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Enhancement Heat Transfer in a Tube Fitted with Passive Technique as Twisted Tape Insert - A Comprehensive Review

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Abstract The process of improving heat transfer is one of the important topics that are constantly studied. There are three techniques to improve the heat transfer (passive, active and compound). Most studies are done using the passive technique because it does not need external energy. its work is only to mix the flow to control the growth of the boundary layer and to increase the thermal exchange between the wall and the fluid flow by placing the techniques inside the flow. In this study, emphasis was placed on the studies and research carried out on the first technique (passive technique) and put in a table according to the years of publication as a reference for the students studying in this subject and for heat exchangers designers who aim to reduce weight and cost in the process of manufacturing heat exchangers for reduce their effort and time to reach the optimal design and get the best results.

Keywords: *heat transfer, twisted tape insert, heat exchanger, enhancement*

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1. Introduction

The need of develop efficient heat exchangers has been partially fulfilled by using increased heat transfer rats. Heat transfer rate can be enhanced by using different methods, these methods can be classified in to three different categories [1,2,3,4].

Active technique/these techniques require some external power input to cause the desired flow modification and improvement heat transfer like surface vibration or electrostatic fields.

Passive technique/these techniques not require any direct input of external power but using of geometrical modifications to the flow channel by incorporating insert or additional devices as a rough surface, swirl device, coil tube, etc.

Compound technique/ it is a hybrid method where both active and passive techniques are combined to increase heat transfer rate.

The design procedure of heat exchangers is quite complicated and the major challenge in designing of heat exchangers is to make the equipment compact and to achieve a high heat transfer rate using minimum pumping power. The goal of improvement heat transfer is to reduction heat exchanger size and operate at smaller velocity, this lead to higher heat transfer coefficient and reduction of pressure drop, and finally mean less operating cost.

Recently, passive technique has widely been applied for improvement heat transfer due to its effectiveness, low cost and easy setting up with increasing pressure drop and efforts deal with decreases pressure drop by augmentation inserts. The using of this techniques cause disturbs of actual boundary layer and swirl in the bulk of fluid to increase effective surface area.

When heat exchangers be old, the resistance to heat transfer increase, this problem is common for heat exchangers. In this case, heat transfer rate can be enhanced by introducing disturbance in fluid flow with using different techniques. In recent years some of papers deal with reviews of heat transfer enhancement tool, but these reviews deal with some of passive technique geometries or take one type of flow.

Heat transfer augmentation: -

In general, some kind of inserts are placed in flow passage to augment the heat transfer rate and this reduce the hydraulic diameter of flow passage [1]. By inserter passive technique, heat transfer will be enhanced in tube flow due to flow blockage, partitioning of flow. When using passive technique, pressure drop and viscos effects will be increase because of reduced free flow area. Blockage also increases the flow velocity and lead to significant secondary flow. Secondary flow improvement thermal contact between the fluid and surface due to swirl flow (except for extended surface), and temperature gradient will be improving due to mixing fluid that is lead to increase heat transfer coefficient.

