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Experimental Study of Heat transfer and friction factor in Double pipe Heat Exchanger using Twisted Tape with different groove angle of V-cut at constant depth.

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Abstract
In present work, experimental investigation on heat transfer and friction characteristics of double pipe heat exchanger for single phase forced convective flow in clockwise twisted tape of pitch 75mm and length 2500mm inserted in the inner tube, has been carried out. This study was done to evaluate the effects of variable V-cut angle on twisted tape inserts while depth of cut is constant (2mm) and compared with plain insert and without insert double pipe heat exchanger on the values of heat transfer rate, performance evaluation criteria, Nusselt Number and friction factor through a circular copper tube using normal water as testing liquid with a range of Reynolds number between 5500 and 10000. In the double pipe heat exchanger (DPHE), hot water passed through inner tube and normal water was passed over inner tube and used as cooling medium between the inner copper tube and the outer GI tube. Findings showed that the characteristics of DPHE like Nusselt number, Performance evaluation criteria and friction factor (etc.) were enhanced with inserted twisted tape, Heat Transfer rate and Nusselt Number increases while frictional resistance also increases at the same time. Found increment in heat transfer rate was 23% greater than the plain tube DPHE. Friction factor varies from 0.044 to 0.0528 for the tube fitted with twisted tape. It is found to be 7% to 28% greater than the plain tube without insert DPHE. Nusselt number varies from 64.84 to 72.95 for the tube fitted with twisted tape. It is found to be 27% to 43% greater than the plain tube DPHE.

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I. Introduction

Heat Exchanger is a device used to transfer heat between two or more fluids (liquids, vapors, or gases) whose primary responsibility is the exchange (transfer) of heat. Heat exchangers may be used for both cooling and heating purposes, in which heat is transferred from hot fluid to cold fluid due to temperature differences. These fluids may be in direct contact to each other or separated by a solid conductive wall to prevent mixing. Heat exchanger can be used in space heating, refrigeration, air conditioning, power stations, etc. The design of a heat exchanger is an exercise in thermodynamics, which is the science that deals with heat energy flow, temperature, and the relationships to other forms of energy. Regardless of the type and design, all heat exchangers operate under the same fundamental principles—namely the Zeroth, First, and Second Laws of Thermodynamics—which describe and dictate the exchange or "transference" of heat from one fluid to another. This Present experimental investigation on heat transfer and friction characteristics of double pipe heat exchanger for single phase forced convective flow in clockwise twisted tape involves twisted tape insert of pitch 75mm and length 2500mm and different groove used is 150, 300 & 450. The aim of this study is to analyse effect of turbulence due to v cut twisted tape inside the tube on the heat transfer effectiveness. V cut is provided with Variable angle (15 degree, 30 degree and 45 degree respectively) at a certain distance on twisted tape and compared data with twisted tape insert without any V-cut angle and plain DPHE observed data.

Twisted Tape Inserts

Twisted tape inserts are one of the most used enhancement methods of heat transfer. Twisted tape inserts increase both convective heat transfer and fluid friction in the flow region. They induce the turbulence and promote the swirl flow. Moreover, geometric configurations of twisted tape inserts can disturb the boundary layer; with this way heat transfer rate can be improved. However, increment of the fluid friction can negatively affect the overall enhancement ratio for a heat exchanger tube. The performance of a heat exchanger with twisted tape inserts depends on pitch and twist ratios. In recent investigations, a lot of researchers have conducted both experimental and numerical studies to determine the optimal configuration in accordance with the ratios of pitch and twist. Twisted tape is illustrated in the next figure.

Fig. 1: – Twisted inserts with V-cut

Literature Survey:-

Suvanjan Bhattacharyya, Devendra Kumar Vishwakarma et al. 2021 [2] used a Circular Tube with Novel Hybrid Grooved Tape Inserts for Turbulent Flow Heat Transfer. The Nusselt number deviates only 5% with Dittus-Boelter correlation and 4% with Meyer and Everts correlation while friction factor differs only 6% with data obtained using Blasius Correlation.

