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Investigation of the thermal performance for a square duct with screwtape and twisted tape numerically

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Abstract

Experiments were performed on a heat exchanger of concentric double pipe through a duct of the square cross-sectional area and a circular annulus. During the experiments, water was used as a heat transfer fluid. The twisted tape had been made of stainless steel and inserts screw-tape with a similar ratio of twisting, y=4. Cold and hot water streams meanwhile annulus and internal duct with square cross-sectional, respectively. The performance for the system with screwtape inserts is greater than that when the twisting tape had been used, also this performance in colder weather is improved when it was working in other conditions. Because tape inserts and impellers have a greater isothermal coefficient of kinetic friction than that of plain tubing by 7.6 and 13.2. Within the laminar region, experiments were carried out with success. Therefore, the mean Nusselt numbers for both twisted and screw tapes are significantly high than that for the ordinary duct over the whole laminar scope. The screw twisted and tape inserts performance are 2.81 and 3.52 times larger than that for a duct's square plain at a constant power of pumping respectively.

Keywords: twisted tape, CFD, screw, duct, performance.

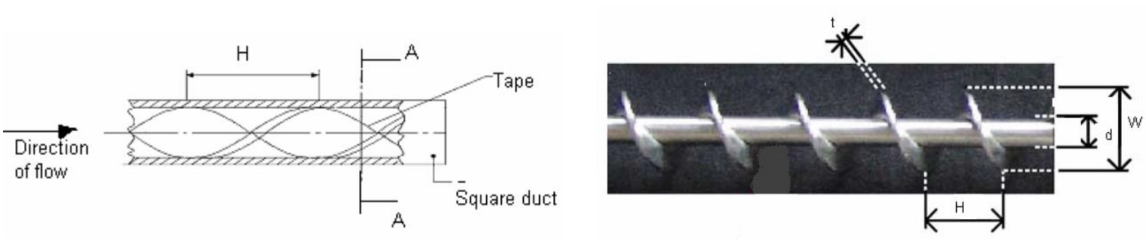
Introduction

Any heating system's performance is improved by growing the coefficient of heat transfer. Such a technique was developed and has extensive use in the applications of heat exchangers such as refrigeration, automotive, process, and chemical industries. Up to this point, a great deal of work has been done to decrease cost and size. Additionally, a higher heat transfer coefficient has the added advantage of dipping the temperature pouring force, increasing the effectiveness of the second law, and declining entropy production [1-2]. For laminar flow as well, heat augmentation techniques are essential. The tape wound on a core-rod is twisted in the method as screw-tape. Although both types of tape produce a swirling flow through a pipe, the tape of helical screw and twisting tape have distinct flow characteristics. Screw-tape whirling flow alternates in a direction with smooth, while twisted-tape twirls with two parallel directions instantaneously. The twisted tape is extra widespread than that helical screw type [3-6], owing to its lower pressure drop and ease of production. The helical screw can be used in the flow with a low Reynolds number. By asset of its pitch length is shorter, that leads to making the swirling flow be a sturdier and lengthier time of residence tube, and therefore, that type will promote higher heat transferred than that for twisting tape [1].

A radial tube equipped with filled helical screw tapes of varying spin ratio values was studied by [7] to determine the laminar thermohydraulic variable features. When the tape inserts were used, they stated an important increase in the heat transfer rate. They also originate that the coefficient of heat transfer augmentation was not knowingly different between twist ratio cumulative and lessening. With the assist of twisted tape inserts, [8-10] considered the amount of heat transferred for the flow of laminar and viscous. For constant flow rate and pumping power, the Nusselt number had been getting to be 2.24 - 5.56 and 1.23 - 3.67 times that for the plain tube. Characteristics for heat transfer and fluid flow with the laminar region through horizontal un circular tube experimentally investigated for that with inserted full length, short-length or frequently spread out the twisting tape was performed by [11]. Aspect ratio, twist ratio (y), and tape length have all been studied to see if they can improve heat transfer. Regularly twisted tape elements exceed short twisted tapes in performance tests [12].