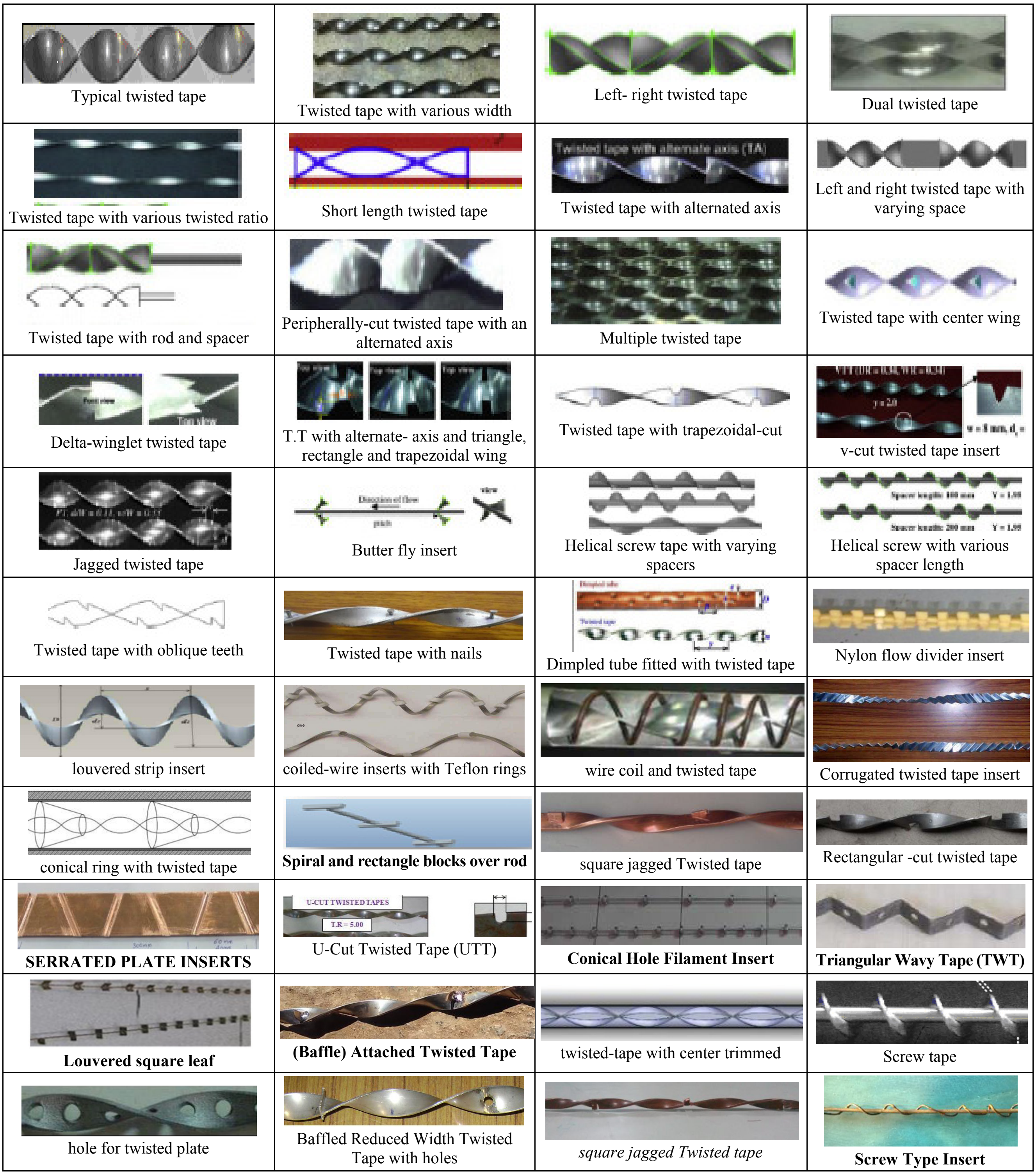
[2] had taken the exhaustive review of some of the method of augmentation. The important outcomes are given in Table 1.

Table 1. Some of method augmentation [145]

Details of Tape used	Remark
Full length twisted tape	Heat transfer rate increases but increase in friction factor also observed
Short length twisted tape	Low friction factor and low Nusselt number observed As the length of the tape reduces, friction factor reduces and heat transfer co-efficient also reduces.
Twisted tape with uniform pitch	Performs better than gradually decreasing length tape
Twisted tape with gradually decreasing pitch	Poor performance as compared to uniform pitch tape
Baffled twisted tape with holes	Better Heat transfer rate is observed but as turbulence increases, increase in friction factor is also observed.
Tight fit and lose fit tapes	Tapes having tight fittings give more frictional loss, whereas reduced Width and centrally located loose fit tape gives better result.

Before starting the study, the types of surfaces and geometries modification inserts in channel in the previous studies are summarized in Table 2.

Table 2. Configuration sketches of different types of surfaces inserts in channel in the previous studies



Typical twisted tape	Twisted tape with various width	Left- right twisted tape	Dual twisted tape
Twisted tape with various twisted ratio	Short length twisted tape	Twisted tape with alternated axis	Left and right twisted tape with varying space
Twisted tape with rod and spacer	Peripherally-cut twisted tape with an alternated axis	Multiple twisted tape	Twisted tape with center wing
Delta-winglet twisted tape	T.T with alternate- axis and triangle, rectangle and trapezoidal wing	Twisted tape with trapezoidal-cut	v-cut twisted tape insert
Jagged twisted tape	Butter fly insert	Helical screw tape with varying spacers	Helical screw with various spacer length
Twisted tape with oblique teeth	Twisted tape with nails	Dimpled tube fitted with twisted tape	Nylon flow divider insert
louvered strip insert	coiled-wire inserts with Teflon rings	wire coil and twisted tape	Corrugated twisted tape insert
conical ring with twisted tape	**Spiral and rectangle blocks over rod**	square jagged Twisted tape	Rectangular -cut twisted tape
SERRATED PLATE INSERTS	U-Cut Twisted Tape (UTT)	**Conical Hole Filament Insert**	**Triangular Wavy Tape (TWT)**
Louvered square leaf	**(Baffle) Attached Twisted Tape**	twisted-tape with center trimmed	Screw tape
hole for twisted plate	Baffled Reduced Width Twisted Tape with holes	*square jagged Twisted tape*	**Screw Type Insert**

2. Literature Review

A. Literature review for reviewing and summarizing previous researchs

A number of previous studies have been conducted summarizing previous research done on the passive technique of heat transfer augmentation with using twisted tape inserts (T.T). But these studies were not comprehensive enough to enrich students and designers to the subject of heat exchangers.

[1] reviewed the researchs for five different type of inserts [twisted tape (T.T) in laminar flow, twisted tape (T.T) in turbulent flow, wire coil in laminar flow, wire coil in turbulent flow and some of other inserts such as ribs, fins, etc].

