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LAMINAR FLOW HEAT TRANSFER AUGMENTATION BY USING INSERTS

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Abstract: *Heat transfer augmentation techniques are used to increase rate of heat transfer without affecting much on overall performance of system. This paper presents the result obtained from experimental investigation of heat transfer and friction factor characteristics in horizontal tube by means of twisted tape inserts of various twist ratios with Non Newtonian solution (0.2 wt . percent CMC solution) as working fluid. The experiments are conducted in Reynolds number range 87 to 347 with twisted tape inserts of different twist ratio(y=H/D) in the range 6.11 to 7.77. The inner tube is made of copper with inner and outer diameter 19.5x10^{-3}m and 24.5x10^{-3}m respectively. Twisted tape is made up of stainless steel of 1 mm thickness and 1.9 m length. Hot and cold fluid flow though tube and shell side respectively Hot fluid is Non Newtonian fluid & is used as a test fluid . The results obtained from twisted tape are compared with plain tube results. The result obtained for Non Newtonian solution conforms that twisted tapes are more effective with Non Newtonian solution than for water. For non-Newtonian solution heat transfer coefficient increases with decrease in twist ratio. Maximum value of Nusselt number is obtained for twist ratio y = 6.11 which is 40% higher than plain tube and friction factor increases by 56.86% than plain tube value. If we compare the experimental results for water and non-Newtonian solution, it is clear that, twisted tape inserts are more effective with Non-Newtonian solution than water as working fluid. From performance ratio we can say that twisted tape performs effectively at low Reynolds number range. Finally new generalized correlations function for predicting heat transfer and friction factor for laminar flow of Non Newtonian solution are proposed with tape inserts.*

Keywords*: Heat transfer augmentation, Non- Newtonian Fluid, friction factor, twisted tape inserts, twist ratio.*

