A Review on Different Types of Inserts used in Heat Transfer Application

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Abstract— Heat exchangers are commonly used in almost all areas of industrial activities on the basis of heat transfer mechanism. The heat transfer mechanism is enhanced by using various parameter like using different shape of inserts, any nanofluids as working medium etc. Therefore by considering the enhancement of heat transfer rate, decrease the size and cost of heat exchanger, used of any swirl device as inserts is best method. This research work acclaims that want to reviews experimental researches done on this passive method in recent years. This paper is studied at turbulent flow region on the basis of heat transfer enhancement ratio, friction factor and overall enhancement ratio.

Keywords: Heat Transfer, Nusselt Number Enhancement Ration, Friction Factor Enhancement Ratio, Overall Enhancement Ratio, Turbulent Flow

I. INTRODUCTION

Heat exchanger is very useful and so common device, which is used in heating and cooling system in various types of industries such as air conditioning, refrigeration system, power plant stations and chemical reactors. Therefore several techniques have been promotes to enhance heat transfer rate, decrease the size and cost of heat exchanger device. It is intended to transfer the desired amount of heat energy as quickly as possible.

The design procedure of heat exchangers is complex because it needs the analysis the heat transfer rate, pressure drop and efficiency. Therefore, the designers are always keen to develop the efficient and compact heat exchanger at lowest investment and running cost. In general, the methods of heat transfer enhancement are classified into three categories which are explained in details as below.

A. Active methods

In this active method of heat transfer enhancement, some external power input is used. Example of this method, in reciprocating plungers, used of magnetic field, surface vibration, fluid vibration, electrostatic field, suction or injection and jet impingement which needs external power supply for enhancement of heat transfer[1,18].

B. Passive method

In this method, surface and geometrical modifications which are applied to the flow passage and implementation of inserts or additional devices are used to augment the heat transfer rate. Inserts, also called as a swirls devices, treated surface, rough surfaces, extended surfaces and additives for fluids, are some examples of this method. Advantage of this method is that, no external power supply is required[18].

C. Compound method

In this method, both active and passive methods are used. In other words, compound method is the combination of any two augmentations which is implemented at the same time like used of rough surface with twisted tape swirl flow device[18].

II. LITERATURE REVIEW

High heat transfer rate is advantageble due to the fact that heat exchanger can be operated at low velocity and gives considerably higher heat transfer coefficient. On the other hand, low operating pressure drop is achieved and also reduced operating cost. In order to improve the efficiency of heat exchangers, it is very important to improve thermal contact and decrease the pumping power. Various passive techniques have been found extremely effective in heat transfer enhancement of tube flow. Used of inserts is always praised due to its ability in enhancing the heat transfer rate by keeping the frictional losses in a workable limit. The literature work of this paper contained overall review on different types of inserts which is effectively played an important role in heat transfer applications. Used of any insert in any device as swirl generator and increase the fluid flowing time within system. So that maximum amount of heat energy is transferred. There are various shape of insert like Twisted tape(TT), modified version of TT called as Corrugated TT, Helical TT, vertex generator insert, wire coils, ribs, fins, dimples wire tape etc.

Watcharin Noothong and smith Eiamsa-ard [1], explained the effect of twisted taped insert in a concentric double pipe heat exchanger on heat transfer and fluid friction characteristic. They showed that, the maximum nusselt number by using this twisted tape insert with TR= 5 and 7 are 188% and 159% respectively higher than that plane tube.

