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Experimental Study of Heat Transfer and Friction Factor in Double Pipe Heat Exchanger Using Twisted Tape Insert At Different Positions

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Abstract

This experimental analysis of Heat transfer and friction factor in double pipe heat exchanger using twisted tape with twist at different length position has been conceded. In double pipe heat exchanger the hot fluid is passed through inner tube and cold fluid is passed in outer tube. The outer layer of inner pipe act as separating layer to avoid mixing of two fluids. A comparative study analysis was done to evaluate the effect of twisted tape with twist at different length with plain tube without insert on the heat transfer rate. Also, Nusselt number and friction factor through circular pipe using water as testing fluid with a range of Reynolds number between 5500-14500. The result shows that the heat transfer characteristics of double pipe heat exchanger were enhanced with twisted tape having maximum twist while frictional resistance also increased at the same time. Maximum increase in heat transfer rate was found to be 52.33% for full length twist, 29.9% for alternate twist; first half was 29.76% whereas 14.58% for second half twist with respect to plain tube. Nusselt number varies from 75.49 to 100.36 for twisted tape with the maximum value of 100.36 for full length twist at Reynolds number 14500, and frictional factor varies from 0.3215 to 0.139 for twisted tape with twist at different length positions ; whereas for plain tube it was 0.028-0.036 and the full length twist tape is found 8.78 times higher than plane tube, second half twist is 7.1 times, for alternate twist is 6.91 times, and 6.2 times for first half twist at Re= 5500. The performance evaluation criteria was found to be decreasing with increase in Reynolds number it was recorded 0.900 to 0.9361 for twisted tape with twist at different length. PEC for full length twisted tape was found to be 20.32%, for alternate twist is 6.10%, for first half twist is 12.34% more than the second half twist. Twisted tape placed in first half enhances more heat transfer rate than the placed in second half..

Keywords: *Heat transfer characteristics, Nusselt number, friction factor, performance evaluation criteria, insert twisted tape***.**

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I. INTRODUCTION

We can easily trace the effect and necessity of energy in our daily life. For betterment and enhancement of energy transfer we use a mechanism which provides optimum results. In same way for transfer of heat we use heat exchanger in many domestic, commercial as well as industries are examples of an application of heat exchangers. Heat exchangers operate on the principle of heat transference. According to operation and use we can design our heat exchanger. For optimum result of heat exchanger the ergonomics of designing plays a vital role. Despite of different use and applications all the heat exchangers operate on same principle of transference as derived in zeroth, first and second law of thermodynamics. The heat exchanger can be classified on mode of operation as active , passive and com pound, on the basis of flow, parallel, counter and cross flow, on the basis of heat exchange direct and indirect and on the basis of design concentric, shell and tube , and multiple shell and tube.

In this experiment we are using DPHE (Double Pipe Heat Exchanger) which is passive operated, counter flow and in centrically design of holding one pipe inside other. To enhance the heat transfer rate we are using twister tape as insert having twist at different length positions length of tape is 2500mm, thickness 0.8mm, width is 14mm and pitch of twist is 50mm.Tapes are (a) First half twist, (b) second half twist, (c) alternate twist and (d) full length twist. Although many researchers have been already carried a series of researches on heat transfer out of them many falls into different categories. However, in some studies just the distinctiveness of working fluid and their modification were studied, few analyses based on either both or only active and passive methods or compounded method, their geometrical change analysis and various methods of heat transfer were focused. Sun Peiyan et al.,2016 [4]They performed on dual pipe heat exchanger for single phase using Alternate Clockwise and Counter Clockwise Twister tape (ACCT) And Typical Twisted Tape (TT) length 2400mm of Reynolds number between 3000-9000 PEC was carried. The maximum values of PEC (Performance Evaluation Criteria) with the full-length ACCT tape insert reached 1.42. Empirical correlations for Nusselt number and friction factors were established and found to fit the experimental data with a deviation within 8%. A K Patil, Pawan S Kathait et al.,[13] They established the comparison using discrete corrugated simple tube and continuous corrugated tube bewteen overall heat transfer and friction factor and Nusselt number and friction factor. It was observed that Nusselt number and friction factor was enhanced by increasing the pitch to height ratio (rib height) [P/e (6-10)] and max. at[P/e=10, e/D= 0.044] whereas the value lower at P/e= 14 (yield).

