International Journal of Scientific Research & Engineering Trends
Volume 5, Issue5, Sep-Oct-2019, ISSN (Online): 2395-566X

Optimization of Heat Transfer in Six-Start Spirally Corrugated Tubes using Taguchi Method

M.Tech. Scholar Sanjoo Sahani
Department of Mechanical Engineering
PIES, Bhopal, MP, India

Professor Poonam Kumar Agade
Department of Mechanical Engineering
PIES, Bhopal, MP, India

Abstract - **In this study, a parametric study is performed to investigate the effects of geometric parameters on the heat transfer characteristic, the flow friction characteristic and overall thermal-hydraulic performance of corrugated tube heat exchangers. The effectiveness of various parameters on the objectives is evaluated and the geometric structure of the corrugated tube is optimized for the best overall thermal-hydraulic performance using Taguchi method. The geometric parameters considered in the model include corrugation height and corrugation pitch. The results show that corrugation height have dominant influence on heat transfer characteristic with contribution ratios of 74.79% respectively while corrugation pitch has minor effects.**

Keywords- **Heat transfer enhancement, Thermal Performance Factor, Twisted tape.**

I. INTRODUCTION

Various techniques have been tested on heat transfer enhancement to upgrade the involving equipment, mainly in thermal transport devices. These techniques unveiled significant effects when utilized in heat exchangers. One of the most essential techniques used is the passive heat transfer technique. Corrugations represent a passive technique. In addition, it provides effective heat transfer enhancement because it combined the features of extended surfaces, tabulators' and artificial roughness.

Basically, three approaches are available yet to enhance the rate of heat transfer, active method, passive method and the compound method [1]. A power source is essential for the active, certain surface modifications or extension, and inserts or fluid additives are used in the passive method, while the compound method is a combination of the above two methods such as surface modification with fluid vibration [2].

The motivation behind this activity is the desire to obtain more effective heat exchangers and other industrial applications [3], with the major objectives being to provide energy, material, and economic savings for the users of heat transfer enhancement technology. In heat exchangers, corrugation and other surface modifications are commonly used because they are very effective in the heat transfer enhancement; also it is appearing very interesting for practical applications because it is a technique that promotes secondary recirculation flow, by inducing non-axial velocity components [4]. Recently, a swirl or helical flow pattern produced by employing surface modifications or any other passive technique for heat transfer enhancement is very interesting [5]. Also, Spiral corrugation increases heat transfer enhancement due to secondary flow swirls and surface curvatures pass by fluid layers, which also causes pressure losses [6].

II. METHODOLOGY

Corrugated tubes are increasingly becoming more fascinating techniques for acquiring higher efficiency in heat exchangers to minimise costs . Hence, a 1 mm thick aluminium tube of six−start spiral corrugations and one smooth tube were modelled using configurations based on Solid Works software package. The primary corrugation parameters are the corrugation height (e) and corrugation pitch (p). The envelope diameter Den of the tubes vary depending on corrugation heights e, and fixed bore diameter Db of 13 mm, as presented in Fig. 1.1. For the 5 tubes used, each having classical parameters of spiral corrugations with heights to diameter e/Dn, spiral corrugations with pitch to diameter p/Dn and severity index $\varphi = e2/(pDn)$ as presented in the first table (Table 1).

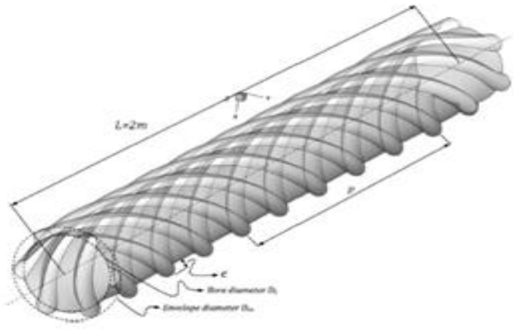

Fig.1. Six–starts spirally corrugated tube.

Table 1: The parameters and their values corresponding to their levels.