Chaitanya Vashistha and Anil Kumar Patil [2], used the multiple inserts arranged in co-swirls and counter-swirl orientation. These experimental data have been collected for single, twin and four twisted tape inserts. The maximum enhancement in heat transfer and friction are found to be 2.42 and 6.96 times that of smooth tube and maximum values of the thermo-hydraulic performance factor found to be 1.25 for a set of four counter-swirls twisted tape with the TR is 2.5. This experiment proved that, counter-swirls twisted tape inserts given better enhancement than co-swirls twisted tape. Durga Prasad and A. Gupta[3], they experimentally investigated the heat transfer enhancement using Al_2O_3/ water nanofluid in a U-tube with twisted tape inserts. In this worked, they varying the volume concentration of nanofluid of 0.001% and 0.03% , to analysis the heat transfer coefficient and corresponding friction factor. The nusselt number for 0.03 % of volume concentration of nanofluids with twisted tape inserts is enhanced by 31.28% and friction factor increased by 1.23 times compared to water of TRs of 5. A. Hasanpour and M. Farhadi [4], presented the paper on a review study on twisted tape inserts for turbulent flow characteristic. Here they found that twin counter-swirl and helical screw twisted tape, can reach the highest values of heat transfer rate. Hong and Bergles [5] reported heat transfer enhancement in laminar, viscous liquid flows in a tube with uniform heat flux boundary conditions. In this experiment, they find the correlation but their correlation has limited applicability as it is valid for a high Prandtl number (approximately 730). The circumferential temperature profile for swirl flow is related to tape orientation. Taiwo O. Oni, Manosh C. Paul, [6], explained the numerical investigation of heat transfer and fluid flow of water through a circular tube induced with divers twisted tape insets. In this experiment, they modified the twisted tape like tube with elliptical cut twisted tape, circular cut twisted tape, triangular cut twisted tape, alternate-axis elliptical cut twisted tape, alternate-axis circular cut twisted tape and alternate-axis triangular cut twisted tape. Thermo-hydraulic performance of the flow system is affected by the shaped of cut on the twisted tape. From this work, they observed that, the tube with alternate-axis triangular cut twisted tape produced the best performance, having a thermal performance factor of 1.43. Smith Eiamsa-ard, P. Seemawute, [7], observed experimentally, the effect of peripheral cut of twisted tape on thermodynamic properties. This type of inserts is called as modified version of twisted tape. Here they take constant pitch and width of twisted tapes but varying peripheral-tape depth and width. This work concluded that, the higher the turbulence intensity of the fluids in vicinity of the tube wall generated by the peripheral-cut twisted tape compared to that induced by the typical twisted tape.

S. Pourahmad and S. M. Pesteei,[8], used the new type of inserts, wavy strip insert. They worked on effective-NTU analysis in a double tube heat exchanger equipped with wavy strip considering various angles were experimentally studied. Effectiveness-NTU analyses were made for the conditions with and without wavy strip inserts including their different angles and compared to each other. It showed result that NTU and effectiveness have a maximum value at the minimum wavy strip angle 45. M. Khoshvaght-Aliabadi [9], studied on vortex-generator insert fitted in tabular heat exchangers with dilute Cu-water nanofluid as a working fluid. They experimentally studied vortex generator by changing four geometrical parameters such as winglets-pitch ratio winglets-length ratio winglets-width. It is found that the vortex generator inserts with lower winglets-pitch ratio and higher winglets-length / width ratios present higher values of heat transfer enhancement and pressure drop. Deshmukh and Vedula [10], explained the use of curved vortex generator inserts for heat transfer enhancement for flow through a tube in the turbulent flow regime. Curved delta wing shaped vortex generators were located close to the tube wall using a specially fabricated insert which provided a swirling motion of the fluid close to the wall. Arezuo Ghadi and Roja Parvizi Moghaddam [11], studied CFD Modelling of increase heat transfer in tubes by wire coil inserts. In this experiment, they has been studied the effect of improving heat transfer coils in heat exchanger in a laboratory by the method of computational fluid dynamics. Friction coefficient and nusselt number in the tubes with wire coils reduce with increase wire coil step. O. Sadeghi and H. Mohammed [12], studied heat transfer and nanofluid flow characteristics through a circular tube fitted with helical tape inserts by using finite volume numerical method. To enhance the heat transfer results, helical tape inserts is used with two different types of nanofluids, Al_2O_3 and SiO_2. By comparing two nanofluids Al_2O_3 nanofluid with cylindrical nanoparticle shape has the highest heat transfer enhancement and PEC compared to SiO_2 nanofluid. A. A. Rabienataj Darzi, and Kurosh Sedighi [13], explained the experimental investigation of turbulent heat transfer and flow characteristics of Sio_2 / water nanofluid within helically corrugated tubes. Experiments were performed for plain tube and five roughened tube with various heights and pitches of corrugations. Results showed that adding the nanoparticle in the tube with high height and small pitch of corrugations augments the heat transfer significantly with negligible pressure drop penalty.. A. Garcia, J. P. Solano and P. G. Vicente [14], studied the influence of artificial roughness shape on heat transfer enhancement. This work analyzes the thermal hydraulic behavior of three types of enhancement technique based on artificial roughness: corrugated tubes, dimpled tubes and wire coils. Heat transfer and pressure drop experimental data in laminar, transition and turbulent regimes are used in this investigation. This study concluded that for reynold numbers lower than 200, the used of smooth tubes is recommended. For reynold number higher 200 and 2000, the employment of wire coils is more advantageous, while for reynold number higher than 2000, the used of corrugated and dimpled tubes is favored over the wire coils because of the lower pressure drop encountered for similar heat transfer coefficient levels. A basic working of vortex generator inserts is presented in S. A. Wani work. S. A. Wani, S. R. Patil and A.P. Shrotri [15], explained a review of various shape vortex generator inserts like rectangular, trapezoidal and delta winglets.