Indri yaningsih, Agungtri Wijayanta, Takahiko Miyazaki et al. 2018 [3] used V cut twisted tape insert and found that effect are best in low Reynolds number and thermos-hydraulic performance tends to decrease with rise of Reynolds number. Nusselt number, friction factor and thermal performance factor are falls under 3% each. Man et al. [4] carried out an experimental investigation on heat transfer and friction characteristics of dual-pipe heat exchanger for single-phase forced convective flow with alternate clockwise and counter-clockwise twisted tape and typically twisted tape for the Reynolds number ranging from 3000 to 9000. They reported that the maximum values of performance evaluation criteria with the full-length alternate clockwise and counter-clockwise twisted tape insert reached in experimental flowing conditions. Suri et al. [5] experimentally investigated the augmentation in heat transfer and friction in a flow through heat exchanger tube with multiple square perforated twisted tape inserts. The experiments were conducted with the Reynolds number between 5000 and 27,000, perforation width ratio a/WT from 0.083 to 0.333, and twist ratio TL = WT from 2.0 to 3.5. The maximum enhancement is observed at a/WT of 0.250 and TL = WT of 2.5. Sundar et al. [6] investigated the effectiveness of solar flat-plate collectors with and without twisted tapes in Al2O3/water Nano fluid flow region. The experimental results indicated that the heat transfer rate enhanced 49.75% with the twist ratio of 5 at the Reynolds number 13,000. The maximum friction penalty of 1.25 times was observed for 0.3% Nano fluid with twist ratio of 5 with the comparison of water in a smooth tube. Saysroy and Eiamsa-ard [7] conducted a numerical study to determine the thermos-hydraulic performance of a multichannel twisted tape inserts in laminar and turbulent flow regions. The numerical results showed that for the laminar flow, the maximum thermal performance factor of 7.28 was obtained by using the tube with the multichannel twisted tape with N = 2 and y/w = 2.5 at the Reynolds number of 2000. Heat transfer and pressure drop of Cu-O/water Nano fluid with twisted tape inserts were explored by Wongcharee and Eiamsa-ard [8]. The results demonstrated that using Cu-O Nano fluid with twisted alternate axis (TA) obtain a higher Nusselt number and thermal performance, and the twisted tape in alternate axis was about 89% more effective than typical twisted tape. Li et al. [9] carried out a numerical study on her transfer enhancement in a tube with centrally hollow narrow twisted tape under laminar flow conditions. They reported that the tube with cross hollow twisted tape inserts has the best overall heat transfer performance for different hollow widths of the tape.

Validation of Experiment Setup

Experimental set-up is validated against the standard correlations as suggested by various authors to check correctness of the data obtained through the experiments. The values of Nusselt number and friction factor the experiments of plain tube are compared with the Gnielinski and Filonenko correlations respectively. The results reveal that the experimental values are within the permissible limits. The maximum deviation found is approx. 13.9% for Nusselt number and 13% for friction factor.

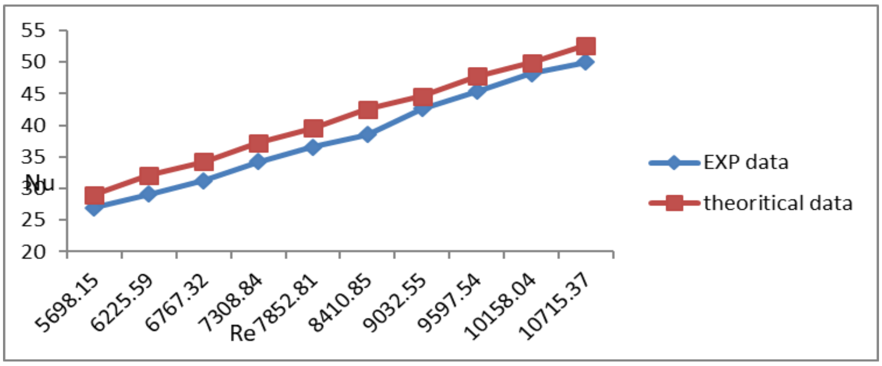

Fig.2. Comparison of the experimental Nusselt number and theoretical Nusselt number for the plain tube.