Parameters	Level		
	I	II	III
Envelope dia. Den	15	17	19
corrugation height, e	2	4	6
corrugation pitch, p	20	14	11

Taguchi Method

The Taguchi method is being extensively used in industrial and engineering problems due to its wide range of applications. The Taguchi method is the commonly adopted approach for optimizing design parameters. The method was originally proposed as a means of improving the quality of products using the application of statistical and engineering concepts. This methodology is based on two fundamentals concepts: First, the quality losses must be defined as deviations from the targets, not conformance to arbitrary specifications, and the second, achieving high system quality levels economically requires quality to be designed into the product. To achieve desirable product quality by design, Taguchi suggests a three-stage process: system design, parameter design and tolerance design.

System design is the conceptualization and synthesis of a product or process to be used. To achieve an increase in quality at this level requires innovation, and therefore improvements are not always made. In parameter design the system variables are experimentally analyzed to determine how the product or process reacts to uncontrollable "noise" in the system; parameter design is the main thrust of Taguchi's approach. Parameter design is related to finding the appropriate design factor levels to make the system less sensitive to variations in uncontrollable noise factors, i.e., to make the system robust. In this way the product performs better, reducing the loss to the customer.

The final step in Taguchi's robust design approach is tolerance design; tolerance design occurs when the tolerances for the products or process are established to minimize the sum of the manufacturing and lifetime costs of the product or process. In the tolerance design stage, tolerances of factors that have the largest influence on variation are adjusted only if after the parameter design stage, the target values of quality have not yet been achieved. Since the experimental procedures are generally expensive and time consuming, the need to satisfy the design objectives with least number of tests is clearly an important requirement. Once the levels are taken with careful understanding four parameters with four levels are used for the established experiments. Table 1 shows the factors to be studied and the assignment of the corresponding levels.

III. RESULT

When analyzing the flow patterns, CFD codes performs an essential and overwhelming role, and the details of the small flow qualities such as the secondary swirl flow and the vorticities could be accounted by the CFD simulation. Significantly increased rate of thermal transfer could be induced by the variations temperature between the wall and the bulk temperature, for instance, the tube with highest ΔT is the tube with higher rate of thermal transfer. It could be deduced from temperature contours below has the greatest difference in temperature. The differences in temperature were attributed to the mixing of fluid layers at the secondary region induced by corrugation, and as the corrugation becomes severe, the mixing will also increase.

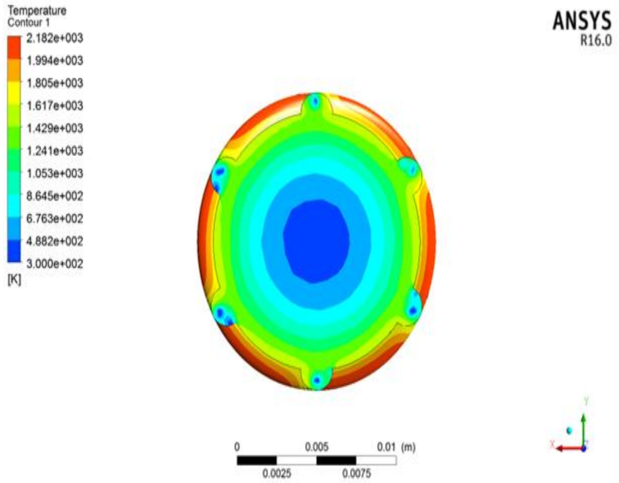

Fig.2. Temperature contour for roughness height, e= 2 mm and pitch of corrugation, p = 20 mm.