The objective of this work is to examine the heat transfer and friction characteristics in a horizontal double pipe heat exchanger using twisted tape with twist at various locations. Specific aim includes:

1. Effect of position of twisted tape on heat transfer rate and friction factor in double pipe heat exchanger.
2. Comparing the data of Nusselt number and friction factor result with plain tube.
3. Evaluating performance evaluation criterion (PEC).

II. Proposed Methodology

The setup mainly includes counter flow double pipe heat exchanger with water as a flowing fluid. Basically, it consist of two circuits, the hot water and the cold water circuit. The cold fluid section includes a cold water reservoir of capacity 200 liters cylindrical in shape, 0.5 hp centrifugal pump, rotameter for governing the flow between 50 to 500 LPH, piping system and relevant flow controlling valves.

The hot fluid section comprises of 200 liters hot water reservoir equipped with solid state relay (SSR) with 0.1 deg. C sensitivity control, stirrer (25 liters) with motor assembly and blades for proper temperature maintaining, rotameter for governing the flow of fluid ranging between 50- 500 LPH and suitable piping assembly with required thick insulation of glass wool for preventing any heat loss in surrounding. The room temperature of experimental lab was maintained between 30-35 deg. C.

The temperature of hot reservoir or hot water tank(boiler) was maintained constant at 72 deg. C ±0.1 deg. C sensitivity. Piping assembly of hot circuit or inner pipe consist of copper tube of length 2500mm, inner diameter is 16mm , thickness of 2 mm as well as the outer tube diameter is 30mm, thickness 3mm and length 2500mm of galvanized iron material . 6 (six) T-type thermocouples on the body of inner tube and 4 RTDs (resistance Temperature detector) calibrated by thermal resistance were attached at inlet and outlet of both the hot and cold piping assemble along with a data logger. An external pen drive was used for collecting data from data logger. To measure the pressure drop of hot water flowing in the tube assembly is measure by an U-Tube manometer was used to consider the frictional losses. The twisted tape used in the experiment of width 14mm , thickness of 1 mm and made of aluminum material. All the value of Temperature, flow rate and pressure drop were only initiated when system (boiler) was in steady state condition.