I. INTRODUCTION

In Industrial Applications, Heat transfer fluid such as water, mineral oil and Ethylene Glycol play an important role. The heat transfer Augmentation with flow of water in circular pipe has been observed; the use of twisted tape inserts for further enhancement is the aim of this study. Nazveez [1] studied the enhancement of pseudoplastic flow using twisted tape inserts. He found substantial increase in heat transfer 50 to 300 percent. S.K. Agarwal and M.Raja Rao [2] experimentally determined the isothermal and non-isothermal friction factors and mean Nusselt Numbers for uniform wall temperature heating and cooling of Servo-therm oil (Pr=195-375) for flow in a circular tube (Re_a=70-4000) with twisted tape insert (y=2.41-4.84).Isothermal friction factor were found to be 3.13-9.71 times the plain tube and Nusselt number 2.28-5.35 based on constant flow rate and constant pumping power respectively. Shaha and Dutta [3] reported experimental data on twisted tape generated laminar swirl flow friction factor and Nussult number for a large Prandtl number (205<Pr< 518) and observed that on the basis of constant pumping power short length twisted tape is good choice because in this case swirl generated by the twisted tape decays slowly down streams which increases the heat transfer coefficient with minimum pressure drop as compared to full length twisted tape. Fig.1 shows the different types of twisted taps. Manglik and Bergles [4] considered twisted tape with twist ratio (3, 4.5 and 6.0) using water (3.5<Pr<6.5) and proposed correlation for Nussult number and friction factor and reported physical description and enhancement mechanism. Loknath [5] reported experimental data on water (240<Re<2300, 2.6<Pr<5.6) of laminar flow through horizontal tube under uniform heat flux condition and fitted with half-length twisted tape. He found that on the basis of unit pumping power and unit pressure drop half-length twisted tape is more efficient than full length tape. Shaha and Chakraborty [6] found that laminar flow of water (145<Re<1480, 4.5<Pr<5.5, tape ratio 1.92<y<5.0) and pressure drop characteristics in a circular tube fitted with regularly spaced, there is drastic reduction in pressure drop corresponding reduction in heat transfer. Thus it appears that on basis of constant pumping power a large number of turn may yield improved thermo hydraulic performance compared with single turn on twisted tape. Royds [7] reported that tube inserted with twisted tape performs better than plain tube and twisted tape with tight twist ratio provides better heat transfer at a cost of increase in pressure drop for low Prandtl number fluid. This is due to the small thickness of thermal boundary layer for low Prandtl number fluid and tighter twist ratio disturb entire thermal boundary layer thereby increasing heat transfer with increase in pressure drop. Date [8] reported that friction and Nu for water flow in tube containing twisted tape deviate 30 percent than experiment with plain tube. Klaczak [9] found usefulness of short length twisted tape with water (1300<Re <8000) than full length twisted tape. Al-fahed et al. [10] found that there is an optimum tape width depending upon twist ratio and Re for best thermodynamic characteristics for full length tape with water. Manglik and Bergles [11] developed correlation for both lamina and turbulent flow (3.5<Pr<6.5) with tape but shows that correlation for laminar turbulent transition need to be developed with water. For more details readers can referee Waghole et al. [12]. Several investigations have been carried out to study the effect of turbulators (turbulent promoters)with different geometries on thermal behaviors in the heat exchanger, for example twisted-tapes [13,14], wire coils [15,16], dimpled or grooved tubes [17,18], winglet/fins [19,20], and combined turbulators. However, twisted tapes as one of passive turbulators have been applied extensively to enhance convection heat transfer in heat exchanger systems due to the need for finding the way to reduce the size and cost of those systems. For decades, the heat transfer enhancement by twisted-tape insert has been widely investigated both experimentally and numerically. Krishna et al. [21] experimentally investigated the heat transfer characteristics in a circular tube fitted with straight full twist insert with different spacer distances. Influence of the tube equipped with the short-length twisted tape on Nu, f and thermal performance characteristics for several tape-length ratios was examined by Eiamsa-ard et al. [22]. The effect of twisted tape consisting wire-nails and plain twisted tapes with three different twist ratios fitted in a heat exchanger pipe using water as the test fluid on thermal characteristics was studied experimentally by Murugesan et al. [23]. Liao and Xin [24] reported the heat transfer behaviors in a tube with three-dimensional internal extended surfaces and twisted-tape inserts with various working fluids. Chiu and Jang [25] presented the experimental and numerical analyses on thermal–hydraulic characteristics of air flow inside a circular tube with 5 different tube inserts; longitudinal strip inserts both with/without holes and twisted-tape inserts with three different twist angles for inlet velocity ranging from 3 to 18 m·s−1. Eiamsa-ard and Promvonge [26] conducted an experimental study on turbulent flow and heat transfer characteristics in a tube equipped with two types of twisted tapes: (1) typical twisted tapes and (2) alternate clockwise and counterclockwise twisted-tapes. Nine different clockwise and counterclockwise twisted-tapes were tested in that work and included the tapes with three twist-ratios and three twist-angles. The experiments were performed for Reynolds number of 3000 to 27000 using water as working fluid. The twin and triple twisted tapes used to generate twin and triple swirl flows in a circular tube were reported by Chang et al. [27].

II. EXPERIMENTAL ANALYSIS

2.1. Experimental Setup

Actual image of experimental setup is shown below.