[5] reviewed research deals with enhancement heat transfer by using twisted tape (T.T) in laminar and turbulent flows.

[2] reviewed a few studies for a few years preceding the review conducted on passive augmentation technique.

[3] reviewed a few number of researches for a few years preceding this review conducted on enhanced heat transfer by using twisted tape (T.T) in tubular heat exchangers.

[6] reviewed a few papers about improving heat transfer in heat exchangers for laminar and turbulent flow with using plain and modified (T.T).

[7] reviewed a researches on heat transfer improvement in circular tube by using nano fluid with (T.T) for laminar and turbulent flow.

[8] reviewed the researches working in circular tube and square duct with using (T.T) and screw tape for laminar and turbulent flow.

[9] reviewed a numerous research artificial for enhancement heat transfer in tube by using different types of inserts. The study focus on the various geometries of inserts and take one research for each insert as a sample of geometries using to produce turbulent flow and effect on heat transfer.

The focus of [10] review is done on various categories of (T.T) (plain T.T, varying width and length T.T, T.T with alternant axis, T.T with modification in the peripheral region, T.T with modification on the surface, T.T with rod and varying spacer and T.T wing) in the turbulent flow.

[11] reviewed a few papers working on the effect of T.T insert on heat transfer, friction factor, thermal performance factor characteristic and pressure drop.

[12] reviewed a few papers working on improvement heat transfer and pressure drop by using suitable insert of T.T in flow channel.

[13] reviewed a few papers working on pressure drop and enhancement heat transfer with circular and square cross section with different types of inserts.

[14] reviewed a few researches working on enhancement heat transfer in pipes with using different type of inserts in laminar and turbulent flow.

[15] reviewed papers that discussion heat transfer augmentation techniques by using simple inserting geometries of T.T and wire coil and tube geometry experimentally.

[16] reviewed papers contains passive enhancement technique considers use of T.T in heat transfer.

[17] reviewed researches working on enhancement heat transfer and pressure drop by using some types of T.T in laminar and turbulent flow.

By looking of previous studies reviews, it is clear that there is no comprehensive and general overview of the enhancement heat transfer rate of heat exchangers by using passive augmentation techniques. In this study, previous researches conducted on this subject will be reviewed based on the years of publication and the type of flow as in Table 3 to be an adequate reference for students and designers of heat exchangers.

Table 3. Summary investigation of passive heat transfer augmentation technique

Authors	Year of publication	Working fluid	Type of flow	Configuration of passive technique	Type of investigation	Observation
[18]	1959	water	Turbulent	Plain TT	Expe.	-increase in heat transfer by using TT -increase in pressure drop
[19]	1963	water	Turbulent	Full and short length of TT	Expe.	-heat transfer by using short length of TT is better than that of full length
[20]	1963	water	Turbulent	Plain TT	Expe.	-Heat transfer enhanced using TT -TT is importing for high (Pr)
[21]	1964	water	Turbulent	Full length TT	analytic	-proposed mathematically model for tape generated swirl mechanism
[22]	1964	Air	Turbulent	Wire coil	Expe.	-propose correlations for heat transfer
[23]	1965	water	Turbulent	Short length TT	Expe.	-heat transfe enhanceing withusing TT -short length TT (25-45)%of tube length perform better than full length tape
[24]	1968	water	Turbulent	Plain TT	Expe.	-increasing heat transfer when using TT -centrifugal force aids convection when fluid is heated up
[25]	1969	water	Turbulent	Plain TT	Expe.	-increasing heat transfer for usinjg TT -isothermal friction factor for swiral flow of liquid is substantially less than for plain tube
[26]	1969	Nitrogen	Turbulent	Short length TT	Expe.	-effectiveness of TT in gas cooled nuclear reaction
[27]	1969	water	Turbulent	TT and transfer ribs	Expe.	-Heat transfer enhanced in both TT and ribs -transfer ribs performed better than TT
[28]	1970	water	Turbulent	Wire coil	Expe.	-proposed correlation for heat transfer -The correlation under predicts by 50%