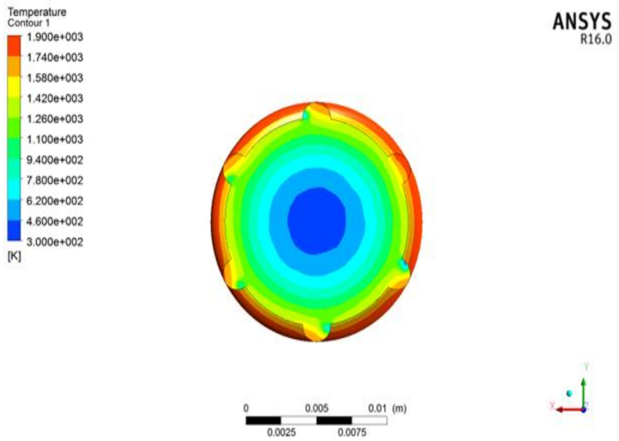

Fig.3. Temperature contour for roughness height, e= 2 mm and Pitch of Corrugation, p = 14 mm.

International Journal of Scientific Research & Engineering Trends
Volume 5, Issue5, Sep-Oct-2019, ISSN (Online): 2395-566X

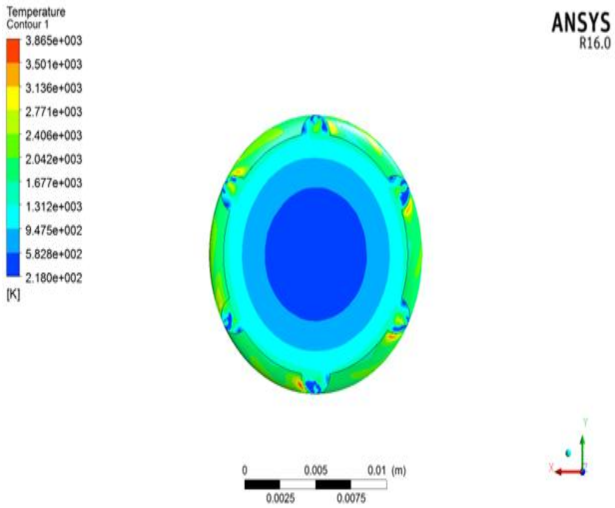

Fig.4. Temperature contour for roughness height, e= 2 mm and Pitch of Corrugation, p = 10 mm.

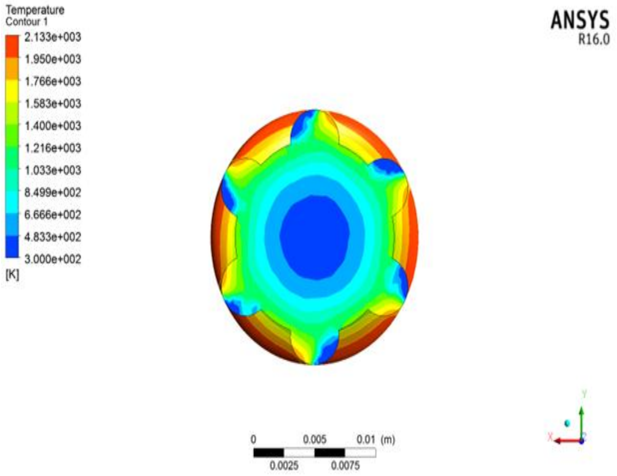

Fig.7. Temperature contour for roughness height, e= 4 mm and Pitch of Corrugation, p = 10 mm.

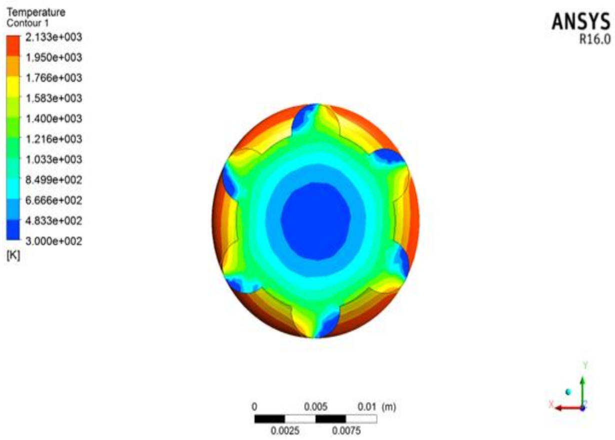

Fig.5. Temperature contour for roughness height, e= 4 mm and Pitch of Corrugation, p = 20 mm.