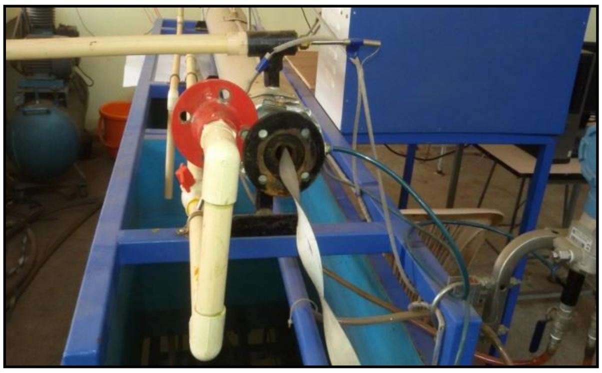

Figure 2.1-a Diagram of experimental setup

Figure 2.1-b Inserts

The experimental set up consist of the test section, fluid tanks, pumps, heaters, temperature control system, data acquisition systems, valves, DP transmitter & pipes etc. The Non Newtonian (0.2 percent wt. CMC) solution is used as a working fluid & is pumped through the flow meter and a heater in series enters in to the inner tube of heat exchanger and continued to be heated to the required experimental temperature. The Non Newtonian solution is heated by six electrical heaters which are placed in series before entering in to the tube of heat exchanger. The heat flux on testing section can be changed to the required value by changing the number of electrical heater during working. Figure 2.1-a shows diagram of experimental set up and figure 2.1-b shows inserts that have been used. The analysis of Nusselt number versus Reynolds number and other parameter for experimental data is carried out. As per experimental data a generalized correlation function for laminar flow heat transfer and friction factor is investigated. The experimental procedure is as follows: At first the fluid pump is switched on and fluid is allowed to flow for few minutes. Then the electrical heaters are switched on. The number of electric heaters in working is adjusted as per requirement. The flow rate of fluid through the shell is set to desired value and kept constant with the help of flow control valve and flow transmitters. Flow transmitter, pressure transmitters and temperature transmitters are connected to data acquisition system. First the variations in wall temperature at all location are observed until constant value is attained at different locations. Then the outlet bulk temperature of fluid is monitored. The steady state condition is attained when outlet fluid temperature did not fluctuate over some duration of time. At the steady state condition thermocouple readings are monitored with help of data acquisition system. The pressure difference between two ends of test section is recorded automatically. The fluid flow rate is changed with the help of flow control valve after each experimental run, hence changed the Reynolds number. Number of electrical heater in working are kept constant so that uniform temperature can be obtained. Different data are taken in similar way in each experimental run at steady state condition.

III. RESULTS & DISCUSSION

3.1. Validation of Experimental Setup

The accuracy with which the friction factor and Nusselt number could be evaluated experimentally with use of present experimental setup is determined by conducting experiment without twisted tape inserts and results compared with standard empirical relationships. Figure 3.1 shows graph of friction factor versus Reynolds number for plain tube. The average difference between actual and theoretical friction factor is 18.13%. The data obtained from the experiments for plain tube is reasonable agreement with literatures available for laminar flow heat transfer. This result allows us to conduct further experimental work.