A Dewan, P. Mahantra [16], presented a review paper on passive heat transfer augmentation techniques. In this work, they studied the various inserts briefly and compared to each other. Sneha Ponnasa, Naidu S. V.[17], explained a comparative study on the thermal performance of water in a circular tube with twisted tapes, Perforated twisted tapes and perforated twisted tapes with alternate axis. In this paper, the effect of perforated twisted tapes with alternate axis (PATT), perforated twisted tapes (PTT) and regular twisted tapes (TT) with twist ratios (TR) of 3,4 and 5 are compared by experimental investigation in a circular tube under constant heat flux condition. Using water as the working fluid, experiments are conducted within the Reynolds number range of 3000 to 16000. At constant pumping power, the maximum thermal performance factor obtained is 1.433, 1.396 and 1.24 respectively for PATT, PTT and TT.

Nomenclature	
A	Surface area of heat transfer, m^2.
D	Channel inner diameter, m
L	Length of test section tube, m
f	Friction factor
h	Heat transfer coefficient, W $m^{-2}k^{-1}$
C_P	Specific Heat of fluids
Nu	Nusselt number
P	Pressure of flow in a tube, pa
Re	Reynolds number
W	Twisted tape width
Y	Twist ratio

ΔP	Pressure drop, pa
M	Mass flow rate, kg s^{-1}
$V^{\cdot}$	Volumetric flow rate
I	Current, A
K	Thermal conductivity of fluids, W $m^{-1}K^{-1}$
Q	Heat transfer rate, W
T	Temperature, K
U	Mean axial flow velocity, m s^{-1}
V	Voltage, V

Greek symbols

μ Fluid dynamic viscosity, Kg s^{-1} m^{-1}
ρ fluid density, kg m^{-3}
η Overall enhancement ratio

Subscripts

b Bulk
c convection
i Inlet
o Outlet
s Surface
p Plain tube
t Tube with inserts

Abbreviations

OER =Overall enhancement ratio
TT =Twisted tape
P. R.= Pitch ratio

Table 1: Nomenclature

III. HEAT TRANSFER ENHANCEMENT MECHANISM.

Heat transfer Swirl generator device is important matter of concern for the heat transfer rate enhancement which leads to increase the performance of system. Twisted tape is very well known swirl generator device for heat transfer enhancement. There are several correlations of heat transfer and pressure drop are developed for different types of twisted tape. Twisted tape or any inserts are used to develop the swirl flow of working fluid inside the tube which gives high velocities near the boundary and mixing of fluid as shown in fig 1.

Use of twisted tapes and other inserts causes flow blockage, flow portioning and production of secondary flow. Free flow area is reduced due to flow blockage and pressure drop and viscous effects are considerably reduced. In addition to this, flow velocity also increases and in many cases secondary flow is induced as shown in fig 2. This secondary flow produces swirl and gives effective mixing of fluid flow which improves temperature gradient and thus heat transfer coefficient.

In heat transfer systems, experiment with twisted tapes, the heat transfer and pressure drop characteristics are governed by pitch ratio of the any inserts. Also, small clearances between inserts and tube boundary are important factor while selecting the width of the inserts. Clearance between inserts and tube boundary should be acceptable because greater clearances can produce bypass flow which lead to performance drop.

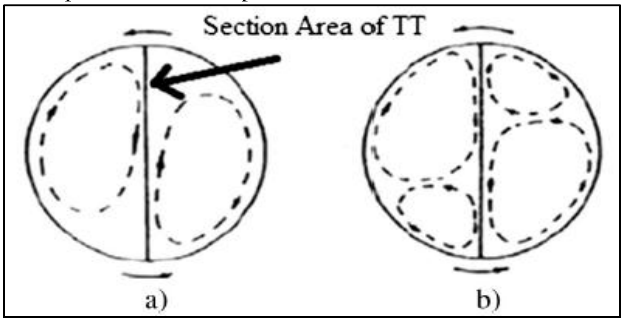


Fig. 1: Secondary induced flow pattern by TT [4]