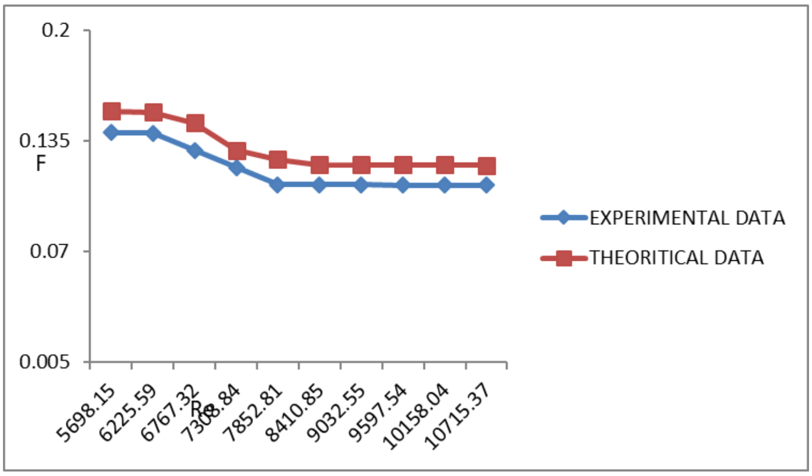

Fig.3 Comparison of the experimental friction factor and theoretical friction factor for the plain tube

Experiment Setup

This section of study describes the devices and components used in the experiment and how the experiment was done. It also includes the procedure that was followed to collect important data.

The experimental setup consisted of a double pipe heat exchanger with water as the flowing fluid. Hot water coming from boiler is flowing through the inner tube whereas cold water from water tank is flowing through the annulus (around inner tube). Hot water Circuit consisted of hot water storage tank of capacity 200 litres equipped with SSR with 0.1-degree Celsius control. Stirrer of capacity 20 litres, 0.5HP centrifugal pump, a rota-meter of governing range from 50LPH to 200LHP and a piping system with adjustable valves is attached in hot water circuit and suitable thickness insulation is provided. Cold water circuit consisted of a cold-water reservoir of capacity 200 litres, 0.5 HP centrifugal pump, a rota-meter of governing range from 50LPH to 200 LPH, a piping system with suitable valves. Inner diameter of inner copper tube is 16mm and thickness is 2mm and length of 2500mm whereas thickness of outer tube is 3mm, inner diameter 30mm and length is 2500mm. The temperature of hot water inside the boiler is maintained at 70 degree whereas inlet temperature of cold water is at room temperature (28-32°C). Twisted tape used in experiment is made up of aluminium of rectangular cross-section and twisted with one direction of pitch 75mm. Thickness of aluminium (T cross-section) is 1.5mm, length 2500 mm and width are 14mm. Ten K-type thermocouples calibrated by thermal resistances with a measurement error of 0.1°C are attached within the piping (Hot water as well as cold water) and connected to a data logger. Pressure drop of hot water flowing in test piece is measured by U-tube manometer to consider frictional losses. Values of temperature, pressure drop and flow rate were recorded for calculation when system reached steady state condition.

The set-up consisted of the following components:

1. AC power supply
2. Hot water Reservoir with SSR control (Boiler)
3. Stirrer
4. 0.5 HP centrifugal Pump for hot & cold water
5. Flow Control Valves

6. Rotameter from 50LPH to 200LPH
7. Plane Steel Tube
8. Concentric Double Pipe (inner pipe of copper and outer steel pipe)
9. Thermocouples
10. Cold water Storage
11. U-Tube Manometer
12. Data Logger
13. Twisted tape
14. Insulating Material - Glass wool (Jain Dori)