Authors	Year of publication	Working fluid	Type of flow	Configuration of passive technique	Type of investigation	Observation
[29]	1970	water	Turbulent	Plain TT	Expe.	The conclusion was that optimum design of heat exchanger with using TT induced swirl flow must consider combination of continues
[30]	1972	water	Laminar	TT	Numerical	-Heat transfer enhancement with using TT -pressure drop increased also
[31]	1972	water	Turbulent	Short length TT	Expe.	Usefulness of tapes in gas cooled nuclear reactors
[32]	1973	water	Turbulent	TT	Expe.	-Nu and friction factor for flow in tube containing TT deviate 30%
[33]	1974	water	Turbulent	TT	numerical	-solved the problem numerically or fully developed flow
[34]	1974	water	Turbulent	TT and transfers ribs	Expe.	-heat transfer by using ribs better than using TT
[35]	1976	Water and ethylene glycol	Turbulent	Full-length TT	Expe.	-Nu is function of twist ratio, Pr and Re -Nu is time that of empty tube -friction factor is effected by TT
[36]	1979	Water	Turbulent	TT	Expe.	-heat transfer enhancement buy using TT
[37]	1979	Water	Turbulent	TT	Expe.	-obtained heat transfer and pressure drop correlations
[38]	1980	Water	Turbulent	TT	Expe.	-The study was of generate a swirl flow by tapes in vertical section -heat transfer enhancement
[39]	1980	Water	Turbulent	TT	Expe.	-increasing in friction losses due to the vortex mixing effect
[40]	1983	Water	Turbulent	TT	Expe.	-study the augmentation of heat transfer in axial duct of electrical machine
[41]	1983	Water	Turbulent	TT	Expe.	-heat transfer enhanced -maximum thermal stress be near piping that contact of cover plate of fire heat exchanger tube
[42]	1984	Water	Turbulent	TT	Expe	-TT imported to mixing fluid and increasing heat transfer
[43]	1985	Water	Turbulent	TT	Expe.	-TT generated swirl flow due to losses of head in hydraulic resistance
[44]	1985	Water	Turbulent	Short TT	Expe.	-soling the governing equation of the short length TT that growth swirl flow
[45]	1986	Water	Turbulent	TT	Expe .	-hot cross tape in flow way of water heater play important role in heat transfer to tube wall
[46]	1987	Water	Turbulent	TT fins	Expe.	-Checked pilot plain having economic by using TT
[47]	1987	Water	Turbulent	TT	Expe.	-study the effect of TT in short tube and high velocity
[48]	1988	Water	Turbulent	TT	Expe.	heat transfer enhanced due to generate swirl flow
[49]	1989	Air	Turbulent	TT	Expe.	-study the effect of TT in annulus -heat transfer enhanced, also increasing in friction factor
[50]	1989	Water	Turbulent	TT	Expe.	-study pressure drop with law heat transfer and law temperature of fluid
[51]	1990	Water	Turbulent	Regularly spaced tapes	Expe.	-when used full length TT, heat transfer enhanced more than regularly spaced tapes
[52]	1992	Non newtonion fluid	Laminar	Wire coil	Expe.	-heat transfer improvement by factor 4
[53]	1993	Water and ethylene glycol	Turbulent	TT with different twist ratio	Expe.	-heat transfer enhancement by using TT -propose correlation for heat transfer and friction factor
[54]	1993	Air	Turbulent	Spherical cavities	Expe.	-Heat transfer enhanced (30-40)%
[55]	1994	Water	Turbulent	Wire coil	Expe.	Heat transfer increased with increasing pitch of wire coil
[56]	1994	air	Turbulent	ribs	Expe.	-heat transfer in ribbed surface develops at location where fluid is relatively cool
[57]	1994	water	Turbulent	Shot length TT in vertical surface	Expe.	-Radiation between tape and pipe wall increases heat transfer rate by 50%

Authors	Year of publication	Working fluid	Type of flow	Configuration of passive technique	Type of investigation	Observation
[58]	1994	Water	Turbulent	TT	Expe.	-study parameters of cooled pipes contains taps -used mathematical model for adiabatic cross section for study bulsed asymmetric heating by calculated hirmophasical parameters and external heat flux
[59]	1995	Water	Turbulent	TT	Expe.	-used mathematical model for adiabatic cross section for study bulsed asymmetric heating by calculated hirmophasical parameters and external heat flux
[60]	1995	water	Turbulent	TT and Teflon tape	Expe.	-compare the effect of stainless steel TT and Teflon tape -study the effect of this different type on heat transfer
[61]	1995	water	Turbulent	TT	Expe.	-used mathematical model for adiabatic cross section
[62]	1995	water	Turbulent	TT	Expe	-Study the effect of rotary TT -heat transfer enhanced when using rotary TT
[63]	1996	water	Laminar	Wire coil	Expe	-Developed correlation for heat transfer and friction factor
[64]	1996	Air	Turbulent	ribs	Exe	-thermal performance is high at angle 45 -heat transfer depends on geometric factors of ribs
[65]	1996	water	Turbulent	Full length TT	Expe	-the optimum tape width depending on Re and twist ratio for best thermal performance
[66]	1996	water	Turbulent	TT	Expe.	-thermal hydraulic characteristic of TT generated swirl flow was studied
[67]	1996	Water	Turbulent	Short length TT	Expe.	-(25-45)%of full length of TT performance better than full length TT
[68]	1997	water	Laminar	TT	Expe.	-half length of TT is more effected than full length
[69]	1997	Water	Laminar	TT	Expe.	-single turn yield less important than large number of turn
[70]	2000	Water	Laminar	TT	Expe.	-Stanton No. increasing by 5.8 time compared with smooth tube
[71]	2000	Water	Turbulent	TT	Expe.	-investigated performance for TT inserts in solar water heater
[72]	2000	water	Turbulent	TT	Expe.	-heat transfer enhanced with using novel TT
[73]	2000	Water	Laminar	TT	Expe.	Heat transfer increase with increasing TT pitch value
[74]	2001	Fluid with 205<Pr<518	Laminar	TT	Expe.	-pinching of TT gives better result in heat transfer than connecting thin rod
[75]	2001	Water	Laminar	Wire coil	Expe.	-low pressure drop loss and high heat transfer obtained by leading edge effect near tube inlet down stream of wire coil
[76]	2001	Gas and liquid	Laminar	Wire coil	Expe.	-friction factor and slug rise velocity are higher for wire coil than smooth tube
[77]	2001	Air	Turbulent	Wire coil	Expe.	-study the effect of varies wire coil spacings on mixing process
[78]	2001	Air	Laminar	dimples	Expe.	-pressure drop and friction factor not increased because no form design is produced by protruding in to flow
[79]	2001	Water	Laminar	Dimples	Expe.	-enhanced heat transfer coefficient 1.25-2.37 time than smoth tube -dimples depth to pitch and dimple depth to diameter is good for heat transfer
[80]	2001	water	Laminar	TT	Expe.	-Nu and friction factor are low -short length TT required small pumping power -uniform pitch performance better the gradually decreasing pitch
[81]	2002	Air	Laminar	Wire coil	Expe.	-wire coil with large pitch spacing increases mixing but reduces max. mean velocity