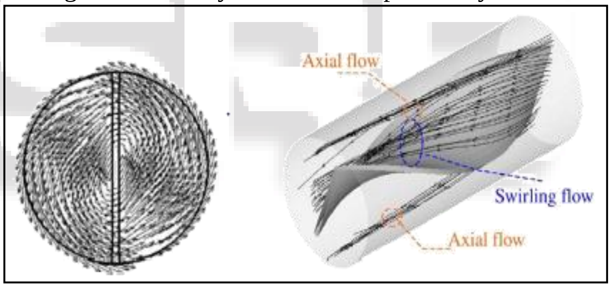
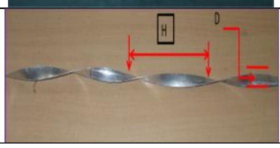
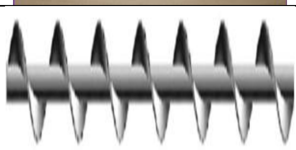
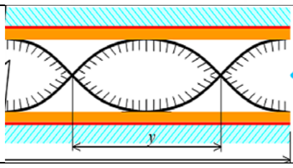
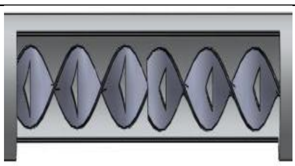
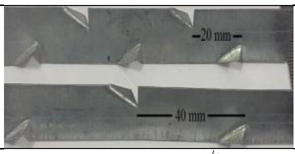
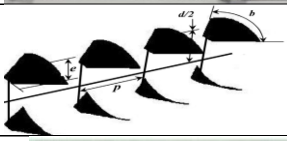
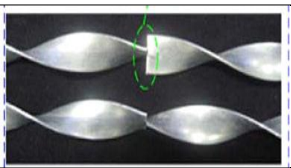
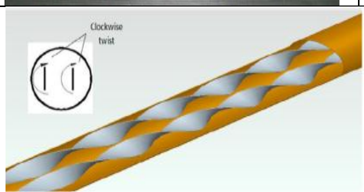
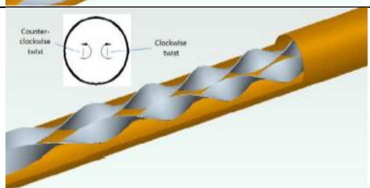
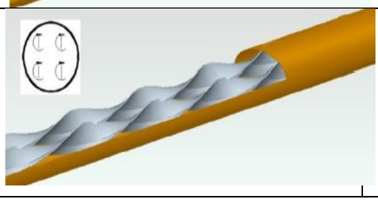


Fig. 2: Swirling flow around TT inserts [4]

Sr No.	Type of insert	Shape of insert	Nu_t/Nu_p	Overall enhancement ratio (OER)	Re number
1	Typical TT[1]		1.59 to 1.88 %	1.80 to 2.15	3000 to 15000
2	TT with nanofluid[3]		18.18% and 31.28%	1.25	3000 to 30000
3	Helical TT[4]		-	2 - 2.5	4000 to 25000
4	peripherally-cut TT[7]		2.6 to 12.8%	1.29 - 4.88	1000 to 20,000

5	alternate-axis triangular cut TT[6]		1.63 – 2.18%	1.35 – 1.43	5000 to 20000
6	VGs inserts with nanofluid[9]		1.25 %	1.83	5,200 to 12,200
7	Triangular shaped VG[10]		1.3–5.0%	-	10,000 - 45,000
8	Spiky TT[2]		2.4 - 11.6%	0.73 - 3.18%	1000 to 400000
9	Co-swirl and counter swirl TT[4]		12.8–41.9% to typical TT	1.4	3000 to 27000
10	Center wings and alternate-axes[4]		17.7% to wing TT	1.4	5200 to 22000
11	Perforated TT[4]	 	1.5 – 2.5	1.32	5500 to 20500
12	Wire coiled with TT[4]		3 - 6	1.6	3000 to 18000
13	Twin Co-swirl TT[4]		1.6-1.3	0.95-0.88	3000 to 13000
14	Twin Counter Swirl TT[4]		1.82-1.65	1.02-0.98	3000 to 13000
15	Four Co-swirl TT[4]		2.1-1.80	1.12-1.10	3000 to 13000

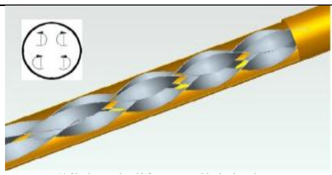
16	Four Counter TT[4]		2.57-2.2	1.3-1.2	3000 to 13000

Table 2: summery of literature view of different inserts in turbulent flow.

