Int. J. Chem. Sci.: 14(3), 2016, 1533-1540
ISSN 0972-768X
www.sadgurupublications.com

MODELING AND EXPERIMENTATION ON DPHE TO STUDY TEMPERATURE DEVIATION ALONG WITH PASSIVE HEAT TRANSFER AUGMENTATION TECHNIQUE

P. B. DEHANKAR*, S. G. GALANDE, P. T. DESAI, G. A. KHANDEKAR and S. V. DESAI

Tatyasaheb Kore Institute of Engineering & Technology, Warananagar, KOLHAPUR (M.S.) INDIA

ABSTRACT

Heat exchanger are widely using in the process industries to recover heat between two process fluids. Although, the necessary equations for heat transfer and the pressure drop in a double pipe heat exchanger (DPHE) are available, using these equations the optimization for heat transfer parameter to standardization of experimental set up in laboratory. In present paper, we prepared the mathematical model for DPHE and validated by experimental work in laboratory. The mathematical model solve the two parameter as outlet temperature for cold fluid (T4) and hot fluid (T2) applying four parameter as inlet temperature and mass flow rate using Newton rapson method. The predicted result comparing with the result obtained from performing experiment work on the lab scale DPHE. In this study, work has been done on smooth pipe and passive method as heat transfer augmentation technique to increases the maximum recovery of heat using twisted tape having twist ration y1 = 4.3 and y2 = 7.7. The temperature deviation predicted by model validated with experimental values and it has been additional 6°C by y1 = 4.3 and 4.5°C by y2 = 7.7 than smooth tube as heat recovery from hot fluid to the cold fluid in the mass flow rate between 0.02-0.07 kg/s.

Key words: Modeling equation, DPHE, Passive method, Temperature deviation.

INTRODUCTION

Double pipe heat exchanger is the simplest device to operate high pressure and high temperature due to small diameter of cylindrical wall. Maximum recovery of heat from hot fluid to cold fluid is possible only when area and high pumping power in the process increases. Heat transfer augmentation techniques have opportunity to reduce heat transfer area for heat exchanger in process industries. By using these techniques, increases performance of heat exchanger to reduces cost, material and energy saving related to the

---

*Author for correspondence; E-mail: dehankarpr@gmail.com

heat exchanger process. In COMSOL multiphysics model impact of turbulence and linear heat exchanger to predict outlet temperature is roughly equivalent to Seider – Tate equation and LMTD method[3]. 2nd order lumped parameter model using LMTD as driving force to find analytical properties of heat exchange infinite dimensional dynamic model[4]. The twisted tape with twist ratio y = 4.167 can enhance maximum heat transfer rate up to 3.540 times of plain heat exchanger at Reynolds number 9072.782 with friction factor 7.532 times[7].

It has been observed that, by using twisted tape inserts in heat exchanger the heat transfer enhancement takes place in the expense of Reynold number, pressure drop and[7-12]. In this present paper, prepared mathematical model and solving with Newton rapson method to predicted outlet parameter as temperature for cold fluid (T4) and hot fluid (T2) applying four parameters as two inlet temperatures and the two mass flow rates for DPHE.

Methodology

Existing enhancement techniques can be broadly classified into three different categories[12]:

1. Passive techniques
2. Active techniques
3. Compound techniques

Passive techniques: In this technique, change is observed in the flow pattern without any external power only by available power in system. This change of flow pattern leads to disturbing thermal boundary layer and pressure drop to enhance the heat transfer rate in heat exchanger e.g. Rough surface, Swirl flow, etc.

Selection & choice of process

The process selected is fluid flowing has water through double pipe heat exchanger in counter current direction. Heat exchanger has many industrial & engineering applications. In design of heat exchange procedure, it needs exact analysis of heat transfer rate & pressure drop estimations along with performance & the economic aspect of the heat exchange equipment. Whenever inserts are used for enhancement of heat transfer, along with heat transfer rate, the pressure drop also increases. This increase in pressure drop increases the pumping cost. Thus, it is highly essential not to allow the pressure drop to go beyond a specified value while going for heat transfer enhancement technique using inserts Passive techniques. When inserts are placed in the path of flow the liquid, create a high degree turbulence resulting in an increase in heat transfer rate & the pressure drop.