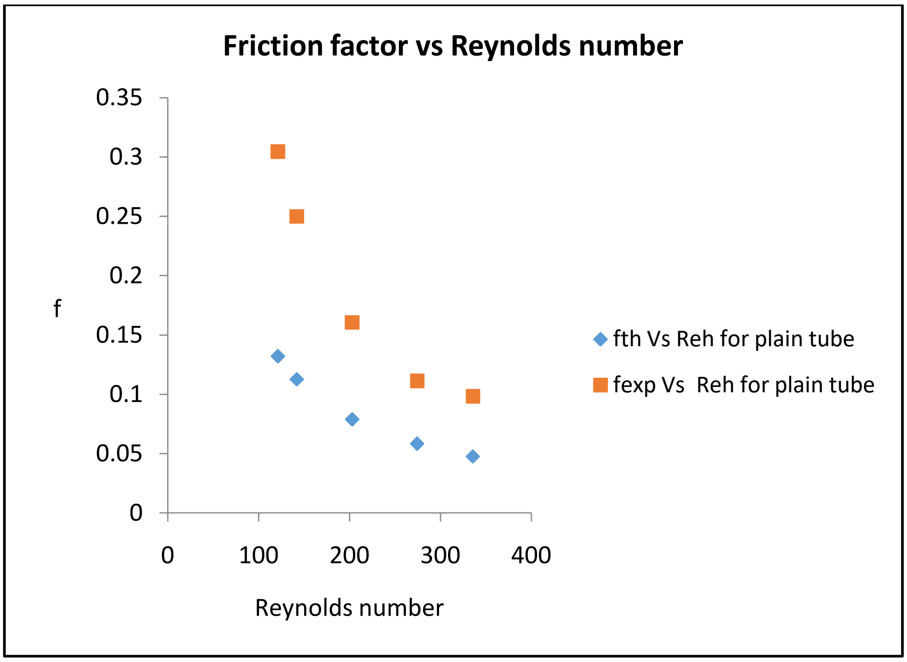

Figure 3.1 Experimental and theoretical friction factor for plain tube

3.2. Friction Factor for Augmented Tube

Figure 3.2 shows that variation of friction factor vs. Reynolds Number for tube fitted with twisted tape inserts of various twist ratio (without twist ,y=6.11,7.22,7.77) and Non Newtonian solution used as working fluid**.** The friction factor for tube with twisted tape higher than for plain tube and decreases with increase in Reynolds number for given twist ratio. From figure 3.2 it could be clear that the friction factor is in similar trend for both plain tube and tube with twisted tape insert. The friction factor for tube with twisted tape is higher than plain tube, because of large contact surface area and pressure generation due to reduced flow area.

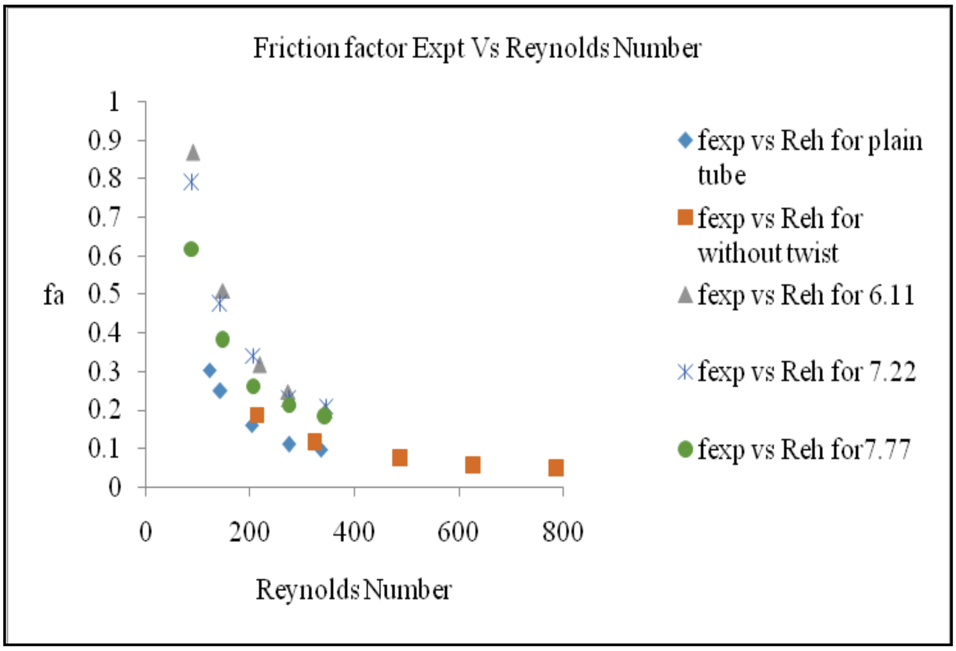

Figure 3.2: Friction factor versus Reynolds number for augmented tube

Friction factor is highest for twisted tape insert with twist ratio 6.11 and minimum for insert without twist. Friction factor increases with decrease in twist ratio, it is of because increase in intensity of swirl generation, secondary flow and increase in pressure drop. In the literature review it is found that, 0.2percent wt. CMC does not show turbulence nature even at high Reynolds number. Therefore reduction in friction factor with increase in Reynolds number for Non-Newtonian fluid through circular pipe is less as compared to water. The curve are very steep for lesser value of Reynolds number, this is because of fact that, for lower Reynolds number the viscous forces dominates inertia force. For less value of Reynolds number friction factor is very high. The friction factor results are summarized below for each twist ratio used.