IV. DATA REDUCTION

The heat transfer and pressure loss results in the tube with or without twisted tape insert were taken according to the experimental procedure described in previous section. During the test, fluid in the test section receives heat (Q_f) from the electrical heat wire mainly via the convective heat transfer mechanism. Thereby, the Q_f is assumed to be equal to the convective heat transfer within the test section which can be written as:

$$Q_f = Qc$$

The heat gained by the water in term of enthalpy change can be expressed as:

$$Q_f = MCp(To \_ Ti)$$

In the experiments, the heat equilibrium test showed that the heat supplied by electrical heating (Q_{VI} = IV) under uniform heat flux condition (UHF) is between 3% and 5% higher than that the heat received by the fluid (Q_f), this is due to the heat leak from the tube wall.

The average value of heat absorbed by the fluid are taken for internal convective heat transfer coefficient calculation by the following equation:

$$Qc = hA(Ts - Tb)$$

where A is the internal surface of the tube wall (pDL) and Tb is the mean bulk flow temperature (Tb = (To + Ti)/2).

The mean inner wall surface temperature (Ts) of the test tube is Average of temperature measured at several distance of test tube section. The mean heat transfer coefficient can be determined using equation shown below:

$$Q_f = Qc$$

$$MCp_f(To – Ti) = hA(Ts – Tb)$$

The mean convective heat transfer coefficient (h) and the mean Nusselt number (Nu) are then estimated as follows:

$$h = MCp_f(To \_ Ti)/ A(Ts – Tb)$$

$$Nu = hD/k$$

In the present work, the friction factor in term of pressure drop (Δp) across the test length (L) determined from a difference in the level of a manometer liquid (water) is acquired under an isothermal flow condition and can be expressed as:

$$f = \Delta P/((l/d)(_{\varrho}U^2/2)$$

An Overall enhancement Ratio(OER) is defined as the ratio of the Nusselt number enhancement ratio to the friction factor enhancement ratio at the same pumping power.

$$\eta = (Nu_t/ Nu_P)/(f_t/f_p)^{1/3}$$

where Nu_t is the Nusselt number in the tube with TT insert, Nu_p is the Nusselt number in the plain tube, f_f is the friction factor in the tube with TT insert, and f_p is the friction factor in the plain tube. The flow regime can be defined from the Reynolds number.

$$Re = \rho UD/\mu$$

All the fluid thermo-physical properties of the working fluids are determined based on the mean bulk fluid temperature (Tb).

V. RESULT AND DISCUSSION

In this work, for details analysis, 13 inserts are selected which is given below table 1.2.

The experimental data obtained from review work of different types of inserts is used to compare with each other. For details studied, the dimensionless parameter pertaining to heat transfer and friction in a tube with different inserts. In order to study the effect of TT geometrical parameters on heat transfer and friction factor, the Nusselt number and friction factor graphs are discussed for the entire range of parameters by varying the reynold number from 3000 to 30000.

The heat transfer enhancement is brought out by the used of various inserts is discussed by plotting the Nusselt number enhancement ratio Nu_t/Nu_p. The frictional losses incurred by inserts are examined with the help of friction factor enhancement ratio $f_t/f_{p.}$ An overall enhancement ratio(OER) or Thermo-hydraulic performance factor is observed briefly for different types of inserts to studied the actual enhancement of heat transfer.

Sr No	Inserts Name	Notation
1	Simple TT	Insert1
2	Perforated TT(TT with center hole)	Insert2
3	Perforated TT(TT with many holes on surface)	Insert3
4	TT with square cut at edge	Insert4
5	TT with wire coil	Insert5
6	Wire coil with PR= 1.72	Insert6
7	Helically corrugated tube with nanofluid	Insert7
8	Perforated TT with alternate axis	Insert8
9	vertex generator insert Angle45	Insert9
10	twin co-swirl TT inserts P.R.= 2.5	Insert10
11	twin counter-swirl TT inserts PR.= 2.5	Insert11
12	four co-swirl TT inserts, P. R.= 2.5	Insert12
13	four counter-swirl TT inserts P. R.= 2.5	Insert13

Table 3:

A. *Effect of Nusselt Number enhancement ratio (Nu_t/Nu_p)*

Nusselt number enhancement ratio is define as nusselt number of any inserts to nusselt number of plain tube. In this review work, studied the different types of inserts basically TT inserts, and their modified version which is used in heat transfer enhancement. From the literature work, it studied that Nusselt number is increase with increase of reynold number for all inserts cases. Here, there are 13 inserts are selected for details studied which compared to each other. Fig 3 shows the variation of nusselt number enhancement ratio Nu_t/Nu_p with the change in the reynold number for different types of inserts. From the fig 3, it observed that the maximum nusselt number enhancement ratio is 6.12 for TT with wire coil around it as shown in Table 1 (Sr. No 12).