Problem description

Figs. 1 and 2 illustrate the specifics for the test section inserts. The present problem was analyzed for a heat exchanger with the concentric tube of two models internal duct with a square cross-section and annulus pipe in the outer. Cold and hot water flow through the test section in the outer and inner respectively. Tube with 21.41 mm inner diameter and outer diameter is 56 mm. dimensions for tube were 2000mm in length and thickness of 2 mm. The two tubes had been made of copper. To reduce heat loss to the environment, the outer tube surface was covered in insulation. The entire length twisted tape, as well as full-length helical tape, incorporate used here assessment were displayed in Figs. 1a and 1b. The dimensional circumstances of the tape inserts and spiral tape implanted had been preserved fixed. The ratio between the distance of 180 ° for swirl and diameter of a tube was named twist ratio.



a b

Fig. 1 shows Diagram for (a) twisting tape, (b) Screw-tape insert

The twisted tape was created using stainless strips with a wall thickness of 1 mm (t) and widths of 19 mm (H=86mm). That one was created by spinning a plain tape around its longitudinal direction whereas holding it under tension on a lathe. Screwtape twist ratio (Y) is defined as the length of one twist divided by the diameter of the twist. The spiral tape is made of stainless steel with *W = 18, d = 8, and t = 1mm*.

CFD meshing

Ansys fluent Workbench had been used to generate a QUAD mesh. There are numerous element and mesh types to choose from. The choice is determined by the problem and the solver's abilities. First, the solar chimney's surface meshes with a QUAD element. For all models, 8452201 elements are used.

Heat transfer calculations

The rate of heat transfer can be calculated through the test section as follows [6-8],

$$Q_c = m_c C_{pc}(T_2 - T_1) \quad 1$$

Convection heat transfer from the hot working fluid (water) can be estimated as,

$$Q_h = m_h C_{ph}(T_3 - T_4) \quad 2$$

average heat transfer had been evaluated,

$$Q_{\text{avg}} = 0.5(Q_c + Q_h) \quad 3$$

$$Q_{\text{avg}} = h_i A_i (\Delta T)_{\ln} \quad 4$$

Heat transfer for isothermal surface had been determined,

$$h_i = \frac{Q_{avg}}{A_i (\Delta T)_{\ln}} \quad 5$$

$$A_i = 4 D_h L \quad 6$$

$$(\Delta T)_{\ln} = \big((T_w - T_1) - (T_w - T_2)\big) / \ln\big((T_w - T_1)/(T_w - T_2)\big) \quad 7$$

To calculate the bulk temperature of the working fluid,

$$T_b = \frac{(T_1+T_2)}{2} \quad 8$$

$$T_w = \sum T_{\text{wall}} /8 \quad 9$$

Nusselt number was calculated as

$$Nu = \frac{h_i D_h}{k} \quad 10$$

Results and discussion

The thermal performance had been estimated by using the following ratios R1 and R2, according to the dimensionless parameter of Nu_a [11].

$$R_1 = (Nu_a/Nu_0)_{m,L,N,\Delta T,T_1,D_h} \quad 11$$

$$R_3 = (Nu_a/Nu_o)_{P,L,N,\Delta T,T_1,D_h} \quad 12$$

Fig.7 illustrated thermal performance ratios for twisted and screw tapes with entire length analyzed individually insert with core rod are affected by enlarged Reynolds numbers (Re_a). As Reynolds number increases for both types of inserts, the thermal performance ratio (R1 at a constant flow rate) also increases. For twisted tape inserts, R1values drop sharply after Reynolds number 1205 and for screwtape inserts, R1 values drop sharply after Reynolds number 1909. Turbulence in the transition region reduces R1 values, which can lead to an increase in Nu_o values as well. For twisted tape and screwtape insert, Reynolds numbers of 1210 and 1909, the optimum performance is 3.45 and 6.52 times the plain square duct.

For both types of inserts, the hydrodynamic and thermal performance ratio R3 increases linearly Re_a. When using twisted tape and screwtape inserts with Reynolds numbers of 1009 and 752, respectively, the performance of the model obtains 2.81 and 3.52 times the plain square duct performance. Re_a continues to rise, while R_3 continues to drop. R3 values fall below 1.0 at high flow rates. That's because when comparable pure duct Reynolds number exceeds 2100 for relating Rea values, Nu_o values are considered to be greater, resulting in a lower performance ratio.