Mathematical model

Assumptions:

- At steady state operation of the exchanger in test region.
- The HE is considered a system with lumped parameter.
- Loss of heat to the surrounding environment is neglected.
- Both fluids are in a liquid phase & don't change the phase.

Modeling equations:

By taking heat balance of hot & cold fluid, we get,

$$Qh \times Cph \times (T1 - T2) = Qc \times Cpc \times T4 - T3) \quad \ldots(1)$$

$$Qh \times Cph \times (T1 - T2) = U \times A \times \Delta Tlm$$

$$= \frac{U \times A \times (T1 - T4) - (T2 - T3)}{\ln\left\{\frac{(T1 - T4)}{T2 - T3}\right\}} \quad \ldots(2)$$

The mathematical model of the heat exchanger has been developed and contains an equation of the heat balance associated to the two material flows Q_h and $Q_{c,}$ as well as the expression of transferred heat flow.

For the heat flow transferred in the heat exchanger, the overall heat exchange coefficient, U, has a known expression as –

The overall HTC can be given by[9],

$$U = \frac{1}{1/hi \times de/di + (de/2k) \times \ln(de/di) + \frac{1}{ho}} \quad \ldots(3)$$

Solving of the mathematical model

Equations (1 and 2) represent a system of two non linear equations with two variables having the form,

$$f1(T2, T4) = 0$$

$$f2(T2, T4) = 0 \qquad \ldots(4)$$

$$f1 = Qh \times Cph \times (T1 - T2) - Qc \times Cpc \times (T4 - T3) \qquad \ldots(5)$$

$$f2 = \frac{Qh \times Cph \times (T1 - T2) - U \times A \times (T1 - T4) - (T2 - T3)}{\ln\left\{\dfrac{(T1 - T4)}{(T2 - T3)}\right\}} \qquad \ldots(6)$$

The unknown variables of the system (4), the outlet temperature of the hot fluid T_2 and outlet temperature of the cold fluid T_4, are at the same time, the output variables of the heat exchanger. The functions f1 and f2 of the system (4) have the expressions defined by the relations (5) and (6).

Experiment setup

Table 1: Specifications of double pipe heat exchanger

Hot fluid	Water
Cold fluid	Water
Inner pipe ID	13 mm
Inner pipe OD	15 mm
Outer pipe ID	23 mm
Outer pipe OD	25 mm
MOC of tube	Cu
MOC outer pipe	PVC
Heat transfer length	90 cm
Outer pipe length	76 cm

About the inserts

An inserts used for the experiment are mild steel twisted tapes. The present work deals with finding the friction factor and the heat transfer coefficient for the twisted tape with twist ratio (y = 4.3, y = 7.7) and comparing those results with that of smooth tube.

