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CFD Analysis for Heat Transfer Augmentation Inside Plain and Finned Circular Tubes with Twisted Tape Inserts

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ABSTRACT

Computational fluid dynamic (CFD) studies were carried out by using the ANSYS FLUENT 13.0 to find the effects of twisted tape insert on heat transfer, friction loss and thermal performance factor characteristics in a circular tube at constant wall temperature. Simulation was performed with Reynolds number in a range from 800 to 10,000 using water as a working fluid. Four turbulent models are examined such as a standard k-ϵ, RNG k-ϵ, standard k-ω and SST k-ω and those compared with standard twisted tape correlations developed by Manglik and Bergles. Plain tube with four different full width twisted tape inserts (FWTT) of twist ratios (y = 2, 3, 4 and 5) were examined, based on constant flow rate Over the range of Reynolds number investigated, based on overall thermal performance factor (η) it is revealed that the plain tube with FWTT (η = 1.12-1.51 in laminar regime & 0.91 – 1.08 in turbulent regime) are suitable in laminar flow region and finned tube with RWTT (η = 0.58-0.91 in laminar regime & 0.83 – 1.31 in turbulent regime) are suitable for turbulent regime.

Keywords : CFD, Heat Transfer Agumentation, Twisted Tape, Reduced Width Twisted Tape, Thermal Performance

I. INTRODUCTION

The economic design and operation of process plants are often governed by the effective usage of heat. A majority of heat exchangers used in thermal power plants, chemical processing plants, air conditioning equipment, and refrigerators, petrochemical, biomedical and food processing plants serve to heat and cool different types of fluids. Both the mass and overall dimensions of heat exchangers employed are continuously increasing with the unit power and the volume of production. This involves huge investments annually for both operation and capital costs. Hence it is an urgent problem to reduce the overall dimension characteristics of heat exchangers. The need to optimize and conserve these expenditures has promoted the development of efficient heat exchangers. Different techniques are employed to enhance the heat transfer rates, which are generally referred to as heat transfer enhancement, augmentation or intensification technique.

a. Applications of Heat transfer Enhancement

The petrochemical and chemical industries are under economic pressure to increase the energy efficiency of their processing plants to compete in today's global market. Hence, these industries must invest in innovative thermal technologies that would significantly reduce unit energy consumption in order to reduce overall cost. In recent years, heat transfer enhancement technology has been widely applied to heat exchanger applications in boiling and refrigeration process industries. Most significantly, the uses of enhancement extend well beyond surface reduction i.e., they can also be used for capital cost reduction, the improvement of exchanger operability, the mitigation of fouling, the improvement of condenser design and the improvement of flow distribution within heat exchangers.

Important applications of heat transfer enhancement are listed below:

- ✓ Heating, Ventilating, Refrigeration and air conditioning
- ✓ Automotive Industries
- ✓ Power sector
- ✓ Process Industries
- ✓ Industrial Heat Recovery
- ✓ Aerospace and others.

b. Twisted pipe inserts

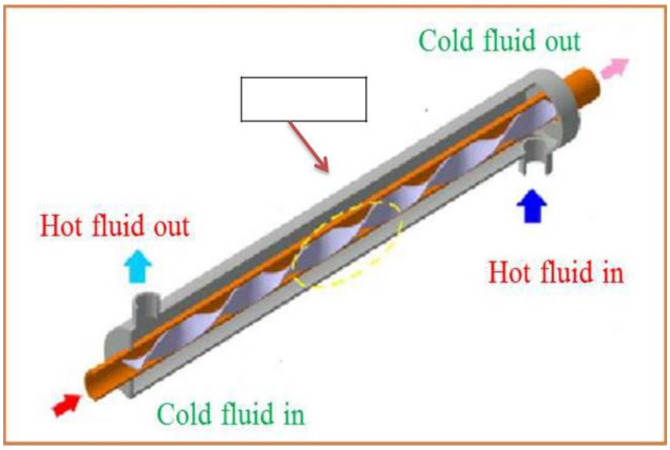


Figure 1. View of the twisted tape inside a plain tube

To enhance the heat transfer rate, some kind of insert is placed in the flow passages and they also reduce the hydraulic diameter of the flow passages. Heat transfer enhancement in a tube flow is due to flow blockage, partitioning of the flow and secondary flow. Flow blockages increase the pressure drop and leads to viscous effects, because of a reduced free flow area [5]

The selection of the twisted tape depends on performance and cost. The performance comparison for different tube inserts is a useful complement to the retrofit design of heat exchangers. The development of high performance thermal systems has stimulated interest in methods to improve heat transfer.

a. Material properties:

Water is selected as the working fluid which is assumed to be incompressible. The dynamic viscosity (μ), thermal conductivity (k), density (ρ) and specific heat at constant pressure (Cp) of water are given as $\mu = 1.003 \times 10^{-3}$ $kgm^{-1}\,s^{-1}$, $k = 0.6$ $Wm^{-1}\,K^{-1}$, $\rho = 998.2$ $kg.m^{-3}$ and Cp = 4182 J. kg-1 K-1.

b. Boundary conditions:

A constant wall temperature is imposed on the tube wall. At the inlet velocity and temperature are specified. At the outlet, a pressure-outlet condition is used. On the surfaces of the tube wall and twisted tape, no slip conditions are applied.