Authors	Year of publication	Working fluid	Type of flow	Configuration of passive technique	Type of investigation	Observation
[82]	2002	Air	Turbulent	rib	Expe.	-heat transfer increase 260 – 300 % compared with smooth tube
[83]	2002	Air	Laminar	Dimple	Expe.	-heat transfer enhanced with using dimple -the vortex periodically shed from the dimple diameter stronger as the non-dimensional channel high to dimple diameter decrease
[84]	2002	Water	Turbulent	Additives	Expe.	-boiling heat transfer enhanced due to additives
[85]	2002	Water	Laminar	deflectors	Expe.	-heat transfer will be important due to addition of angled deflectors
[86]	2002	Water and lithium bromide	Laminar	Additive	Expe.	-additives in vapor of water has stronger effect on surface tension than liquid -surface tension of lithium bromide is effected surfactant
[87]	2002	Water with lub. Oil (Pr=418)	Laminar	TT	Expe.	-large value of heat transfer produced in water to water mode with oil to water mode by using TT
[88]	2002	Water	Laminar	TT	Expe.	-heat transfer enhanced with using TT -if pressure coefficient is considered, TT has poor overall efficiency
[89]	2002	Water	Laminar	Wire coil	Expe.	-effected wire coil on heat transfer and friction factor elucidate under values –of flow velocity, wire coil diameter, length and pitch
[90]	2003	Water	Laminar	TT	Expe.	-proved existence of secondary flow in duct with helical static element
[91]	2003	Water	Laminar	TT	Expe. In larg diameter annulus	-friction factor is large value -heat transfer in annulus has been measured by using different configuration of TT
[92]	2003	Air	Turbulent	Porous baffles and solid baffles	Numerical in rectangular duct	-porous type baffles is good for thermal performance - performance dose not depend on baffles
[93]	2003	Water	Laminar	TT	Numerical work for square duct	-proposed correlation for Nu and friction factor -by using square duct the hydrothermal is higher than circular duct -heat transfer enhanced due to using TT
[94]	2004	Water	Laminar	TT	Expe.	-heat transfer enhance by using TT with large value of friction factor when using large diameter annulus
[95]	2006	Water	Turbulent	Regularly TT	Expe.	-friction factor and heat transfer increase with increasing twist ratio and spacing between tow TT
[96]	2006	Water	Turbulent	TT	Expe.	-heat transfer important with using TT also increasing in pressure drop
[97]	2007	Air	Turbulent	TT in converge – diverging tube	Expe.	-best performance was at twisted ratio 4.72 and rotation angle 180
[98]	2007	Water	Laminar	Wire coil	Expe.	-study performance of heat transfer and friction with wire coil insert -the result show very effect of wire coil in heat transfer
[99]	2007	Water	Turbulent	Conical ring +TT	Expe.	-heat trahsfer enhancement efficiency of 4 to 8 % with using TT higher than that tube without TT
[100]	2007	Water	Turbulent	Serrated TT	Expe.	Heat transfer and friction factor increase as twist ratio decrease
[101]	2007	Air	Turbulent	Broken TT	Expe.	-Nu and friction factor increase as the twisted ratio decrease in tube fitted with broken TT
[102]	2008	Air	Turbulent	Serrated TT	Expe.	-serrated TT cause swirl motion -TT increases thermal performance factor
[103]	2008	Water	Turbulent	TT in square duct	Expe.	-heat transfer performance for full length TT better than that short length TT
[104]	2008	Fluid with 5.64<Pr<5.8	Turbulent	Rotor assemble strand	Expe.	-heat transfer improve with Nu increase by 101.6% - 106.6% -friction factor increase by 52.2% -84.2% when using rotor assemble strand