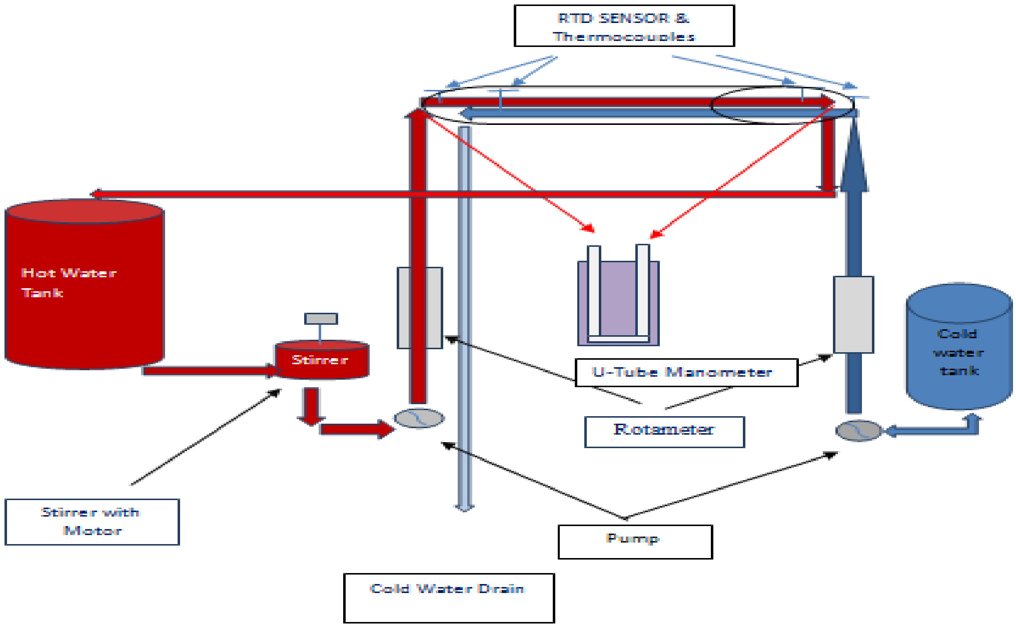

Figure 1- Schematic diagram of experimental setup

This experimental setup consists of various instruments which were used in the setup for the heat transfer analysis. Power supply, Hot water tank (Boiler with SSR), Stirrer, Stirrer motor with starter, Insulating material (Glass Wool or Jain Dori), Rotameter (50 LPH- 200LPH), Pump 0.5 HP centrifugal type.,U-Tube Manometer, Hot pipe, Cold pipe, Cold water tank (Cylindrical plastic tank), Data logger, Sensors (RTD and thermocouple), Twisted tapes and Flow control valves. The following twisted tapes were used for performing this experiment (a) First half twist (b) second half twist (c) alternate twist and (d) full length twist. The most effective way of heat transfer can be done by using twisted tape insert, it increases both the fluid friction in working (flow) region and convective heat transfer rate. It stimulates turbulence and encourages swirl in flow. Consequently, the twisted tape increases the boundary layer within the geometric configuration also, if , there in increase in fluid friction which effects the overall enhancement ratio of heat exchanger tube but heat transfer rate in optimized. The main component on which performance of heat exchanger depend is pitch ratio and twist ratio. It is generally seen that all the recent researchers have conducted experimental, numerical and both studies to determine the effective output in relevance to pitch ratio and twist ratio.

Figure 2 Second half twisted tape

Figure 3 First half twisted tape

Figure 4 Full length twisted tape

Figure 5 Alternate twisted tape

Mathematical relations used for calculations:

Mean velocity (hot water) $Uh = (Vh \times \rho in)/(\pi \times D2x\ \rho h/4)$

Heat transfer release rate (hot water) $Qh = \rho h \times Vhx\ Cph\ (Thi - Tho)$

Heat transfer release rate (cold water) $Qc = \rho cx\ Vc \times Cpc\ (Tco - Tci)$

Wall temperature (Average) $Tw = (T1 + \ldots\ldots + T6) / 6$

Heat transfer rate (Deviation) $Qh - Qc / Qh \times 100\%$

Heat transfer rate (Mean Value) $Q = (Qh + Qc) / 2 = hi \times A\ (Th - Tw)$

Nusselt number $Nu = (hi \times D1) / Kh$

Filonenko Correlation $F = (1.82 \log Re-1.64)-2$

Friction factor $f = \Delta p / (\rho h \times U2 /2) \times (L/D1)$

Figure 6 Actual Experimental Setup

Sl. No.	Parameter(s)	Value (mm) / material	Value (m)
1	Outside diameter of inner tube	20	0.02
2.	Inside diameter of inner tube	16	0.016
3.	Outer diameter of outer tube	33	0.033
4.	Length of plain tube	2500	2.5
5.	Inner diameter of outer tube	36	0.036
6.	Hot water pipe material	Copper	Cu
7.	Cold water pipe Material	Galvanized Iron	Fe
8.	Heat transfer area	251.2 mm2	0.2512 m2

Table 1 Specification of DPHE

Setup validation

To perform the experiment the setup was correlated as per the standard suggested by the researcher as to validate the data of heat transfer resulted by this experiment. Also, the result of this experiments values are as per validated standards. Deviation for Nusselt number and for friction factor is 11.4% and 9.48 % respectively. The validation was done using experimental and theoretical values of Nusselt number and Gnielinski and between friction factor and Filonenko friction factor. The graph plotted is as