Twist ratio y1 = 4.3

Twist ratio y2 = 7.7

Twisted tape thickness = 2 mm

Twisted tape length = 90 cm

Twist width = 1.2 cm

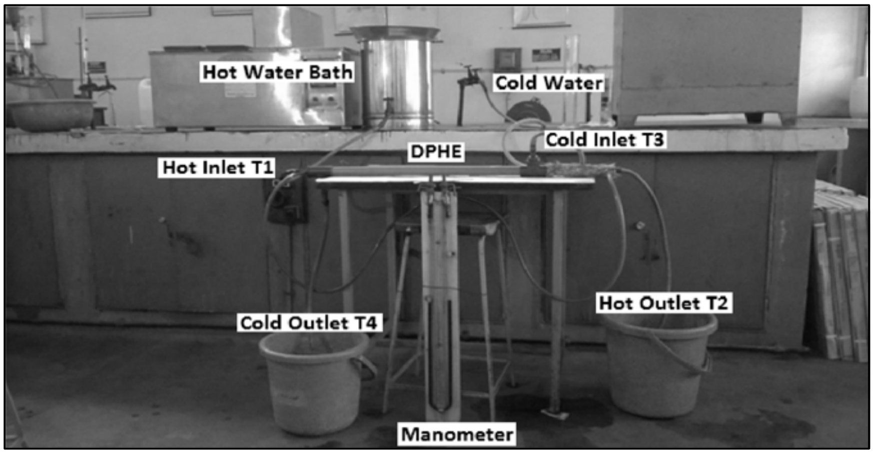
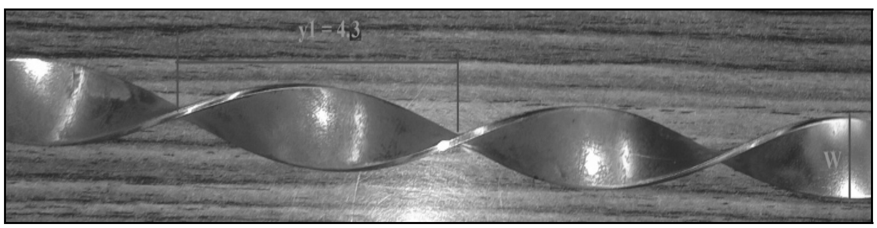
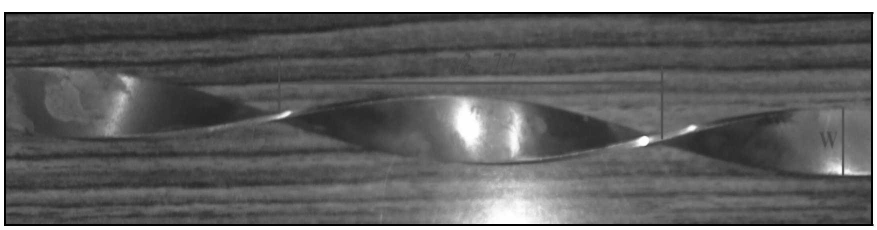


Fig. 1: Lab scale experimental setup of DPHE



(a)



(b)

Fig. 2: Twisted Tape Insert having Twist ratio (a) y1 = 4.3 (b) y2 = 7.7

RESULTS AND DISCUSSION

In DPHE, predicted result from mathematical model validated through experimental work. Fig. 3 shows that the temperature deviation along flow rate has been found averagely 4°C more for mathematical model as compared with experimental values through entire result due to some manual errors.

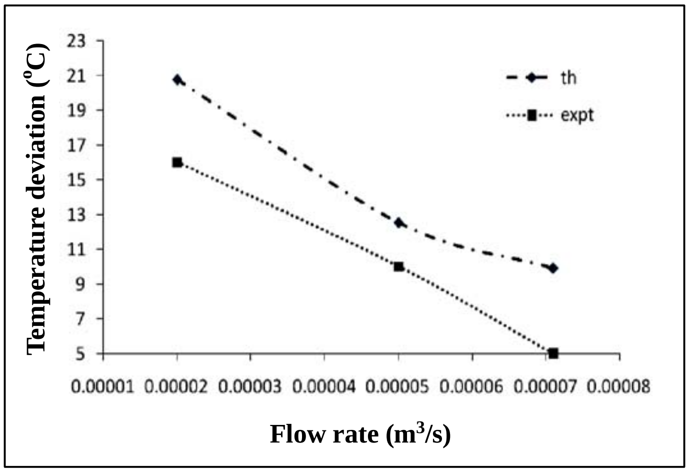


Fig. 3: Comparison between mathematical model and experimental work

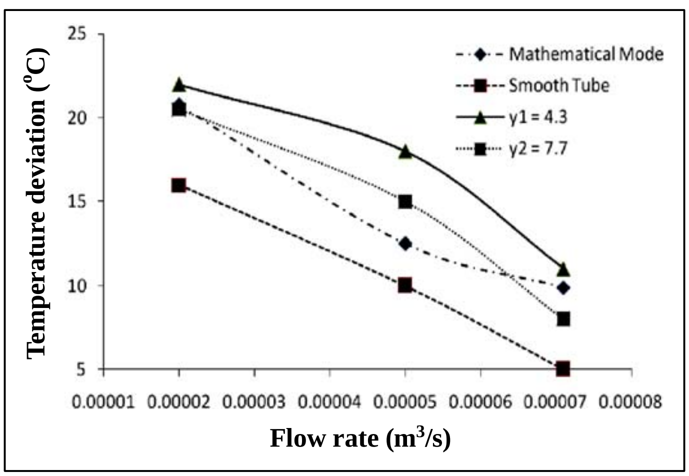


Fig. 4: Comparison between mathematical model and experimental work for smooth tube, twisted tape having twist ration (y1 = 4.3 & y2 = 7.7)