After starting Heater (Boiler) wait to achieve steady state inside the hot water tank. When water inside the tank achieved steady state open outlet valve and allow hot water to flow through it. After tank stirrer is provided to increase temperature and then through pump superheated water is pumped into heat exchanger inlet piping and then it flows through inner copper tube where hot fluid is cooled by colder water which is flowing through outer tube. To immersed the inner tube completely the inlet of cold water in outer tube positioned at top position. The flow of cold water is regulated by adjustable valve and pump provided and governed by rotameter at the inlet of outer tube, this cold water then takes away heat from hot water to drainage. Mass flow rate of cold water is governed by Rota-meter at the inlet of outer tube. Also, mass flow rate of hot water is governed by Rota-meter before inlet of inner tube and the hot water outlet is circulated to hot water tank for re-utilizing of that water. By taking this hot water into boiler we conserved the wastage draining of hot water at outlet. Now in the hot water boiler placed at bottom we use a heater of wattage rating 9Kw, which can provides hot water between 60º-90ºC in short period so we can reduce waiting time. Total 10 thermocouples are used to take readings of temperature at inlet & outlet of cold and hot water and also surface temperature of inner tube. A U-tube manometer is attached at inlet and outlet of copper tube to take frictional losses into consideration. A data logger is attached in the setup to store readings of different temperatures after regular interval. Different types of twisted tape with v-cut and winglet angle is inserted inside the copper tube and take readings at various mass flow rate for comparison and further analysis.

II. Result And Discussion

Nusselt number increases in the tube with inserted twisted tape when V cut angle is increases from 15^0 to 45^0 at constant cut depth of 2mm. As discussed, Nusselt number is found to be maximum (51.041 at Re 10715.37 and 28.98 at Re 5698.15) for plain tube (no twisted tapes insert), (64.84 at Re 10606.28 and 33.72 at Re 5616.03) for plain tube with twisted tapes insert (33.08 at Re 5635.42 and 66.94 at Re 10159.27) for 2mm depth cut at 15^0 V-cut angle (72.1056 at Re 10366.3 and 36.94 at Re 5588.52) for 2mm depth cut at 30^0 V-cut angle & (72.92587 at Re 10119.11 and 37.94574 at Re 5581.94) for 2mm depth cut at 45^0 V-cut angle.

This highest value of Nusselt number of (twisted inserts is 1.26 times greater than the values for Nusselt number for plain tube, twisted tape insert with depth of V cut 2 mm and V angle 15^0 is 1.35 times greater than the values for Nusselt number for plain tube, twisted tape insert with depth of V cut 2 mm and V angle 30^0 is 1.42 times greater than the values for Nusselt number for plain tube and twisted tape insert with depth of V cut 2 mm and V angle 45^0 is 1.49 times greater than the values for Nusselt number for plain tube.

Highest value of Nusselt number is obtained for V cut depth 2 mm and V angle 45^0 as it induces maximum increase in the secondary flow with respect to plain twisted tape and twisted tape with other configurations used for the experiments. This results in a reduction in the formation of boundary layer and increases the overall fluid velocity consequently; maximum value of Nusselt number is obtained for the given range of parameters.

The Variation of Nusselt number with Reynolds number for different combination is shown in Fig 4. It shows that Nusselt number increases with the increment of Reynolds number (Reynolds number increases when mass flow rate increases) and it is due to turbulence effect in continuously flowing hot water and therefore convective heat transfer rate increases. Experiment also indicates that Nusselt number for the tube fitted with insert is higher than plain tube and it also increases when V-cut angle increases. Main reason for this is swirl flow generated because of twisted insert and V-cut angle. Variation of friction factor with Reynolds number are shown in figure 5. It shows when friction factor deceases Reynolds number increases in all cases. Friction factor for tube fitted with twisted tape and 45 degree V-cut angle are higher than the friction factor for plain tube and lower V-cut angle twisted insert and it is due to compact cross sectional area through which hot fluid is flowing.