Table 1. Dimensions of twisted tape inserts

S.No.	Twist ratio, y	Pitch, H,mm	Width, mm	Thickness, δ,mm
1	2	44	24	1
2	3	66	24	1
3	4	88	24	1
4	5	110	24	1

II. RESULTS AND DISCUSSION

Results:

Heat transfer Enhancement studies with different twist ratios

The Shear Stress Transport (SST k-ω) model is used in the simulation for finding the Nusselt number and friction factor with twist ratios of 2, 3, 4 and 5. Vector plots of velocity, Pathlines, contour plots of static pressure and Temperature fields shown in figures 2, 3,respectively in the Re = 2000 at twist ratio y=2.Velocity was found increase with decrease in twist ratio

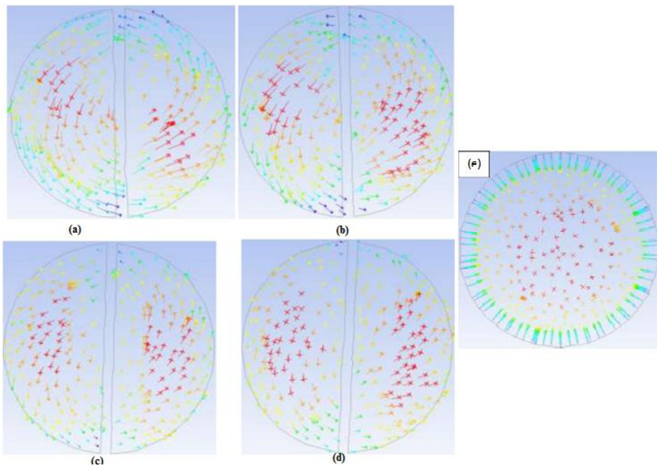
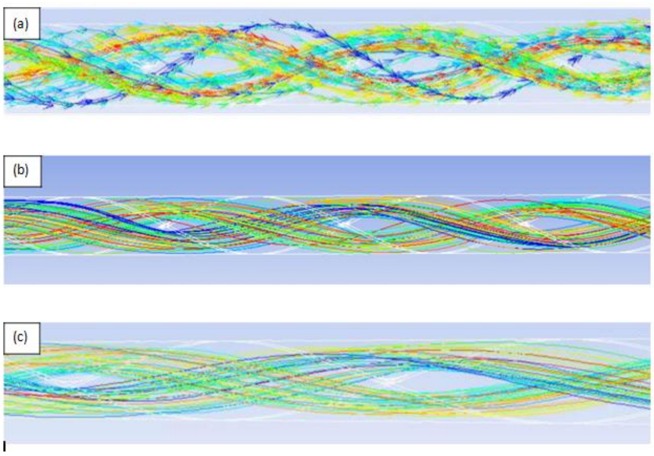


Figure 2. Vector plots of velocity at different twist ratios for Re= 2000: (a) y= 2, (b) y=3, (c) y=4, (d) y= 5, (e) plain tube



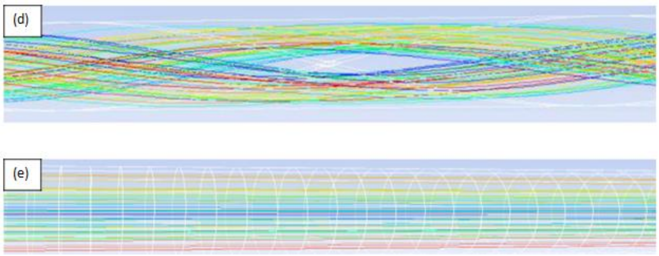


Figure 3. Pathlines at different twist ratios for Re= 2000: (a) y= 2, (b) y=3, (c) y=4, (d) y= 5, (e) plain tube

Heat transfer results

Effect of the twist ratios on the heat transfer rate is numerically studied; the values are given in Table.A.5. The results for the tube fitted with all twisted tapes are also compared with those for a plain tube under similar operating conditions. The heat transfer rate is considered in terms of Nusselt numbers Fig, 4 and 5 shows the Nusselt number ratio (Nu_a/Nu_0) with Reynolds number of the tube equipped with four different twist ratios (y = 2, 3, 4 and 5).