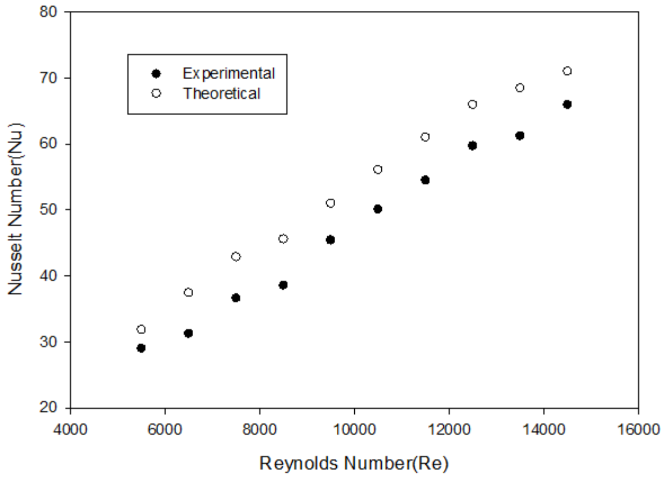

Figure 7 Setup validation comparison between Nusselt number and Gnielinski Nusselt number.

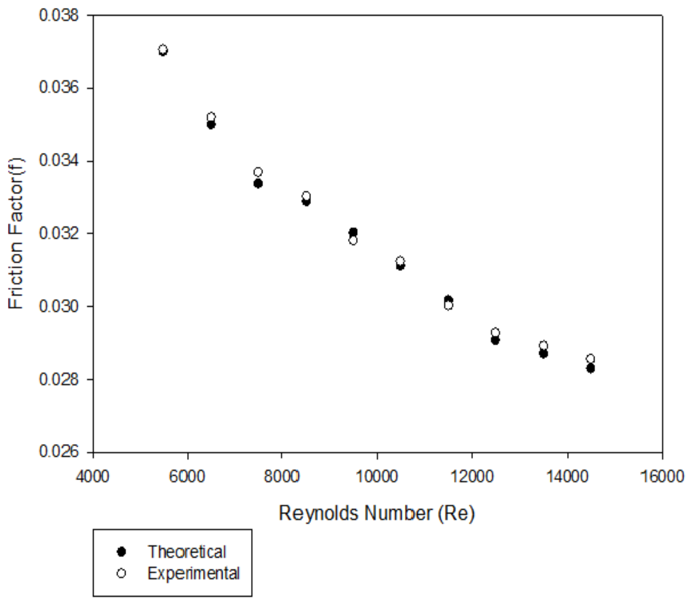

Figure 8 Setup validation comparison between friction factor and filonenko friction factor.

III. RESULT AND DISCUSSION

The deviation of Nusselt number with Reynolds number for various twisted tapes is shown in figure 4.3 where it is clearly seen that the Nusselt number is increasing with the increase in Reynolds number because of the turbulence effect caused by continuously flowing fluid (hot water) , resulting in increase of convective heat transfer rate. The value of Nusselt number tends to increases rapidly when the tapes with twist in various position viz second half, first half, intermediate (Alternate twist) and full length twist respectively. The Nusselt number is maximum at Re (Reynolds number) 14500 for plain tube is 65.88027, second half is 75.49724, for first half is 85.49517, for alternate twist is 85.63233 and for full twist is 100.36.shown in figure 9.The Nusselt number is 52.33% higher for full length twist tape than the value of plain tube, alternate tube is 29.9%,and First half is 29.76%, whereas second half is 14.58% higher than plain tube at Re14500.