The value of friction factor for plain tube is found to be 0.0299 (for Re=10715.37) and 0.0418 (for Re=5698.15), for twisted tape insert it is found to be 0.03173 (for Re=10606.28) and 0.04401 (for Re=5616.035), for twisted tape insert for 2mm depth cut at 15^0 V-cut angle it is found to be 0.0470 (for Re=5635.42) and 0.033 (for Re=10159.27),for twisted tape insert for 2mm depth cut at 30^0 V-cut angle is found to be 0.0350 (for Re=10366.3) and 0.0494 (for Re=5588.52),for twisted tape insert for 2mm depth cut at 45^0 V-cut angle is found to be 0.03817 (for Re=10119.11) and 0.0528 (for Re=5581.94).

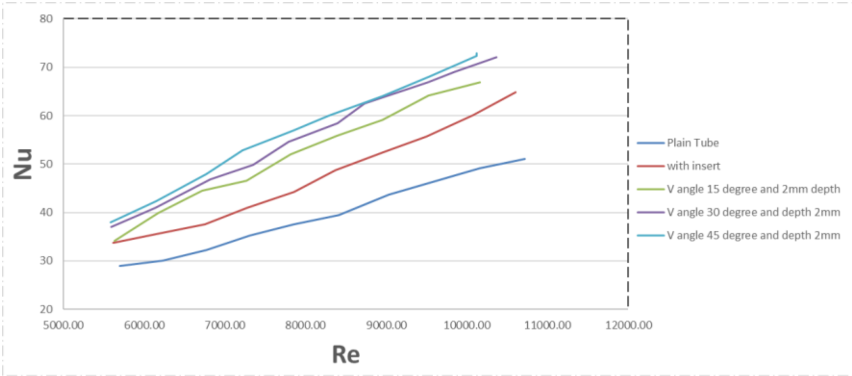

Fig.4:- Variation of Nusselt number (Nu) with Reynolds number (Re) for the typical twisted tapes at different V-cut angle at constant depth of 2mm.

Friction factor for twisted tape with plain insert is found to be 1.06 times whereas twisted tape with 2mm depth cut at 15^0 V angle is reported to be 1.12, 1.17 (for 2mm depth cut and 30^0 V angle) and 1.27 (for 2mm depth cut and 45^0 V angle) times respectively greater than as comparison with friction factor for the plain tube. A graph depicting the variation in friction factor with respect to Reynolds number is depicted in Figure 5.

The variations in performance evaluation criteria (PEC) with Reynolds number in the plain tube and in tubes fitted with twisted tapes with V cut depth 2mm and V angle 15^0 , 30^0 & 45^0 respectively is presented in Figure . It can be emphatically deduced from the Figure that the performance evaluation criteria decreases with an increase in Reynolds number for all cases which reflects when Reynolds number increases, the impact of friction factor becomes more and more significant in comparison to Nusselt number.

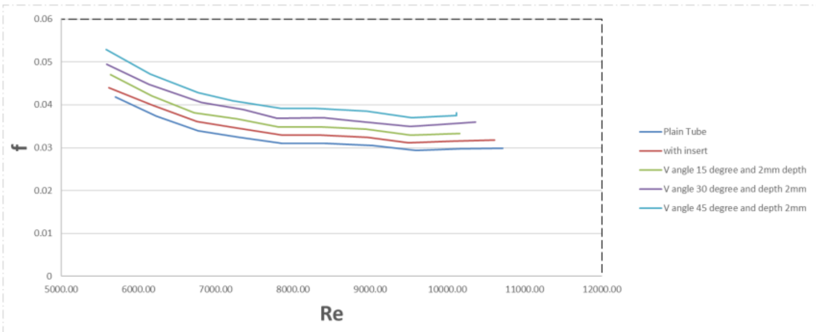

Fig 5:- Variation of friction factor with Reynolds number for the typical twisted insert at variable V-cut angle of constant depth 2mm.