3.3. Nusselt Number for Augmented Tube

Figure 3.3 shows variation of Nusselt number with Reynolds number for plain tube and tube fitted with twisted tape insert of various twist ratio (without twist , y=6.11,7.22,7.77) by using Non Newtonian solution as working fluid

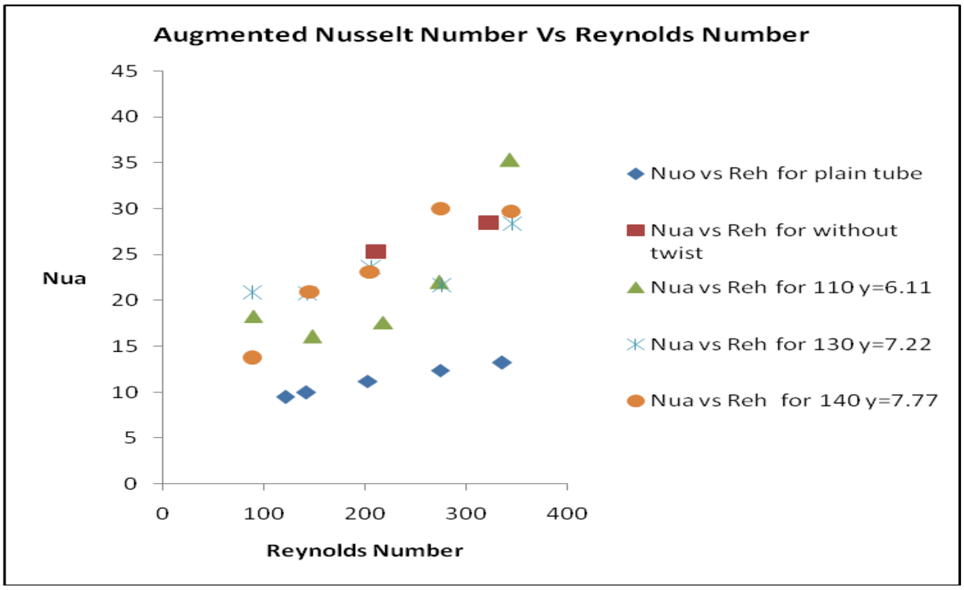

Figure 3.3 Nusselt number versus Reynolds number for augmented tube

From figure 3.3 it is clear that Nusselt number for tube with twisted tape insert is higher than Nusselt number for plain tube for given Reynolds number. As twist ratio decreases, a higher degree of swirl is generated which increases turbulence and hence the Nusselt number increases as twist ratio decreases. From figure it is clear that, much higher improvement in Nusselt number is observed for twisted tape with twist ratio 6.11 because it increases secondary flow generation which disturbs the entire thermal boundary layer. It is also observed that Reynolds number increases with decrease in twist ratio and increase in Reynolds number causes random movement of fluid which consequently enhance the thermal dispersion of the flow. Use of twisted for non-Newtonian fluid breaks viscous sub layer generated at wall which offers maximum resistance to the heat transfer, hence the rate of heat transfer increases when twisted taps are inserted in flow channel.

3.4. Performance Ratio R1 and R3 for Augmented Tube

Figure 3.4 shows plot for performance ratio R1versus Reynolds Number for different tapes inserts. Performance ratio R1 evaluates effectiveness of tube inserts on equal flow rate basis.