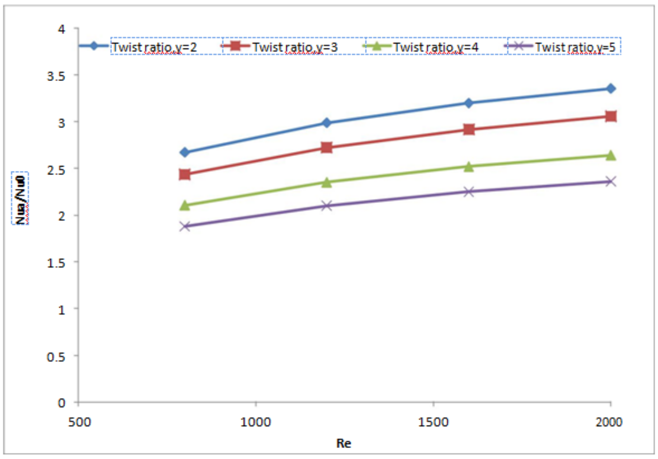


Figure 4. Variation of Nu_a/Nu_0 with Reynolds number in laminar regime for FWTT

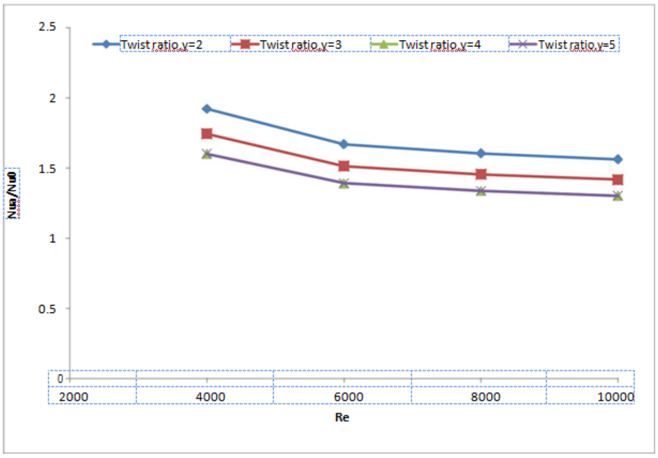


Figure 4. Variation of Nu_a/Nu_0 with Reynolds number in turbulent regime for FWTT

The Nusselt number in the tube with the twist ratios y= 2, 3, 4 and 5, are around 2.67 to 3.35, 2.43 to 2.19, 2.10 to 2.64, and 1.87 to 2.35 times of that in the plain tube in laminar region. Similarly in turbulent region 1.92 to 1.56, 1.74 to 1.41, 1.65 to 1.34, and 1.6 to 1.3 times of that in the plain tube.

III.CONCLUSION

Plain tube with full width twisted tape inserts, (FWTT) of twist ratio, (y=2, 3, 4, 5) results show that Nusselt number and friction factor values were found to decrease with increasing in twist ratio. Twisted tape inserts for twist ratio (y=2) can enhance heat transfer rates up to 3.5 times at Reynolds number 2000 and increase in friction factors nearly 9 times in comparison with those of the plain tube. Thermal performance factor (η) was found to increase with increase in Reynolds number in the laminar region and decrease in the turbulent region. The maximum value of the thermal performance factor was found to be 1.6 for Twisted tape (y=3) in plain tube at a Reynolds number of 2000.

IV. REFERENCES

[1]. Saha, S. K. Dutta, A. and Dhal, S. K. (2001), Friction and heat transfer characteristics of laminar swirl flow through a circular tube fitted with regularly spaced twisted-tape elements. Int. J. Heat and Mass Transfer, Vol. 44, pp. 4211-4223.

[2]. Al-Fahed, S. Chamra, L. M. Chakroun, W. (1999), Pressure drop and heat transfer comparison for both micro-fin tube and twisted-tape inserts in laminar flow. Exp. Thermal and Fluid Sci., Vol.18, pp.323-333.j

[3]. Liao, Q. and Xin, M. D. (2000), Augmentation of convective heat transfer inside tubes with three-dimensional internal extended surfaces and twisted tape inserts. Chem. Eng. J.Vol.78, pp. 95-105.

[4]. Ujhidy. A, Nemeth, J. Szepvolgyi, J. (2003), Fluid flow in tubes with helical elements. Chem. Engg and Processing, Vol.42, pp.1-7.

[5]. Suresh Kumar, P., Mahanta, P. and Dewan, A. (2003), Study of laminar flow in a large diameter annulus with twisted tape inserts. In Proceedings of 2nd International Conference on Heat Transfer, Fluid Mechanics, and Thermodynamics, Victoria Falls, Zambia, paper KP3.