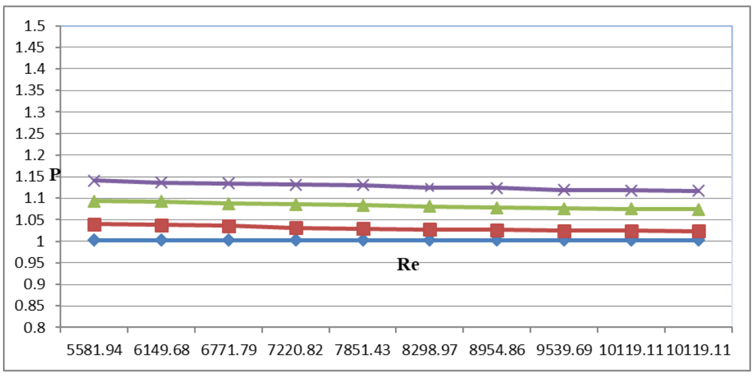

Fig 6:- Variation of PEC with Reynolds number for the typical twisted insert at variable V-cut angle of constant depth 2mm.

The ratio of Nusselt number decreases with an increase in Reynolds number which means twisted tape with groove angle gives better result in weak turbulence. Over the range of Reynolds number investigated, maximum PEC is found at V cut angle 45^0 with a value of 1.138 (Re=10119.11) and 1.001 (Re=5581.94) and it is 1.12-1.06 times for plain twisted tapes. On the other hand, maximum value of performance evaluation criteria is 1.163 for V angle of 15^0 & 1.15 for V angle of 30^0 and it is greater than plain inserted twisted tapes.

III. Conclusion

Experimental Study of Heat transfer and friction factor in Double pipe Heat Exchanger using Twisted Tape with different groove angle of V-cut at constant depth have been carried out in this investigation. Following conclusions can be drawn from obtained data:

Heat transfer characteristics of DPHE are found to be enhanced with twisted tape while frictional resistance increases at the same time. Heat transfer characteristics of DPHE are found to be enhanced with twisted tape insert with increase in V-cut angle while frictional resistance increases at the same time.

The maximum increase in heat transfer rate was found to be 23% greater than the plain tube. Friction factor varies from 0.044 to 0.0528 for the tube fitted with twisted tape. It is found to be 7% to 28% greater than the plain tube without insert. Nusselt number varies from 64.84 to 72.95 for the tube fitted with twisted tape. It is found to be 27% to 43% greater than the plain tube without insert.

The friction factor is found to be directly proportional to angle of V cut at twisted tape. It increases with an increase in angle of V cut at constant depth. It is on account of reduction in the flow area which in turn provides more contact surface resistance.

As the Reynolds number increases, the effect of twisted tape with V cut depth on friction factor becomes more dominating with respect to Nusselt number. Therefore minimum value of friction factor is reported for plain tube without any twisted tape insert.

Furthermore a performance evaluation criterion (PEC) at 45^0 v angle at constant depth 2mm is maximum which reflects that Nusselt number is predominant over friction factor.

It can be emphatically deduced from the Figure that the performance evaluation criteria decreases with an increase in Reynolds number for all cases which reflects when Reynolds number increases, the impact of friction factor becomes more and more significant in comparison to Nusselt number.

REFERENCES

[1]. Thomas net articles related to Heat exchanger and Heat and mass transfer book by R K Rajput.

[2]. Omidi M., Farhadi M., Jafari M. A comprehensive review on double pipe heat exchangers. Appl. Therm. Eng. 110 (2017) 1075-90.

[3]. Zhang X., Liu Z., Liu W. Numerical studies on heat transfer and flow characteristics for laminar flow in a tube with multiple regularly spaced twisted tapes. Int. J. Therm. Sci. 58 (2012) 157-67.

[4]. Zhang Z., Yang W., Guan C., Ding Y., Li F., Yan H. Heat transfer and friction characteristics of turbulent flow through plain tube inserted with rotor-assembled strands. Exp. Therm. Fluid Sci. 38 (2012)33-39.

[5]. Saha S., Saha S.K. Enhancement of heat transfer of laminar flow of viscous oil through a circular tube having integral helical rib roughness and fitted with helical screw-tapes. Exp. Therm. Fluid Sci. 47 (2013)81-9.