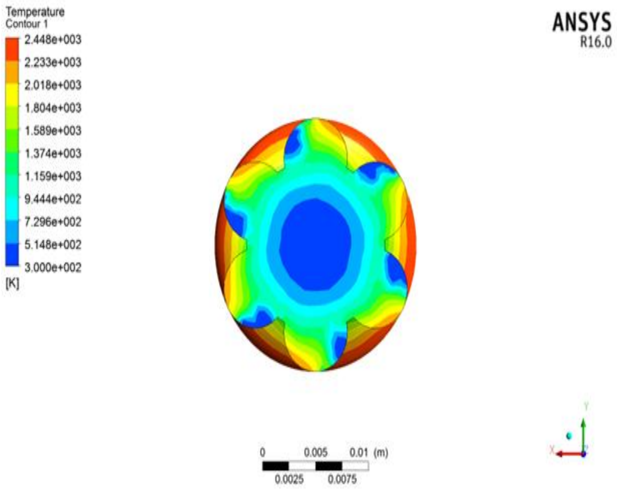

Fig.8. Temperature contour for roughness height, e= 6 mm and Pitch of Corrugation, p = 20 mm.

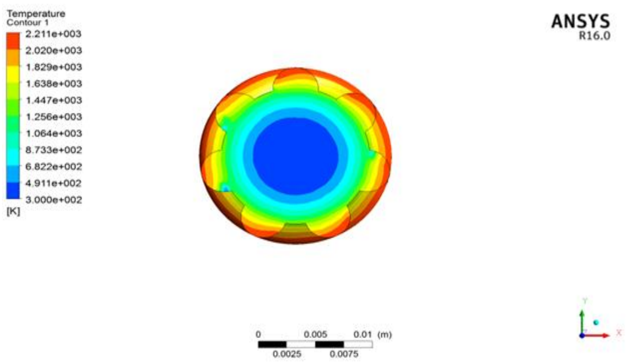

Fig.6. Temperature contour for roughness height, e= 4 mm and Pitch of Corrugation, p = 14 mm.

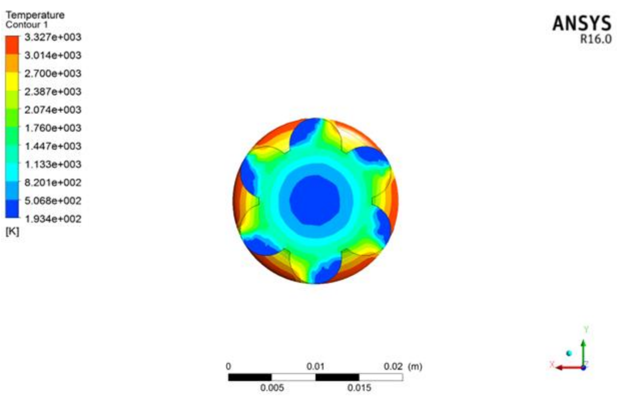

Fig.9. Temperature contour for roughness height, e= 6 mm and Pitch of Corrugation, p = 14 mm.

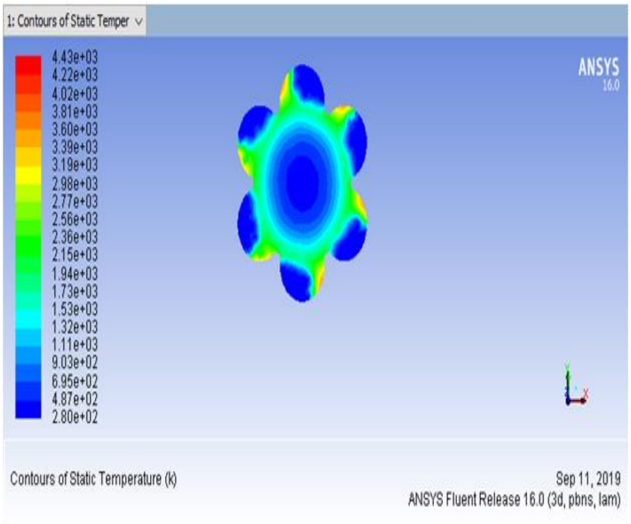

Fig.10. Temperature contour for roughness height, e= 6 mm and Pitch of Corrugation, p = 10 mm.