Also by comparing single TT (insert 1), Twin- swirl TT (Insert 10), twin counter swirl TT(Insert 11), four co-swirls TT(Insert 12), and four counter swirl TT(Insert 13), its observed that the performance of four counter TT shows the maximum nusselt number enhancement ratio i. e. 2.57 than other for minimum P. R.

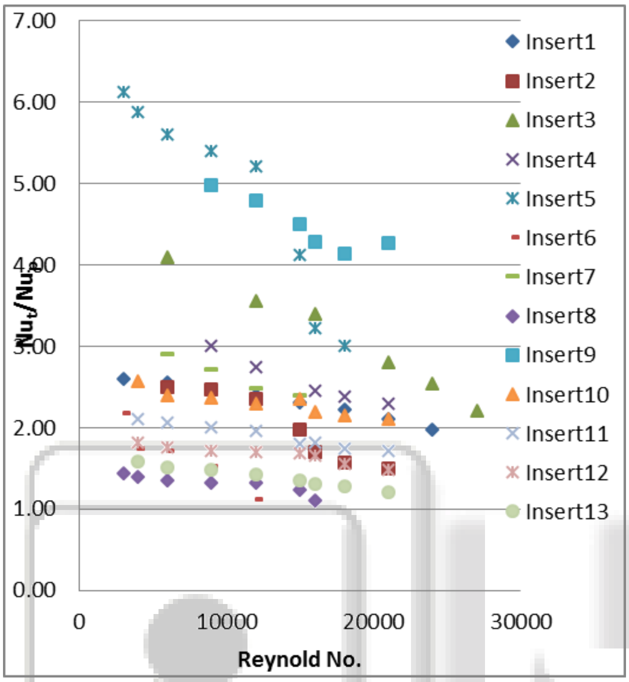


Fig. 3: Variation of Nusselt No. enhancement ratio (Nu_t/Nu_p) Ratio Vs Reynold Number for different types of inserts

B. *Effect of Friction factor enhancement ratio (f_t/f_p)*

The friction factor enhancement ratio **(**f_t/f_p**)** is defined as the ratio friction factor of any insert to friction factor without any insert. The frictional losses occurred due to inserts in tube is observed by using friction factor. It Studied that friction factor is decrease with an increase of reynold number. Fig 4 shows the variation of friction factor enhancement ratio with the change of reynold number for different types of inserts. The triangular vortex generator inserts with curved angle 45^0 shows maximum friction factor enhancement ratio is 13 which is shown in Table 1 (Sr. No 7).

As compared the simple TT inserts (without modified version of TT inserts), the four counter- swirl TT inserts (inserts 13) approached to the maximum friction factor enhancement ratio that other (insert 1,10,11,12).

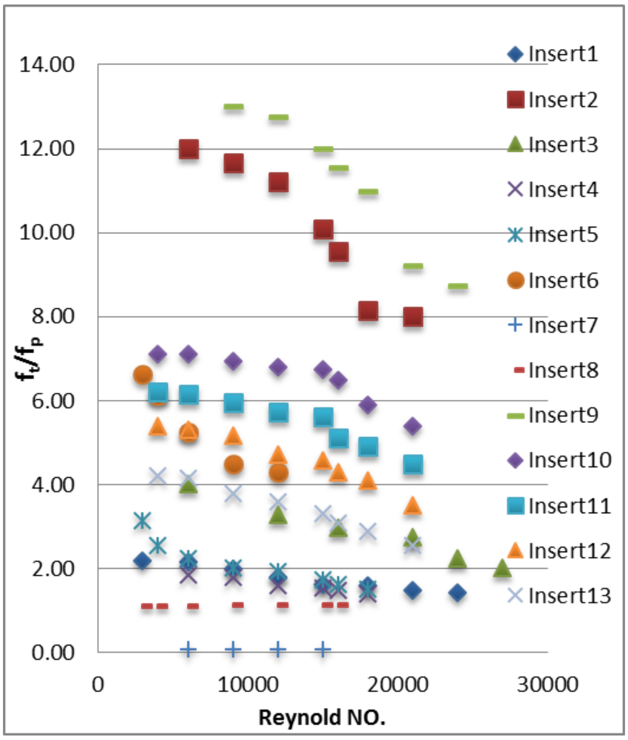


Fig. 4: Variation of Friction factor enhancement Ratio (f_t/f_p) Ratio Vs Reynold Number for different types of inserts