[6]. Anvari A.R., Javaherdeh K., Emami-Meibodi M., Rashidi A.M. Numerical and experimental investigation of heat transfer behavior in a round tube with the special conical ring inserts. Energy Convers. Manage. 88 (2014) 214-217.

[7]. Zhang C., Wang D., Ren K., Han Y., Zhu Y., Peng X., et al. A comparative review of self-rotating and stationary twisted tape inserts in heat exchanger. Renew. Sust.Energ. Rev. 53 (2016) 433-449.

[8]. Zarringhalam M., Karimipour A., Toghraie D. Experimental study of the effect of solid volume fraction and Reynolds number on heat transfer coefficient and pressure drop of CuO–water Nano fluid. Exp. Therm. Fluid Sci. 76 (2016) 342-351.

[9]. Yu X., Yu T., Peng D., Jiang S., Luo J. Twisted strip with oblique teeth to efficiently remove fouling and enhance heat transfer at low flowing velocity. J. Chem. Ind. Eng. (China) 4 (2005).

[10]. Yu L., Liu D. Study of the Thermal Effectiveness of Laminar Forced Convection of Nano fluids forLiquid Cooling Applications. IEEE Trans. Compo. Packag. Manuf. Technol. 3 (2013) 1693-1704.

[11]. Yehia M.G., Attia A.A., Abdelatif O.E., Khalil E.E. Heat transfer and friction characteristics of shell and tube heat exchanger with multi inserted swirl vanes. Appl. Therm. Eng. 102 (2016) 1481-91.

[12]. Yang L., Du K. A comprehensive review on heat transfer characteristics of TiO2Nano fluids. Int. J. Heat Mass Transf. 108 (2017) 11-31.

[13]. Wongcharee K., Eiamsa-ard S. Friction and heat transfer characteristics of laminar swirl flow through the round tubes inserted with alternate clockwise and counter-clockwise twisted-tapes. Int. Commun. Heat Mass Transf. 38 (2011) 348-352.

[14]. Wongcharee K., Eiamsa-ard S. Heat transfer enhancement by twisted tapes with alternate-axes and triangular, rectangular and trapezoidal wings. Chem. Eng. Process.ProcessIntensif. 50 (2011) 211-219.

[15]. Wadekar V.V. Ionic liquids as heat transfer fluids–an assessment using industrial exchanger geometries. Appl. Therm. Eng. 111 (2017) 1581-1587.

[16]. Vashistha C., Patil A.K., Kumar M. Experimental investigation of heat transfer and pressure drop in a circular tube with multiple inserts. Appl. Therm. Eng. 96 (2016) 117-129.

[17]. Tuo H., Hrnjak P. Effect of the header pressure drop induced flow mass distribution on the micro channel evaporator performance. Int. J. Refrig. 36 (2013) 2176-2186.

[18]. Tuo H., Hrnjak P. Flash gas bypass in mobile air conditioning system with R134a. Int. J. Refrig. 35 (2012) 1869-1877.

[19]. Tu W., Wang Y., Tang Y. A numerical study on thermal-hydraulic characteristics of turbulent flow through a circular tube fitted with pipe inserts. Appl. Therm. Eng. 101 (2016) 413-421.

[20]. Thianpong C., Eiamsa-ard P., Wongcharee K., Eiamsa-ard S. Compound heat transfer enhancement of a dimpled tube with a twisted tape swirl generator. Int. Commun. Heat Mass Transf. 36 (2009) 698-704.

[21]. Thianpong C., Eiamsa-ard P., Promvonge P., Eiamsa-ard S. Effect of perforated twisted-tapes with parallel wings on heat transfer enhancement in a heat exchanger tube. Energy Procedia. 14 (2012) 1117-1123.

[22]. Thianpong C., Eiamsa-ard P., Eiamsa-ard S. Heat transfer and thermal performance characteristics of heat exchanger tube fitted with perforated twisted-tapes. Heat Mass Transf. 48 (2012) 881-892.