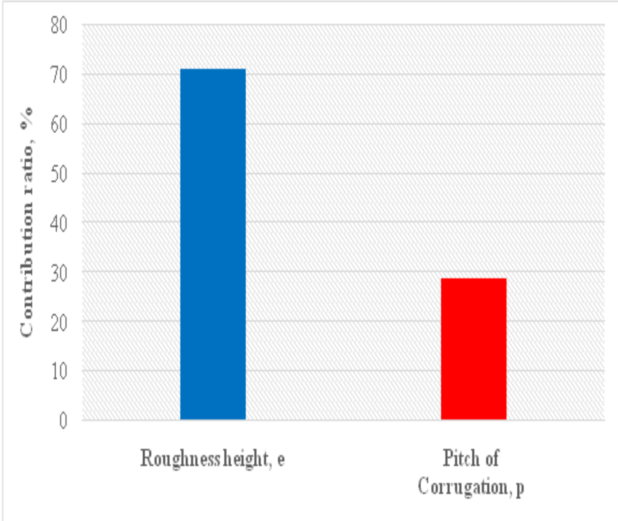

Fig.13. Contribution ratio of factor towards pressure drop.

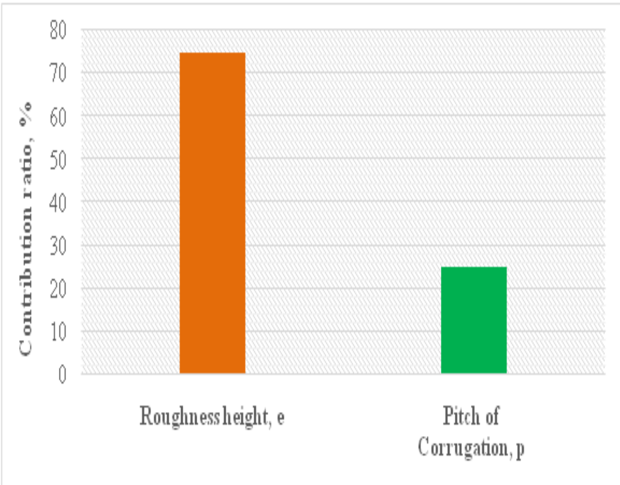

Fig.11. Contribution ratio of factor towards Nu.

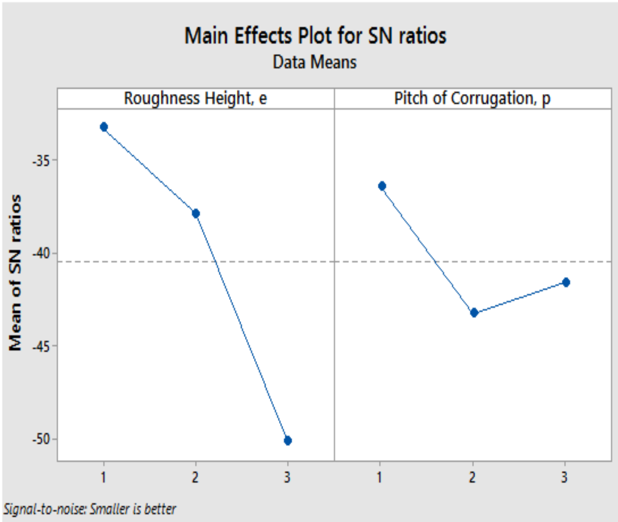

Fig.14. Main-effect plots for SNR-Pressure drop.

