tube heat exchanger with helical coil and turbulator are graphically represented. Effectiveness, Nusselt number and overall heat transfer coefficient in all the flow rate combinations were compared.

4.1. Effectiveness

Effectiveness for 0.03 kg/s cold fluid flow rate and hot fluid flow rates ranging from 0.03 kg/s to 0.12 kg/s is shown in figure 4.1. Effectiveness is closely travelling in this mass flow rate combination except in the first combination (0.03 kg/s). Addition of turbulator is not showing much deviation in the effectiveness.
Figure 4.1 Effectiveness ($m_c = 0.03 \text{ kg/s}$)

Figure 4.2 Effectiveness ($m_c = 0.06 \text{ kg/s}$)

Figure 4.3 Effectiveness ($m_c = 0.09 \text{ kg/s}$)

Figure 4.2 shows the effectiveness for the cold mass flow rate of 0.06 kg/s and for hot flow rate of 0.03 to 0.12 kg/s. The effectiveness is increasing as the mass flow rate hot fluid is increasing in both the cases i.e. with and without turbulator.
Figure 4.3 shows the effectiveness for the cold mass flow rate of 0.09 kg/s and for hot flow rate of 0.03 to 0.12 kg/s. The effectiveness is increasing as the mass flow rate hot fluid is increasing in both the cases i.e. with and without turbulator. For the combination of 0.09 kg/s in both hot and cold fluid with turbulator is giving higher effectiveness and it is higher than the without turbulator. This difference is more comparing with other flow rate combinations.

![Figure 4.4 Effectiveness (m_c = 0.12 kg/s)](image)

Figure 4.4 shows the effectiveness value of the cold flow rate of 0.12 kg/s and four different values of hot fluid flow rates. In this combination, effectiveness of heat exchanger in both with and without turbulator cases showing the same manner of results. In all the above twelve flow rate combinations, the 0.09 kg/s in both hot and cold flow rates is giving the best effectiveness value.

### 4.2. Nusselt number

Nusselt number is the major focusing parameter in the heat exchanger analysis which decides the heat transfer performance. The Nusselt number variation for the different hot and cold flow rate combinations are discussed in this section.
Figure 4.5 represents the Nusselt number variations for the sixteen combinations of hot and cold fluid flow rates with turbulator. Except in the 0.03 and 0.09 flow rates of hot fluid, all the other flow rate combinations are showing the same nature of values. 0.03 flow rates in hot and cold flow rate results in some higher Nusselt number and 0.09 flow rate in hot and cold flow rate gives the highest value of Nusselt number.

4.3. Overall heat transfer coefficient

Overall heat transfer coefficient value for the different flow rate combinations of hot and cold fluid flow rates are plotted in the figure 4.6. From the figure it is clear that the cold flow rate of 0.06 kg/s for different flow rates of hot fluid is giving better overall heat transfer performance.
Figure 4.6 Overall heat transfer coefficient

5. Conclusion

Heat transfer characteristics of the shell and helical coil heat exchanger with turbulator arrangement have been analyzed experimentally. Analysis has been carried out under counter flow configuration. The attachment of turbulator resulted that fluid particles undergoes turbulent flow in the shell and tube this causes fluctuation in the heat transfer rates. By observing the performance of the heat exchanger the following results were concluded. The maximum effectiveness is achieved at the flow rate combination of \( m_h=0.12 \) kg/s and \( m_c=0.09 \) kg/s. Overall heat transfer coefficient is maximum in the mass flow rate combination of \( m_h=0.12 \) kg/s and \( m_c=0.12 \) kg/s. Nusselt number is maximum in the flow rate combination of \( m_h=0.09 \) kg/s and \( m_c=0.09 \) kg/s. From the above results, the best combination of flow rates for better heat transfer performance is 0.09 kg/s in both the fluids.

Reference

[1] Amol Andhare and Kriplani V M, Thermal analysis of a helical coil heat exchanger, international journal of research in advanced engineering, volume(1) issue 12, December 2014.

[2] Sahiti N, Heat transfer enhancement by pin elements, International Journal of Heat and Mass Transfer 48 (2005) 4738–4747
[3] Paisarn Naphon, *Thermal performance and pressure drop of the helical-coil heat exchangers with and without helically crimped fins*, 19 December 2006, International Communications in Heat and Mass Transfer

[4] Amitkumar Puttewar S and Andhare A M, *Design and thermal evaluation of shell and helical coil heat exchangers*, International Journal of Research in Engineering and Technology. Volume: 04 Issue: 01, Jan-2015, eISSN: 2319-1163 | pISSN: 2321-7308.

[5] Nasser Ghorbani, *An experimental study of thermal performance of shell-and-coil heat exchangers*, International Communication in Heat and Mass Transfer, 37(2010) 775-781.

[6] Sivakumar K, *Performance analysis of heat transfer and effectiveness on laminar flow with effect of various flow rates*, International Journal of Chem Tech Research CODEN (USA): IJCRGG ISSN: 0974-4290 Vol.7, No.6, pp 2580-2587, 2014-2015

[7] Mehdi Bahiraei, *A novel application for energy efficiency improvement using nanofluid in shell and tube heat exchanger equipped with helical baffles*, ELSEVIER, Accepted 24 October 2015, Energy 93 (2015).

[8] Ya-Ping Chen, *Experimental investigation on performances of trisection helical baffled heat exchangers for oil–water heat transfer*. Accepted 16 May 2015, Energy Conversion and Management 101 (2015).

[9] Ming Pan, *Improving heat recovery in retrofitting heat exchanger networks with heat transfer intensification, pressure drop constraint and fouling mitigation*, 20 September 2015, Applied Energy (2015)

[10] Zhang-Jing Zheng, *Optimization of porous insert configurations for heat transfer enhancement in tubes based on genetic algorithm and CFD*, 5 April 2015, International Journal of Heat and Mass Transfer 87 (2015) 376–379

[11] Jie Yi, *Heat transfer characteristics of the evaporator section using small helical coiled pipes in a looped heat pipe*, 5 July 2002, Applied Thermal Engineering 23 (2003) 89–99,

[12] Shive Dayal Pandey, *Experimental analysis of heat transfer and friction factor of nanofluid as a coolant in a corrugated plate heat exchanger*, 2 January 2012, Experimental Thermal and Fluid Science 38 (2012) 248–256.

[13] Jian-Zhong Lin, *Flow and heat transfer characteristics of nanofluids containing rod-like particles in a turbulent pipe flow*, 16 September 2015, International Journal of Heat and Mass Transfer 93 (2016) 57–66

[14] Mohammed Reza Salimpour, *Heat transfer coefficient of shell and coiled tube heat exchangers*, Experimental Thermal and Fluid Science 33 (2009) 203–207. Doi: 10.1016.