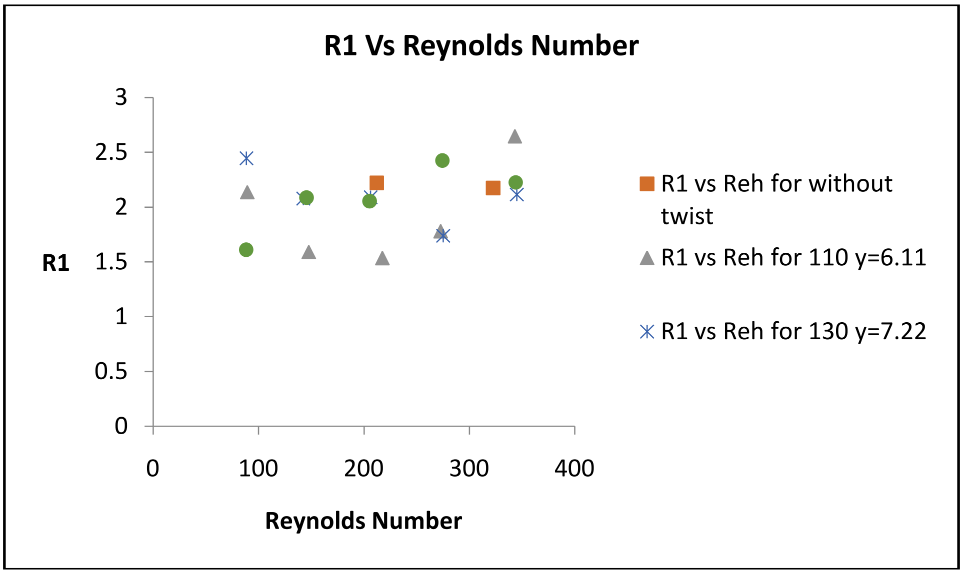

Figure 3.4: Performance ratio R1 versus Reynolds number for augmented tube

It is applicable for situation where heat transfer enhancement is more important than pressure drop. From figure 3.4 it could be seen that maximum R1 for given condition is observed for twist ratio 6.11 then decreases as twist ratio increases. Therefore on the basis of performance ratio R1 twisted tape with twist ratio 6.11 is best suitable for enhancing rate of heat transfer if increase in pressure drop is not important. Maximum value of R1 is observed for highest Reynolds number and then increases as Reynolds number increases. When we use twisted tape in turbulent flow of Newtonian fluid to enhance secondary flow, the effect is not that high because the turbulence is already high because of high flow rate. But for non-Newtonian fluid, increase in turbulence with increase in Reynolds number is very less, therefore increase in Reynolds number does not increase heat transfer rate. For this reason, twisted tapes are effective for non-Newtonian fluid even at high Reynolds number. Average value of performance ratio R1 and R3 for different twist ratio are listed in table 3.1.

Table 3.1. Performance ratio R1 and R3 for augmented tube

Twist Ratio (y=H/D)	Average value of R1	Average value of R3
Plain insert without twist	1.2461	1.1434
Insert with twist ratio y = 6.11	1.3933	1.2045
Insert with twist ratio y = 7.22	1.3752	1.2064
Insert with twist ratio y = 7.77	1.2957	1.1850