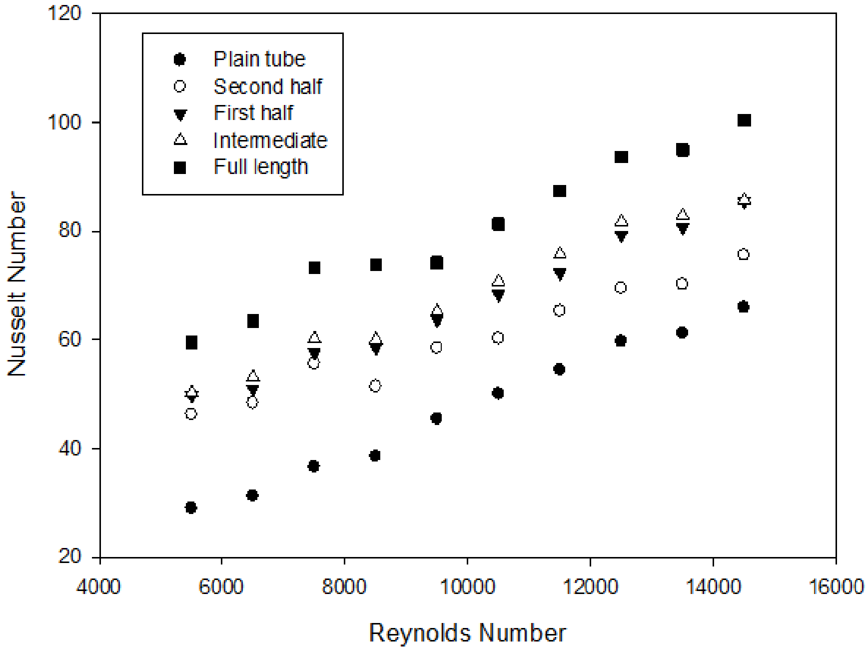

Figure 9 Variation of Nusselt number with Reynolds number for twisted tape at various length positions

The highest value of Nusselt number is obtained in inserted tape with large number of twist that in full length twist tape.The variation of Friction factor with Reynolds number is plotted in figure 4.3. The friction factor decreases rapidly with increase in Reynolds number. From the figure it is clear that friction factor for fully twisted tapes are higher and also lower for less twisted tapes due to the impact of cross-sectional area of flowing fluid (hot water). From figure we can depict the value of friction factor for plain tube is 0.036997 at Re 5500 and 0.028292 at Re 14500, for first half twist is 0.231532 at Re 5500 and 0.123855 at Re 14500, for second half twist is 0.264819 at Re 5500 and 0.12865 at Re 14500, for Intermediate (Alternate twist) is0.284937 at Re 5500 and 0.131517 at Re 14500 and for fully twisted tape is 0.325 at Re 5500 and 0.139 at Re 14500.

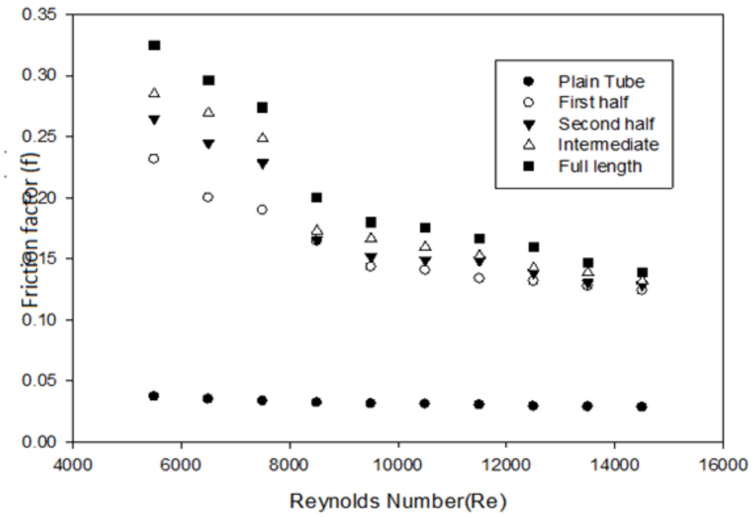

Figure 10 Data variation Friction factor (f) with Reynolds Number (Re) twisted tape with twist at various length positions.