[6]. Wang, L. and Sunden, B. (2002), Performance comparison of some tube inserts. Int. Commun. Heat Transfer, Vol. 29, pp.45-56.

[7]. Saha, S. K. and Chakraborty, D. (1997), Heat transfer and pressure drop characteristics of laminar flow through a circular tube fitted with regularly spaced twisted tape elements with multiple twists. In Proceedings of 3rd ISHMT-ASME Heat and Mass Transfer Conference, India, pp. 313-318

[8]. Mekala P., Kunuthur M.R., Chandramohana Reddy B. (2019) Evaluation of the Mechanical Properties of Recycled Jute Fiber-Reinforced Polymer Matrix Composites. In: Vasudevan H., Kottur V., Raina A. (eds) Proceedings of International Conference on Intelligent Manufacturing and Automation. Lecture Notes in Mechanical Engineering. Springer, Singapore DOI https://doi.org/10.1007/978-981-13-2490-1_26

[9]. Guo, J. Fan, A. Zhang, X. Liu, V. (2011), A numerical study on heat transfer and friction factor characteristics of laminar flow in a circular tube fitted with center-cleared twisted tape, International Journal of Thermal Sciences, Vol. 50, pp. 1263-1270

[10]. Kumar, P. M. Kumar, K. (2012), Enhancement of heat transfer of laminar flow in a square ribbed duct with twisted tape International Journal of Engineering Science and Technology, Vol. 4, pp. 3450-3456

[11]. Zhang, X. Liu, Z. Liu, W. (2012) Numerical studies on heat transfer and flow characteristics for laminar flow in a tube with multiple regularly spaced twisted tapes, International Journal of Thermal Sciences Vol.58, pp. 157-167

[12]. Kunuthur M.R., Reddy B.C. (2019) Investigation of Moisture Absorption in Jute Fiber Polymer Matrix Composites. In: Vasudevan H., Kottur V., Raina A. (eds) Proceedings of International Conference on Intelligent Manufacturing and Automation. Lecture Notes in Mechanical Engineering. Springer, Singapore DOIhttps://doi.org/10.1007/978-981-13-2490-1_34

[13]. Manglik, R. M. and Bergles, A. E. (1993), Heat transfer and pressure drop correlations for twisted tape insert in isothermal tubes. Part 1: laminar flows. Trans. ASME, J. Heat Transfer, Vol. 116, pp. 881-889.

[14]. Kumar, A. and Prasad, B. N. (2000), Investigation of twisted tape inserted solar water heater heat transfer, friction factor and thermal performance results. Renewable Energy, vol. 19, pp. 379-398.

[15]. AI-Fahed, S. and Chakroun, W. (1996), Effect of tube tape clearance on heat transfer for fully developed turbulent flow in a horizontal isothermal tube. Int. J. Heat and Fluid Flow, Vol.17, pp. 173-178.

[16]. Rao, M. M. and Sastri, V. M. K. (1995), Experimental investigation for fluid flow and heat transfer in a rotating tube twisted tape inserts. Int. J. Heat and Mass Transfer, Vol. 16, pp. 19-28.

[17]. Sivanshanmugam, P. and Sunduram, S. (1999), Improvement in performance of heat exchanger fitted with twisted tape. J. Energy Engg, Vol.125, pp. 35-40.

[18]. Agarwal, S. K. and Raja Rao, M. (1996), Heat transfer augmentation for flow of viscous liquid in circular tubes using twisted tape inserts. Int. J. Heat Mass Transfer, Vol. 99, pp.3547-3557.

[19]. Chung, S. Y. and Sung, H. J. (2003), Direct numerical simulation of turbulent concentric annular pipe flow. Part 2: heat transfer.Int. J. Heat and Fluid Flow, Vol. 24, pp.399-411.

[20]. Gupte, N. S. and Date, A. W. (1989), Friction and heat transfer characteristics of helical turbulent air flow in annuli. Trans.ASME, J. Heat Transfer, Vol. 111, pp. 337-344.

[21]. Rahimi, M. Shabanian, S.R. Alsairafi. A.A. (2009), Experimental and CFD studies on heat transfer and friction factor characteristics of a tube equipped with modified twisted tape inserts, Chemical Engineering and Processing, Vol.48, pp.762-770

[22]. Murugesan, P. Mayilsamy, Suresh, K. (2010), Heat Transfer and Friction Factor Studies in a Circular Tube Fitted with Twisted Tape Consisting of Wire-nails, Chinese Journal of Chemical Engineering, Vol. 18, pp. 1038-1042

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