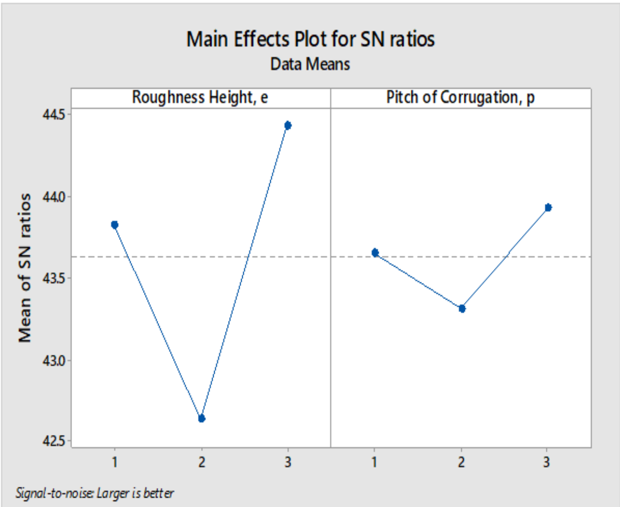

Fig.12. Main-effect plots for SNR-Nu.

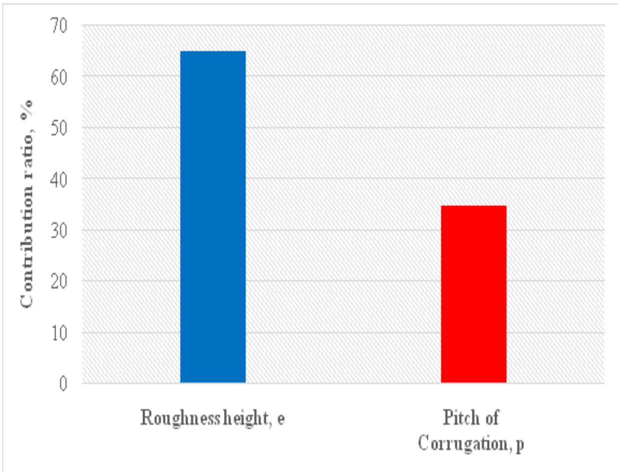

Fig.15. Contribution ratio of factor towards pressure drop.

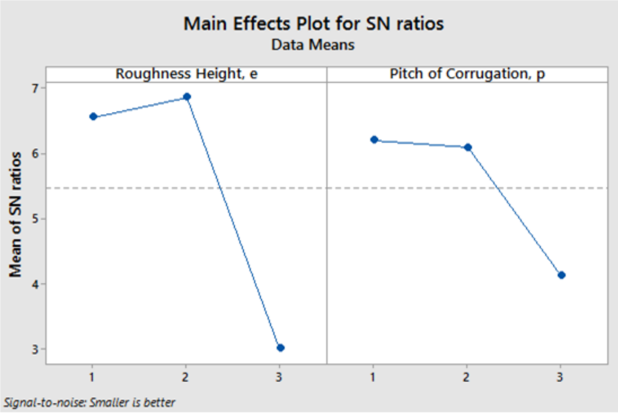

Fig.16. Main-effect plots for SNR-friction factor.

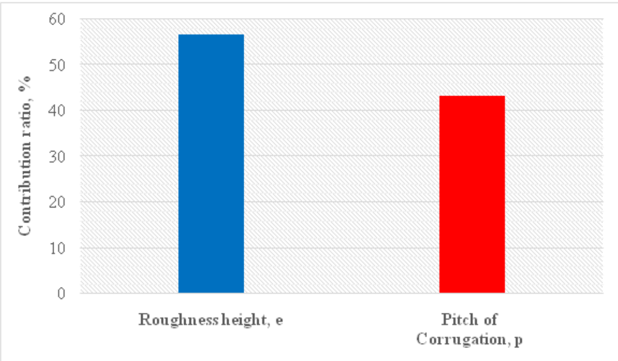

Fig.17. Contribution ratio of factor towards TPC.