Figure 11 reflects the data variation of PEC (performance evaluation criteria) with Reynolds number in twisted tubes with twist at various length position and plain tube. It can be easily depicted from both figures4.5 that PEC (performance evaluation criteria) deceases as the Reynolds number increases in all twisted tubes, this means that friction factor with relation to Reynolds number impacts more significantly when compared with

Nusselt number. The PEC for twisted tape in full length is found to be maximum 1.002629 at Re 0.936145 and 0.900861 at Re 14500. The value for maximum PEC for first half is 0.936145, for second half is 0.833272, and for alternate twist is 0.88417. PEC for full length twisted tape is 20.32%, for alternate twist is 6.10%, and for first half twist is 12.34% more than the second half twist.

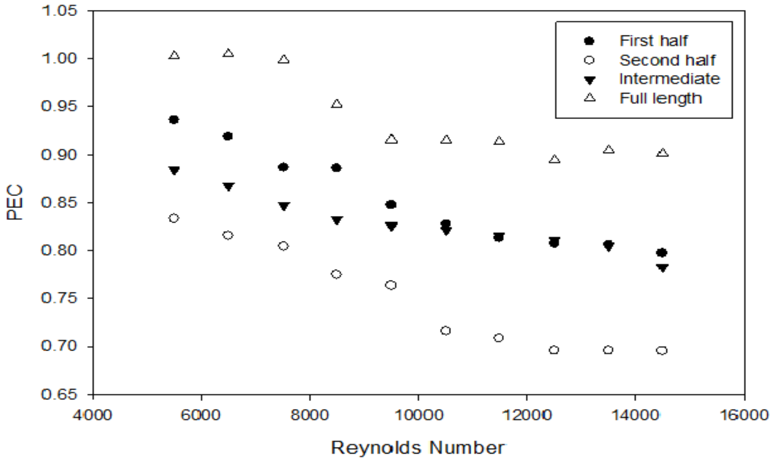

Figure 11 Data variation of PEC with Reynolds number for twisted tapes at various length positions.

IV. CONCLUSION

Experimental investigation using single phase forced convective flow of Double pipe heat exchanger (DPHE) with plain tube and twisted tube at varying length positions i.e at first half twist, second half twist, alternate twist, and full length twist are perfomed for studying rate of heat transfer and friction factor. After the calculation of both the heat transfer enhancement and friction factor's effect were studied.

The following conclusions after the analysis can be drawn:

1. Nusselt number increases with increase in Reynolds number for every cases, it means Nusselt number is directly related with turbulence whereas friction factor decreases with increase in Reynolds number for every cases, it means friction factor dominates more in laminar flow than the turbulent flow.
2. Twisted tape placed in first half enhances more heat transfer rate than the placed in second half.
3. The Nusselt number of full length twisted tape was found to be maximum and it is 52.36% higher than plane tube, 29.9% for alternate twist, 29.76% for first half and 14.5% for second half twist at Re 14500. The maximum value was 100.36 for full length twist at Reynolds number 14500.
4. Friction factor varies from 0.123 to 0.325 for twisted tape whereas; it is from 0.0282 to 0.0369 for plain tube and full length twist tape is 8.78 times higher than plane tube, second half twist is 7.1 times , for alternate twist is 6.91 times, and 6.2 times for first half twist at Re5500.
5. PEC (Performance evaluating Criteria) decreases as the Reynolds number increases in each cases which dominantly reflects the impacts of friction factor is more significant to Nusselt number at higher value of Reynolds number. PEC for full length twisted tape is 20.32%, for alternate twist is 6.10%, for first half is 12.34% more than the second half twist.

For aspect of future scope this experimental research and analysis featuring DPHE provides possibilities to investigate and research with twisted tape with twist at varying lengths are enlighten for future research:

- Experimental study of heat transfer coefficient and friction factor using DPHE with twisted tape placed at different position length with nano fluid.
- Experimental study of heat transfer and friction factor in DPHE using twisted tape with stamping placed at different position.
- Experimental study of heat transfer and friction factor in DPHE using twisted tape with V-cut placed at different position.