C. *Effect of Overall Enhancement Ratio (OER)*

The overall enhancement ratio is defining the ratio of Nusselt number enhancement ratio to friction factor enhancement ratio. It also called as thermo-hydraulic enhancement factor. This ratio is studied for different types of TT inserts to know the actual enhancement in the performance. It is evidence from existing literature history that number of TT inserts and their modification versions have significant effect on nusselt number and friction factor. Fig 5 show a plot of variation of overall enhancement ratio of different reynold number for different types of inserts. From Fig 5, it is observed that helically corrugated TT inserts with nanofluid (Insert 7) shows maximum OER range from 2.32 to 1.53. It also examine that in case of co-swirl TT, the unidirectional swirl motion is induced in the main flow whereas counter- swirl TT produce swirl motion in opposite direction which enhance the overall enhancement ratio. Therefore by comparing single TT (insert 1), Twin- swirl TT (Insert 10), twin counter swirl TT(Insert 11), four co-swirls TT(Insert 12), and four counter swirl TT(Insert 13), its proved that OER for four counter TT shows higher performance that other for minimum P. R.

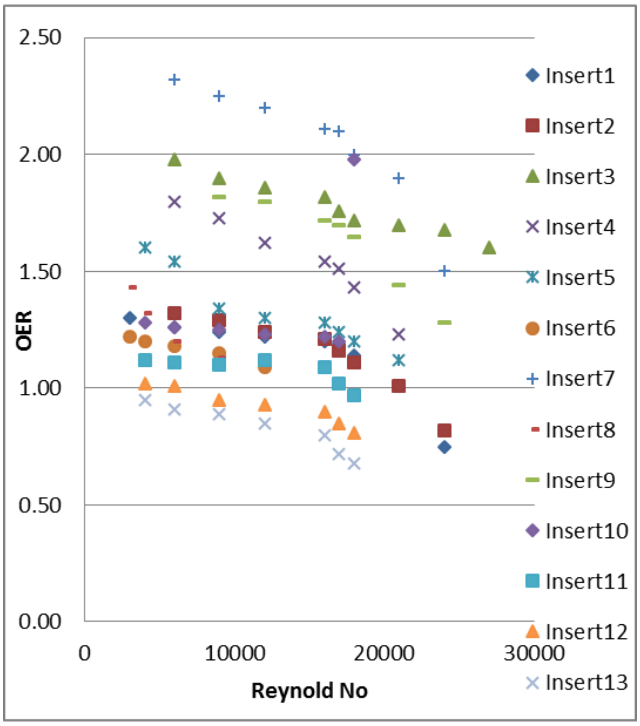


Fig. 5: Variation of Overall enhancement Ratio (OER) Vs Reynold number for different types of inserts.

VI. CONCLUSION

In this review paper very recent experimental studies of using different types of inserts like TT, modified TT, TT with wire coil vortex generator inserts in the heat exchanger are presented. Used of any swirl generator inserts in test section tube which improved the overall enhancement ratio than simple test section tube. There are a lot of works which emphasize the increased heat transfer rate and decreased pressure drop or minimized friction factor. By giving the importance to the definition of overall enhancement ratio, these two opposite behaviors can be gathered in one unique factor. Hence its means that the main criteria for choosing superior any inserts configurations is the high value of OER which is related to minimum pressure drop with maximum heat transfer rate or nusselt number. The variations of Nusselt number enhancement ratio and friction factor enhancement ratio has been examined for different types of inserts by varying reynold number in the range of 3000 to 30,000.
Based on the present review work, following conclusions can be drawn:

1) The enhancement ratios of the nusselt number and friction factor decreases as reynold number increases in all cases of inserts. The highest nusselt number enhancement ratio is 6.12 for TT with wire coil inserts in case of modified version of TT and on other hand for simple TT, four counter swirl TT inserts have highest results for smallest P. R.
2) The overall enhancement ratio is higher for helically corrugated TT inserts with nanofluid as working fluid. Also four counter swirls TT inserts shows significant result in case of simple TT inserts.
3) The nusselt number increases and friction factor decreases as the Reynold number increases for all types of insert.
4) The counter-swirl types of TT inserts brought out higher heat transfer and friction in comparison to the co- swirl TT inserts.