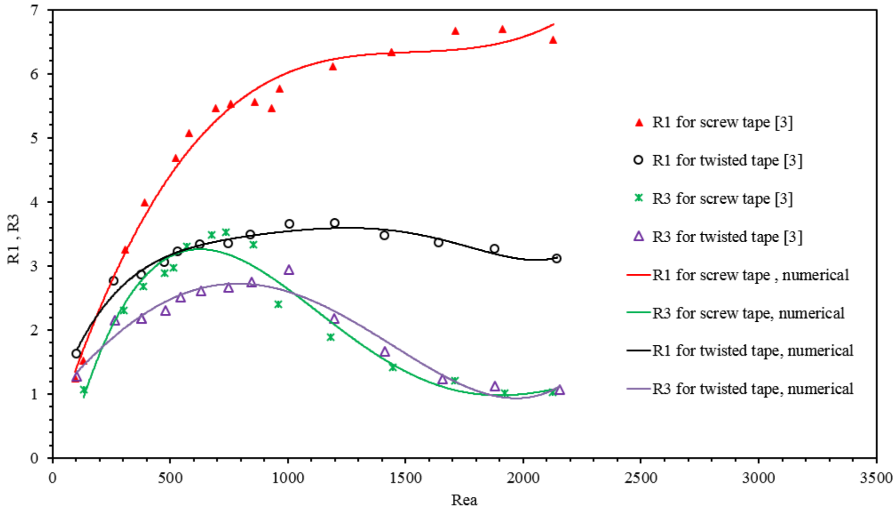


Fig.7 the ratio of performance alteration with Re_a

Conclusions

A square duct with twisted tape and helical screw-tape with a core-rod inside was subjected to heat transfer and isothermal friction factor experiments to obtain the data. Screwtape inserts with helical spirals improve heat transfer rates by a significant amount. Using a rod with helical screw tape results of heat transfer is great by 3.45 times that for a square duct at a constant flow rate.

References

[1] S. Eiamsa-ard, P. Promvonge, “Enhancement of heat transfer in a tube with regularly-spaced helical tape swirl generators”, Solar Energy, Vol. 78, pp. 483–494, 2005.

[2] P. Sivashanmugam, S. Suresh, “Experimental studies on heat transfer and friction factor characteristics of laminar flow through a circular tube fitted with helical screw-tape inserts”, Applied Thermal Engineering, vol.26, pp. 1990–1997, 2006.

[3] V. Suhas, P. Patil, and V. Vijay Babu “Performance Comparison of Twisted Tape and Screw Tape Inserts in Square Duct”, Proceeding of the International Conference on Advanced Science, Engineering and Information Technology. Malaysia, 14 - 15 January 2011.

[4] S.K. Agarwal, M. Raja Rao, “Heat transfer augmentation for the flow of a viscous liquid in circular tubes using twisted tape inserts”, Int. J. Heat Mass Transfer, Vol. 39,pp. 3547–3557, 1996.

[5] Saha,S.K ,Mallick D.N.,“Heat Transfer and Pressure Drop Characteristics of Laminar Flow in Rectangular and Square Plain Ducts and Ducts With Twisted-Tape Inserts”, Transaction of ASME , Journal of Heat Trasfer, vol. 127,pp. 966-977, 2005.

[6] W.G. Steele, H.W. Coleman, “Experimental and Uncertainty Analysis for Engineers”, Wiley, New York, 1989..

[7] Kline, S. J., and McClintock, F. A., “Describing Uncertainties in Single Sample Experiments,” Mech. Eng., (Am. Soc. Mech.Eng.), Vol. 75(1), pp. 3–8, 1953.

[8] Khudheyer, Ahmed F. 2020. "Numerical investigation and exergetic analysis of convergent-divergent absorber tube in concentrated solar trough. Journal of Green Engineering, 10(10), 8083-8104.

[9] M. S. Mahmoud, “Numerical investigation of conjugate combined convective heat transfer for internal laminar flow of Al2O3/water nanofluid through tube - Flat plate solar collector,” J. Eng. Sci. Technol., vol. 16, no. 3, pp. 2378–2393, 2021.

[10] Abbas, A. S., Mahmoud, S. M., and Khudheyer, Ahmed. F., 2020. "Improvement of heat transfer for airflow through a solar air heater channel with cut-off desecrate baffles". Journal of Green Engineering, 10(7), 4292-4308.

[11] Mahmoud Sh. Mahmoud, Ahmed F. Khudheyer and Qusay J. Abdul Ghafoor, 2020. "A Novel design of the solar central receiver to improve the performance of the central solar power tower plant". IOP Conf. Ser.: Mater. Sci. Eng. 928 022003. doi:10.1088/1757-899X/928/2/022003

[12] Mahmoud Sh. Mahmoud, Ahmed F. Khudheyer, Ali Sabri Abbas. 2020. "Solar parabolic trough collector tube heat transfer analysis with internal conical pin fins". Journal of Green Engineering, 10(10), 7422-7436.