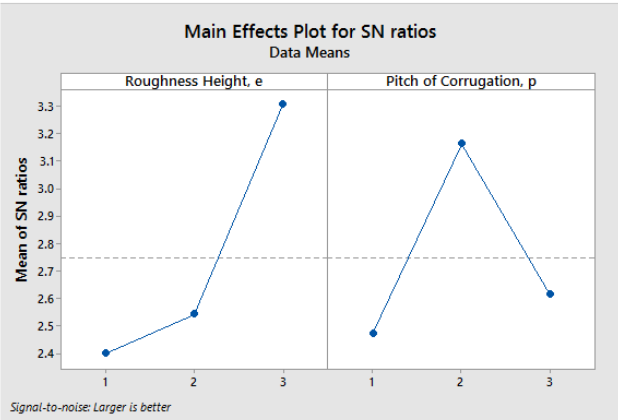

Fig.18. Main-effect plots for SNR-TPC.

IV. CONCLUSION

The main conclusions are drawn as follows:

- The geometric parameters considered in the model include corrugation height and corrugation pitch. The results show that corrugation height have dominant influence on heat transfer characteristic with contribution ratios of 74.79% respectively while corrugation pitch has minor effects.
- As far as pressure drop and flow friction characteristic is concerned, corrugation height have also dominant influence on pressure drop and flow friction characteristic with contribution ratios of 71.24% and 65.12% respectively while corrugation pitch has minor effects.
- The effects of corrugation height and corrugation pitch on overall thermal-hydraulic performance are investigated. The results show that the corrugation height have dominant influence on heat transfer characteristic with contribution ratios of 56.77 % respectively while corrugation pitch has minor effects.
- The optimal combination for SNR-TPC is determined as A3B2
- The optimal combination for SNR-f is determined as A3B3
- The optimal combination for SNR-P is determined as A3B2
- The optimal combination for SNR-Nu is determined as A3B3.

REFERENCES

[1]. Saha, S.K., Dutta, A., Dhal, S.K., 2001. Friction and heat transfer characteristics of laminar swirl flow through a circular tube fitted with regularly spaced twistedtape elements. Int. J. Heat Mass Transf. 44 (22), 4211–4223.

[2]. Eiamsa-ard, S., Thianpong, C., Promvonge, P., 2006. Experimental investigation of heat transfer and flow friction in a circular tube fitted with regularly spaced twisted tape elements. Int. Commun. Heat Mass Transfer 33 (10), 1225–1233.

[3]. Eiamsa-ard, S. et al., 2009. Convective heat transfer in a circular tube with shortlength twisted tape insert. Int. Commun. Heat Mass Transfer 36 (4), 365–371.

[4]. Sarada, S.N. et al., 2011. Enhancement of heat transfer using varying width twisted tape inserts. Int. J. Eng., Sci. Technol. 2 (6), 107–118.

[5]. Piriyarungrod, N. et al., 2015. Heat transfer enhancement by tapered twisted tape inserts. Chem. Eng. Process. 96, 62–71.

[6]. Esmaeilzadeh, E. et al., 2014. Study on heat transfer and friction factor characteristics of c-Al2O3/water through circular tube with twisted tape inserts with different thicknesses. Int. J. Therm. Sci. 82, 72–83.

[7]. Eiamsa-ard, S., Promvonge, P., 2010. Performance assessment in a heat exchanger tube with alternate clockwise and counter-clockwise twisted-tape inserts. Int. J. Heat Mass Transf. 53 (7–8), 1364–1372.

[8]. Patil, S.V., Babu, P.V.V., 2014. Heat transfer and pressure drop studies through a square duct fitted with increasing and decreasing order of twisted tape. Heat Transfer Eng. 35 (14–15), 1380–1387.

[9]. Patil, S.V., Vijaybabu, P.V., 2012. Heat transfer enhancement through a square duct fitted with twisted tape inserts. Heat and Mass Transfer/Waerme- und Stoffuebertragung 48 (10), 1803–1811.
[10]. Eiamsa-ard, S., Wongcharee, K., Promvonge, P., 2012b. Influence of no uniform twisted tape on heat transfer enhancement characteristics. Chem. Eng. Commun. 199 (10), 1279–1297.