Fig. 4 shows the comparative study of mathematical model and the experimental work. The experiment work contain smooth tube having without insert and with insert as twisted tape having twist ration y1 = 4.3 and y2 = 7.7. Recovery of heat from hot fluid to cold fluid has increase as increasing temperature deviation. When applying passive method as heat transfer augmentation technique the maximum recovery of heat from hot to cold fluid. It has observed that the temperature deviation enhanced using twist tape insert averagely 6^{o}C for the twist ration y1 = 4.3 and 4^{o}C for the twist ration y2 = 7.7 as comparative smooth tube.

CONCLUSION

As a result, the mathematical model prepared for DPHE used for to predict two outlet parameters as hot fluid and cold fluid in process application. Heat transfer augmentation technique can be used to enhance the maximum recovery of heat from hot fluid to cold fluid. As using twisted tape, temperature deviation increases averagely 6^{o}C for y1 = 4.3 and 4^{o}C for y2 = 7.7 as resulted values from smooth tube because of increasing turbulence in inner side of the tube.

REFERENCES

1. C. Patrascioiu and S. Radulescu, Modeling and Simulation of the Double Tube Heat Exchangers, Case Studies, Adv. Fluid Mechanics Heat & Mass Transfer, pp. 35-41.
2. S. Kumar, K. V. Karanth and K. Murthy, Numerical Study of Heat Transfer in a Finned Double Pipe Heat Exchanger, World J. Modelling Simulation, **11(1)**, 43-54 (2015).
3. Louis Desgrosseilliers and Dominic Groulx, Double Pipe Heat Exchanger Modeling – COMSOL Uses in Under Graduate Education, Excerpt from Proceeding of the 2011 COMSOL Conference in Boston.
4. A. Zavala-R and R. Santiesteban-Cos, Reliable Compartmental Models for Double-Pipe Heat Exchangers: An Analytical Study, Appl. Mathe. Modelling, **31**, 1739-1752 (2007).
5. M. S. B. Alias, Design of Small Heat Exchanger.
6. Y. Jing, J. Hou and P. Yang, Research on Performance of Ground-Source Heat Pump Double U Underground Pipe Heat Exchange, Open J. Modelling Simulation, **1**, 1-6 (2013).

7. P. S. Rao and K. K. Kumar, Numerical and Experimental Investigation of Heat Transfer Augmentation in Double Pipe Heat Exchanger with Helical and Twisted Tape Inserts, Int. J. Emerging Technol. Adv. Engg., **4(9)**, 180-192 (2014).

8. Panida Seemawute and Smith Eiamsa-Ard, Visualization of Flow and Heat Transfer in Tube with Twisted Tape Consisting of Alternate Axis, 2012 4th International Conference on Computer Modeling and Simulation (ICCMS 2012), IPCSIT, **22**, 36-40 (2012).

9. S. Selvam, Pr. Thiyagarajan and S. Suresh, Experimental Studies on Effect of Bonding the Twisted Tape with Pins to the Inner Surface of the Circular Tube, National Inst. Technol., Trichy.

10. S. D. Patil, A. M. Patil and G. S. Kamble, Analysis of Twisted Tape with Straight Winglets to Improve the Thermo-Hydraulic Performance of Tube in Tube Heat Exchanger, Int. J. Adv. Engg. Res. Studies, **1(4)**, 99-103 (2012).

11. K. M. Stone, Review of Literature on Heat Transfer Enhancement in Compact Heat Exchangers, Air Conditioning and Refrigeration Center University of Illinois (1995).

12. P. B. Dehankar and N. S. Patil, Heat Transfer Augmentation - A Review for Helical Tape Insert, Int. J. Sci. Engg. Technol., **3(10)**, 1236-1238 (2014).

13. P. B. Dehankar, A Double Pipe Heat Exchanger-Fabrication and Standardization for Laboratory Scale, April'15', IJRITCC, ISSN-2321-8169, **3(4)**, 1845-1847.

Revised : 06.05.2016 *Accepted : 09.05.2016*