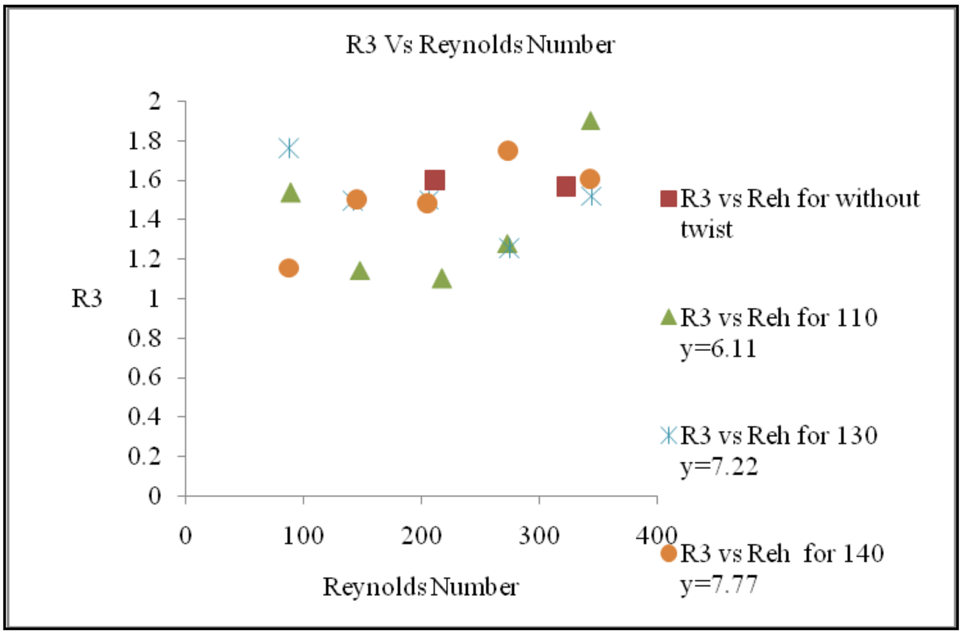

Figure 3.5 Performance ratio R3 versus Reynolds number for augmented tube

Performance ratio R3 is thermo-hydraulic assessment of tube insert. From figure 3.5 it can be observed that maximum value of R3 is observed for twist ratio 6.11 and minimum for insert without twist. Maximum value of R3 is obtained for twist ratio 6.11. Therefore on the basis of performance ratio R1 and R3 we can say that twisted tape with twist ratio 6.11 is found to be best, because it gives maximum increase in heat transfer rate with less expense of pressure drop.

IV. CONCLUSION

An experimental study is conducted to investigate heat transfer performance by means of twisted tape insert The study conducted revels that use of twisted tape insert cause an increase in rate of heat transfer at cost of increase in pressure drop. From experimental result we can conclude that

5.1. Maximum increase in Nusselt number and friction factor for twisted tape with Non Newtonian solution for y=6.11 was found to be 62.88% and 185.17% respectively.

5.2. Maximum increase in Nusselt number and friction factor for twisted tape with Non Newtonian solution for y=7.22 was found to be 62.41% and 159.17% respectively.

REFERENCES

[1] Nazmeev Y.G., “Intensification of convective heat exchange by Ribbon swirlers in the flow of anomalously viscous liquids in pipes,” Journal of Engineering Physics,37,910-913,1979

[2] Agarwal, S. K. and Raja Rao, M. “Heat transfer augmentation for flow of viscous liquid in circular tubes using twisted tape inserts.” Int. J. Heat Mass Transfer, vol.39 No.17 pp.3547– 3557,1996.

[3]. Shah S.K. and Dutta A, Friction and Heat Transfer characteristics of laminar swirl flow through a circular tube fitted with regularly spaced tube element, International Journal of heat and mass transfer, 2001, 44, 4211-4223

[4] Manglik R.M. and Bergles A. E. Heat transfer and pressure drop relation for twisted tape inserts in isothermal tube, Journal of heat transfer, 1993, 116,881-889.

[5] Loknath. An experimental study on performance plate heat exchanger and augmented shell and tube heat exchanger, ASME, Heat and mass transfer conference,2002,pp863-868.

[6] Shaha and Chakraborty. Heat and pressure drop characteristics of laminar flow in circular tube fitted with regularly spaced twisted tape element with multiple twist, ISHMT, Heat and mass transfer conference,1997,pp 313-318.

[7] Royds. Heat transfer by radiation, convection and conduction, constable and camp ltd, 1921, pp 190-201.

[8] Date A.W. Flow in tube containing twisted tape Heat and vent Engg, journal of environmental science, 1973, 47, pp 240-24.

[9] Klaczak A. Heat and pressure drop in tube with short tabulator, Warme and stoeffebetragung, 1996, 31, pp 399-401.