Authors	Year of publication	Working fluid	Type of flow	Configuration of passive technique	Type of investigation	Observation
[105]	2009	Air	Turbulent	Dimple with TT	Expe.	Heat transfer is higher in dimple tube with TT than using TT only -heat transfer and friction factor increases when pitch ratio and twist ratio decrease
[106]	2009	Air	Turbulent	Short length TT	Expe.	-short length TT performance lower heat transfer and friction factor than the fully length TT around 14% -21%
[107]	2009	Water	laminar	Half length TT	Expe.	-heat transfer increase with using TT insert -Nu increase by 40% with TT -pressure drop is more efficient with half length TT than full length TT
[108]	2009	Water	Laminar	TT with rod and spacer	Expe	-heat transfer in TT collector is higher than the plain tube -Nu with TT is 13.5 % higher than the plain tube and friction factor is given as 14.85
[109]	2009	Water	Laminar	Spirally grooved tube with TT	Expe.	-heat transfer rate by using spirally grooved tube with TT is higher compared with plain tube
[110]	2009	Air – water bubbly flow	Turbulent	Spiky TT	Expe.	Heat transfer is higher than the plain TT
[111]	2009	water	Turbulent	Trapezoidal –cut TT	Expe.	-Nu and friction factor increased by using trapezoidal –cut TT with decreases twist ratio
[112]	2009	Water	Laminar	TT	numerical	-study the effect of conduction in tope of Nu -study the relation between the absolute voracity flux and Nu to the thermal B. C
[113]	2009	AL_2O_3 nani fluid	Turbulent	TT	Expe.	-heat transfer enhancement with using AL_2O_3 nani fluid compared with water flow --heat transfer enhancement with using AL_2O_3 nani fluid and TT
[114]	2009	Water	Turbulent	Twin TT	Expe.	-twin count TT is use as counter swirl flow generators while twin TT is used as co-swirl flow generators and heat transfer enhancement
[115]	2010	water	Turbulent	Peripherally-cut TT with alternate axis	Expe.	Heat transfer enhances 184% by using Peripherally-cut TT with alternate axis and 57% when used plain TT with respect to plain tube
[116]	2010	Al_2O_3 nano fluid	Turbulent	TT	Expe.	-heat transfer enhancement when using nano fluid with TT compared with water in plain tube
[117]	2010	Water	Turbulent	TT	Expe.	-pressure drop become higher with using TT with increase Re -Nu increase with TT and decrease with increase Re
[118]	2010	Water	Turbulent	Multiple TT vortex generator	Expe.	-heat transfer increasing by 170% and friction factor in the range 1.47 -5.7with using TT -heat transfer rate is 1.4 than the plain tube
[119]	2010	Water	Turbulent	Alternate counter /co twisted tape	Expe.	-Nu of counter clockwise TT increases with decrease of twisted ratio -counter clockwise TT creates more of fluid inside the tube
[120]	2010	Water	Turbulent	Edge fold TT	Expe.	-edge fold TT give max. thermal performance -thermal efficiency slowly decrease as swirl ratio increase
[121]	2010	Water	Turbulent	Serrated TT	Expe.	-heat transfer increase and friction factor with using serrated TT above plain tube
[122]	2010	Water	Turbulent	Oblique teeth TT in square duct	Expe.	-oblique teeth TT show high performance than TT with higher than the plain tube
[123]	2010	Water	Turbulent	Center wing and alternate axis TT	Expe.	-heat transfer with center wing with TT higher than the plain tube
[124]	2010	Water	Turbulent	Delta winglet TT	Expe.	-using delta winglet TT reduce size of the heat exchanger
[125]	2010	Water	Turbulent	Peripherally cut TT	Expe.	-heat transfer increases with increase in depth ratio