REFERENCES

[1] Watcharin Noothong, Smith Eiamsa-ard and Pongjet Promvonge, Effect of Twisted tape Inserts on Heat transfer in a tube, The 2nd Joint International Conference on “Sustainable Energy and Environment (SEE 2006)”, Bangkok, Thailand.
[2] Chaitanya Vashista, Anil Kumar Patil, Experimental Investigation of heat transfer and pressure drop in a circular tube with multiple insert, Applied thermal Engineering, 2005, pp 117-129.
[3] P. V. Durga Prasad, A.V.S. S.K. Gupta, Experimental investigation on enhancement of heat transfer using Al_2O_3/water nanofluid in a U-tube with twisted tape inserts, International communications in heat and mass transfer, (Article in press, ICHMT-03381; No of Pages 8), 2016.
[4] Hasanpour, M. Farhadi and K. Sedighi, A review on twisted tape inserts on turbulent flow heat exchanger: The overall enhancement ratio criteria, International Communications in Heat and Mass Transfer, 2014, pp 2977-2987.
[5] Hong, S. W. and Bergles, A. E. Augmentation of laminar flow heat transfer in tubes by means of twisted-tape inserts. Trans. ASME J. Heat Transfer, 1976, 98, 251–256.
[6] Taiwo o. Oni, Manosh C. Paul, Numerical investigation of heat transfer fluid flow of water through a circular tube induces with divers tape insert, Applied Thermal Engineering (Accepted Manuscript, DOI http://dx.doi.org/doi: 10.1016/j.applthermaleng.2015.12.039.) , 2015.
[7] S. Eiamsa-ard, P. Seemawute, K. Wongcharee, Influence of peripherally-cut twisted tape insert on heat transfer on heat transfer and thermal performance characteristics in laminar and turbulent tube flows, Experimental Thermal and Fluid science,34,2010, pp 711-719.
[8] Saman Pourahmad, S. M. Pesteei, Effectiveness-NTU analysis in a double tube heat exchanger equipped with wavy strip considering various angles, Energy conservation and Management, 2016, pp 462-469.
[9] M. Khoshvaght-Aliabadi, M. H. Akbari, F. Hormozi, An empirical study on Vortex-Generator Inserts Fitted in Tabular Heat exchangers with Dilute Cu-Water nanofluid flow, Chinese journal of chemical engineering, (Accepted Manuscript, DOI 10.1016/j.cjche.2016.01.014), 480, 2015.
[10] P.W. Deshmukh, R. P. Vedula, Heat transfer and friction factor characteristics of turbulent flow through a circular tube fitted with Vortex generator insert, International journal of heat and mass transfer, 2014, pp 551-560.
[11] Ghadi, R. P. Moghaddam, M. T. Mazandarani, CFD Modelling of Increase Heat transfer in Tubes by Wire Coil Inserts, World Applied Sciences journal, 2012, pp 1443-1448.
[12] Omidreza Sadeghi, H. A. Mohammed, M. A. Wahid, Heat transfer and nanofluid characteristics through

circular tube fitted with helical tape inserts, International communications in heat and mass transfer, (Article in press ICHMT-03305; No of pages 11), 2015.
[13] Rabienataj Darzi, Mousa Farhadi and Kurosh Sedighi, Experimental investigation of turbulent heat transfer and flow characteristics of SiO_2 / water nanofluid within helically corrugated tubes, International Communications in Heat and mass Transfer 39, 2012, pp 1425-1434.
[14] Garcia, J. P. Solano and P. G. Vicente, The influence of artificial roughness shape on heat transfer enhancement: Corrugated tubes, dimpled tubes and wire coils, Applied Thermal Engineering 35, 2012,pp 196-201.
[15] S. A. Wani, S. R. Patil and A. P. Shrotri, A review on effect of vortex generators on flow characteristics and heat transfer in heat exchanger, International journal of engineering science and research technology (ISSN : 2277-9655), 2015.
[16] Dewan, P. Mahanta, Review of passive heat transfer augmentation techniques,Applied Theraml Engineering 2001, PP 509-527.
[17] Sneha Ponnasa, Naidu S. V., A compareative study on the theramla performance of water in acircular tube with twisted tapes,Perforated twisted tapes and perforated twisted tspes with alternate axis,International journal of Thermal science 136, 2019, PP 530-538.
[18] P. Murugesan, K. Mayilsamy, S. Suresh, P.S.S. Srinivasan, Heat transfer and pressure drop characteristics in a circular tube fitted with and without V-cut twisted tape insert, ICHMT 38 (2011) 329–334.