[10] Al-fahed et al. Effect of tube tape clearance for heat transfer for fully developed turbulent flow in horizontal isothermal tube, International journal of heat and fluid flow,1996, 17, pp173-178.

[11] Manglik R. K. and Bergles A.E. Heat transfer and pressure drop correlation for twisted tape inserts I isothermal tube part II, ASME, Journal of heat transfer, 1993, 115, pp 890-896.

[12] D.R.Waghole, R.M.Warkhedkar, V.S. Kulkarni, N. K. Sane. A Review on Heat Transfer Augmentation using Twisted Tape inserts in Absorber/Receiver of PTC. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) Second National Conference on Recent Developments in Mechanical Engineering PP. 33-36.

[13]S. Eiamsa-ard, C. Thianpong, P. Promvonge, 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) (2006) 1225–1233.

[14] S.W. Chang, T.L. Yang, J.S. Liou, Heat transfer and pressure drop in tube with broken twisted tape insert, Exp. Thermal Fluid Sci. 32 (2) (2007) 489–501.

[15] P. Promvonge, Thermal performance in circular tube fitted with coiled square wires, Energy Convers. Manage. 49 (5) (2008) 980–987.

[16] S. Gunes, V. Ozceyhan, O. Buyukalaca, Heat transfer enhancement in a tube with equilateral triangle cross sectioned coiled wire inserts, Exp. Thermal Fluid Sci. 34 (6) (2010) 684–691.

[17] Y. Wang, Y.L.,Y.G. Lei, J. Zhang, Heat transfer and hydrodynamics analysis of a novel dimpled tube, Exp. Thermal Fluid Sci. 34 (8) (2010) 1273–1281.

[18] K. Bilen, M. Cetin, H. Gul, T. Balta, The investigation of groove geometry effect on heat transfer for internally grooved tubes, Appl. Therm. Eng. 29 (4) (2009) 753–761.

[19] S. Skullong, P. Promvonge, Experimental Investigation on Turbulent Convection in Solar Air Heater Channel Fitted with Delta Winglet Vortex Generator, Chin. J. Chem. Eng. 22 (1) (2014) 1–10.

[20] P. Promvonge, S. Skullong, S. Kwankaomeng, C. Thiangpong, Heat transfer in square duct fitted diagonally with angle-finned tape—Part 1: Experimental study, Int. Commun. Heat Mass Transfer 39 (5) (2012) 617–624.

[21] S.R. Krishna, G. Pathipaka, P. Sivashanmugam, Heat transfer and pressure drop studies in a circular tube fitted with straight full twist, Exp. Thermal Fluid Sci. 33 (3) (2009) 431–438.

[22] S. Eiamsa-ard, C. Thianpong, P. Eiamsa-ard, P. Promvonge, Convective heat transfer in a circular tube with short-length twisted tape insert, Int. Commun. Heat Mass Transfer 36 (3) (2009) 365–371.

[23] P. Murugesan, K. Mayilsamy, S. Suresh, Heat transfer and friction factor studies in a circular tube fitted with twisted tape consisting of wire-nails, Chin. J. Chem. Eng. 18 (6) (2010) 1038 1042.

[24] Q. Liao,M.D. Xin, Augmentation of convective heat transfer inside tubes with three dimensional internal extended surfaces and twisted-tape inserts, Chem. Eng. J. 78 (2–3) (2000) 95–105.

[25] Y.W. Chiu, J.Y. Jang, 3D numerical and experimental analysis for thermal–hydraulic characteristics of air flow inside a circular tube with different tube inserts, Appl. Therm. Eng. 29 (2–3) (2009) 250–258.

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

[27] S.W. Chang, K.W. Yu, M.H. Lu, Heat transfer in tubes fitted with single, twin and triple twisted tapes, Exp. Heat Transfer 18 (2005) 279–2