Authors	Year of publication	Working fluid	Type of flow	Configuration of passive technique	Type of investigation	Observation
[126]	2010	Water	Turbulent	v-cut TT	Expe.	-heat transfer and friction factor in tube with v-cut TT inserts increase with decreasing twisted ratio and width ratio -Nu and friction factor increase with increasing depth ratio
[127]	2010	Refrigerant HFC-134a	Turbulent	Peripherally cut TT	Expe.	-when decrease in twist ratio, heat transfer rate will be increase -pressure drop increase when twist ratio decrease
[128]	2011	Air	Laminar	Central clearance TT	Numerical	-central clearance TT is good technique and heat transfer enhanced with change in center clearance ratio
[129]	2011	Water	Laminar	TT with alternate axis with CuO nano fluid	Expe.	-heat transfer increases with increase in Re and fluid concentration -TT makes more swirl in flow with increased heat transfer efficiency
[130]	2011	Water	Turbulent	Short length TT	Expe.	-Nu and friction factor is low for short length TT -multiple shot length TT Pasaladi, M. et al performance in high comparted with other TT
[131]	2011	Water	Turbulent	Peripherally –cut TT	Expe.	-pressure drop become higher with an increase in Re and twist ratio -overall Nu increases with tighter TT and decreases with increase Re
[132]	2011	Water	Turbulent	Short-length TT	Numerical	- Enhancement heat transfer with using TT - Short–length TT have good effect on heat transfer
[133]	2012	water	Turbulent	Twisted wire brush	expe.	-twisted wire provided significant enhancement of heat transfer with increase friction factor -Nu and friction factor increases with twisted wire insert -thermal efficiency increase 1.85than the plain tube
[134]	2012	Water	Turbulent	Helical TT	Expe.	-heat transfer enhancement by using TT -max. Nu be increased by 160% for full length helical tape and 150% for helical tap with rod and 145% for regularly spaced helical tap compared with plain TT
[135]	2012	Water	Turbulent	TT with wire mesh	Expe.	-friction factor and heat transfer increases with decrease twisted ratio -twisted mesh for twisted ratio 7 and 5 enhanced heat transfer rate 2.09 and 4.69 time compared with plain tube
[136]	2012	Water	Laminar	Square ribbed duct with TT	Expe.	-higher TT ratio make higher Nu
[137]	2012	Water	Turbulent	Alternate axis TT	Expe.	-alternate axis TT give better fluid mixing and higher heat transfer than that TT
[138]	2012	Air	Turbulent	Elliptic ring	Expe.	-Nu and friction factor increasing when using elliptic ring compared with plain tube -Nu and friction factor increase with decrease ring spacing
[139]	2013	Water	Turbulent	Full length TT with hole and baffles	Expe.	- Heat transfer be percentage 8.9% - Heat transfer coefficient of TT with hole and baffle wave less as compared to full length TT
[140]	2013	Water	Laminar	TT With hole	Expe.	-heat transfer and friction factor increases with decrease twist ratio
[141]	2013	Air	Turbulent	Double TT	Expe.	-Nu and friction factor increase with decrease twist ratio -Nu increases with increase Re
[142]	2013	air	Turbulent	Threads with varying depth	Expe.	-heat transfer enhancement -friction factor increases with TT -friction factor increase with depth -pressure drop observed to 1.06 time of plain tube
[143]	2013	Water	Turbulent	Rectangular cut TT	Expe.	-heat transfer increase by using rectangular cut TT compared with plain tube

Authors	Year of publication	Working fluid	Type of flow	Configuration of passive technique	Type of investigation	Observation
[144]	2013	Air	Turbulent	Conical hole filament	Expe.	-heat transfer enhanced by using filament insert with convergent hole by 20% - pressure drop increase by 10%
[145]	2013	Air	Turbulent	Square leaf	Expe.	-Nu increase by 128.3%, 121%, 81.3 and 30.03% in present of 90, 60 forward, 60 backward and 30 degree -overall enhancement ratio is highest for 60 degree backward
[146]	2013	Air	Turbulent	TT	Expe.	-Nu increase with Re -TT of twist ratio 1.78 yielded the highest value of Nu
[147]	2014	Water	Turbulent	Wave TT	Expe.	-highest Nu obtain wave TT at width 13mm -=reduction in wave – width causes increment in Nu as well as rise pressure drop
[148]	2014	Water	Turbulent	TT with pins	Expe	-Re increase with decrease twist ratio -friction factor for twist ratio 4.29is less when compared with 3.33
[149]	2014	Water	Turbulent	Square jagged TT	Expe.	-square jagged TT increase Nu and pressure drop -Nu increase with76% and friction factor 19.5% when compared with plain tube
[150]	2014	Water	Turbulent	Opposite parallel wing TT	Expe.	-opposite parallel wing TT give superior thermal performance
[151]	2014	Titanium dioxide nano fluid	Turbulent	TT	Expe.	-by using TT with nano fluid , heat transfer coefficient was obtain 10 -25 % higher than water with plain tube
[152]	2014	Water	Laminar	TT	Numerical	-heat transfer in tube with TT is more effective than that with no TT -Re decrease with increase twist ratio
[153]	2015	Air	Turbulent	Triangular wavy TT	Expe.	-Nu in the range of 13 -79 and friction factor 0.18 -2.03 -heat transfer improvement relative to smooth tube
[154]	2015	Air	Laminar	TT	numerical	-heat transfer with TT is higher when compared without insert -optimum distance causes greater efficiency
[155]	2015	Air	Turbulent	Insert pattern	numerical	-improvement heat transfer dependence on pattern of insert and Re
[156]	2015	Air	Turbulent	u-cut and v-cut TT	Expe.	-the result show that heat transfer with u-cut TT batter than the other -Nu increase with decrease Re
[157]	2015	Liquid collector	Laminar +turbulent	Wire coil	Expe.	-the efficiency is enhancement with decrease in pitch to tube diameter ratio -thermal efficiency increases with increase wire thickness
[158]	2015	Air	Turbulent	TT	Expe.	-Nu and friction factor increase with decrease twisted ratio and taper angle -for twisted ratio 3.5 and taper angle 0.9 yielded max. thermal performance
[159]	2015	Water	Laminar	TT	Numerical	-Nu increase with decrease twisted ratio and increase Re
[160]	2015	Water	Turbulent	TT	Expe.	-higher heat transfer can be obtaining at high rotating TT -this study help to understand the flow rate with rotating TT
[161]	2015	Air	Turbulent	TT with divergent cuts	Expe	-Nu increase with decrease twisted ratio -Nu increase for the same mass flowrate and same area of cut -changing in cut profile being in triangular cut
[162]	2015	Gas	Turbulent	Porous TT	Expe.	-large number of holes enhance better heat transfer -heat transfer was higher for porous surface area flowing by plain TT and plain tube
[163]	2015	Air	Turbulent	Helical TT	Numerical	-with using helical TT heat transfer enhancement increase by 10 -15 %