REFERENCES

[1]. Heat exchanger and Heat and mass transfer book by Er. R K Rajput.

[2]. Devendra kumar vishwakarma, S Bhattacharya, s Chakraborty, Rahul Roy Turbulent flow heat transfer through a circular tube with novel hybrid groved tape insert. March 2021 13(6):3068

[3]. Indri Yaningsih, Agung Tri Wijayanta, Takahiko Miyazaki, Shigeru Koyama Vcut twisted tape insert effect on heat transfer enhancement using single phase turbulent flow heat exchanger 10.1063/1.5024097

[4]. Changzhong Man, Xiaogang Lv, Jingwei Hu, Peiyan Sun, Yunbang Tang Experimental study on effect of heat transfer enhancement for single-phase forced convective flow with twisted tape inserts International Journal of Heat and Mass Transfer (IF5.584), DOI: 10.1016/j.ijheatmasstransfer.2016.10.026

[5]. Amar raj singh Suri, Rajesh Maithani, ANIL KUMAR, Effect of square wings in multiple square perforated twisted tapes on fluid flow and heat transfer of heat exchanger tube. https://doi.org/10.1016/j.csite.2017.03.002
[6]. L. syam Sundar, A.Kirubeil, V. punniah, manoj K Singh, Antonio C.M.Sousa Effectiveness analysis of solar flat plate collector with Al2O3 water nanofluids and with longitudinal strip inserts https://doi.org/10.1016/j.ijheatmasstransfer.2018.08.025
[7]. Khashayar Pakzad, Farhad Afsarpanah Numerical study of heat transfer enhancement using perforated dual twisted tape inserts in converging-diverging tubes DOI:10.1002/htj.21340
[8]. Wongcharee K., Eiamsa-ard S. Friction and heat transfer characteristicsof laminar swirl flow through the round tubes inserted with alternateclockwise and counter-clockwise twisted-tapes. Int. Commun. Heat Mass Transf.38 (2011) 348-352.
[9]. Zhang Z., Yang W., Guan C., Ding Y., Li F., Yan H. Heat transferand friction characteristics of turbulent flow through plain tube inserted withrotor-assembled strands. Exp. Therm. Fluid Sci. 38 (2012)33-39
[10]. Shiwei Zhang, Wei Yuan, Guoyun fang, yong Tang Heat Transfer and Friction Characteristics of Turbulent Flow through a Circular Tube with Ball Turbulators Appl. Sci. 2018, 8, 776; doi:10.3390/app8050776
[11]. Shanas Tian Pramesti , saddenio lionize Experimental Study of Baffle Angle Effect On Heat Transfer Effectiveness Of The Shell And Tube Heat Exchanger Using Helical Baffle ISSN: 1024-1752 CODEN: JERDFO
[12]. Shekhol-eslami, Mohammed Faleh performance using circular ring on perforated circular ring on the outer surface using DPHE (Double pipe Heat Exchanger) july 2016.
[13]. Kathait, Pawan Singh, Patil, Anil Kumar Thermo-hydraulic performance of a heat exchanger tube with discrete corrugations DOI: 10.1016/j.applthermaleng.2014.01.069
[14]. Agung tri Wijayanta, Budi Kristwan, W Mohammed Computational Fluid Dynamics Analysis of an Enhanced Tube with Backward Louvered Strip Insert https://doi.org/10.3390/en12173370
[15]. Li Zhang, Hongmei Guo, Jianhua Wu, Wenjuan Du Compound heat transfer enhancement for shell side of double-pipe heat exchanger by helical fins and vortex generators 10.1007/s00231-011-0959-5
[16]. M. Moawed Heat transfer and friction factor inside elliptic tubes fitted with helical screw-tape inserts. Journal of Renewable and Sustainable Energy 3, 023110 (2011); https://doi.org/10.1063/1.3582940.