Authors	Year of publication	Working fluid	Type of flow	Configuration of passive technique	Type of investigation	Observation
[164]	2016	Water	Turbulent	Square rod with different type of welded blocks	Numerical	-friction factor increase while using all types of block insert -heat transfer enhanced with using blocks in compression to plain tube -max. heat transfer be for piral rectangular blocks insert
[165]	2016	Air	Turbulent	TT	numerical	-heat transfer enhanced by using double side flow TT
[166]	2016	Water	Laminar	TT	Expe + numerical	-heat transfer enhancement using TT -high heat transfer can be obtain at high TT rotating
[167]	2016	Water	Turbulent	Modify TT	Expe.	-heat transfer ratio increased 1.13% with plain TT -heat transfer ratio increased 1.16% with modify TT -friction factor decrease with increase Re
[168]	2016	Water	Laminar	Center trimmed TT	Numerical	-equations solved with FVM -heat transfer with center trimmed TT is better compared with plain tube -Nu, friction factor and thermal efficiency increases with decreasing twisted ratio -
[169]	2016	AL_2O_3 nano fluid/water	Turbulent	Multiple TT	Expe.	-heat transfer increase with multiple TT -Nu and friction factor increase with increase number of tapes -for quadruple counter tape led to the highest performance factor up to 1.64
[170]	2016	Air	Turbulent	v-jagged TT	Expe.	-heat transfer enhancement compared with plain TT -aluminum v-jagged TT gives highest heat enhancement of 75% and friction factor is less about 0.04 as compart to other insert
[171]	2016	cuo/water	Turbulent	Square-jagged TT	Expe.	-heat transfer enhancement and friction factor increase -the nono fluid with square jagged TT with twisted ratio 4 show increasing Nu by 87% and friction factor increase 23% compared to the smooth tube
[172]	2017	Air	Turbulent	Non-metallic TT	Expe.	-Nu increase between 112-187% -friction factor to pressure drop increase by 0.06-0.08
[173]	2017	Air	Turbulent	Non- metallic divider TT	Expe	-Nu increase by 170% than the plain tube -overall enhanced efficiency for different Re was above unity (1.5-2)
[174]	2017	Water	Laminar	Nail TT	Expe	-Nu enhanced with nail TT compared with plain TT -max. efficiency of collector performance be with smallest twisted ratio -efficiency of TT absorber increases with increase in solar intensity and with twisted ratio
[175]	2017	Air	Turbulent	Conical ring TT	Expe.	-max. heat transfer rate of 370% by using conical ring TT with twisted ratio 205
[176]	2017	Water	Turbulent	Different types of TT	Expe.	-max. heat transfer rate be in twisted ratio of 2 -heat transfer increase with insert TT
[177]	2017	Air	Turbulent	Serrated TT	Expe.	-heat transfer and pressure drop increases -Nu increase 60-76% with serrated TTand frictio factor 39% for 6mm slot and 5mm plate thickness copper compared with plain tube
[178]	2017	Water	Turbulent	TT	Expe.	-Nu increase with increase twisted ratio -heat transfer and pressure drop increase by using TT
[179]	2017	Air	Turbulent	Inclined elliptical ring	Numerical	-the insert ring with 60 degree inclined yields heat transfer enhancement 3.6 -6.7 above the smooth tube

3. Conclusion

Through this study it is clear that: -

1- increasing heat transfer by using (passive technique) of all types and geometries accompanied by increased pressure drop and friction coefficient
2- Some types if inserts mix the bulk flow very well in laminar flow such as plain and modification twisted tape (T.T) and some of others well in turbulent flow as wire coil.
3- The aim of the study to make a comparison between increasing of heat transfer and friction factor and access to the optimal situation
4 - The effect of this technique (passive) in the turbulent flow is greater than in the laminar flow
5- There are many types and forms of inserts to flow for the purpose of improving heat transfer and more than one type can be combined into one study
6 - This study summarizes what has been done previously on this technical to be an important reference and shorten the time and effort of students and designers heat exchangers
7- Previous studies show that more researchers used the same (twisted taps TT) but with different (Re, Pr and Twist ratio) or change the diameter and length of the tube.

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