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Influence of Various Types of Twisted Tape inserts on Hydrodynamic, Pressure Drop and Thermal Heat Performance in Heat Exchangers: A Review Study

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ABSTRACT

Numerous inserts types are employed in different heat transfer improvement application devices. In this review study is forced on various types of twisted tape inserts in heat exchanger pipe. Geometrical configurations of twisted tape for example twist direction; length, width, space, twist ratio etc. were highly effect on flow pattern, hydrodynamic flow and heat transfer performance. In this review study observed that using different types of twisted tapes can improve thermal performance and hydrodynamic as compared to smooth pipe (without twisted tape). The review investigations found that improvement of thermal performance happens owing to decrease in pipe cross area, leads to rise in mixing flow, turbulence flow intensity flow and rise in swirl flow established through different kinds of twisted tapes. This article dealt with investigations published in corrugated pipes with varying field applications to provide good information for engineers and designers whom dealing and concerning with improvement of heat performance in heat exchanger corrugated pipes.

1. Introduction

Different heat transfer devices were employed for heat recovery and conversion in various domestic and industrial applications. Last decades, there were concentrated efforts to find and develop new heat exchanger design in order to decrease cost and material as well as energy requirement. Generally, using enhancement of heat transfer methods can decrease the thermal resistance in flow through generating turbulence flow and rising effective surface area of heat transfer. The important parameter used to evaluate heat transfer enhancement effectiveness is called thermal performance factor (TPF). Augmentation of heat transfer methods inside pipes led to a valuable improvement in the hydraulic and thermal performance in different applications [1-2]. Various techniques in active and passive analysed for thermal rates augmentation within pipes, the varied inserts types were used, mainly when the flow turbulent was considered. Many approaches have been applied to rise thermal heat performance devices for example, rough surfaces, coiled tubes, treated surfaces, swirling flow devices, twisted tape, dimples and corrugated surfaces [3-4]. The twisted tapes devices can classify as swirl device and hence improvement of heat performance in heat exchangers is ascribed to several influences. First one is blockage and partitioning of pipe flow cross area through a tape surfaces, resulting in higher value of velocities flow. Secondly, due to insert twisted tape that leads to reduce the pipe hydraulic diameter and hence that effects on heat transfer coefficient. Thirdly, helically twisting flow inside the pipe has an efficiently higher flow fluid path. Four one is generation of secondary flow around the twist tape, that leads to cause more mixing flow then enhance convection heat transfer [5-6].

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In order to calculate heat transfer coefficient (h) researchers were used the below expression [3]:

$$h = \frac{q}{(T_w - T_b)} \tag{1}$$

The Nusselt number equation is defined as follows [4]:

$$Nu = \frac{h\,d}{k} \tag{2}$$

For friction factor, they used the Darcy equation as follows [7]:

$$f = \frac{2\,\Delta p\,d}{pL\,U^2} \tag{3}$$

The important parameters for thermal performance have been used in most of investigations was thermal performance factor (TPF). It can be calculated by below formal [7, 8]:

$$TPF = \frac{(Nu/Nu_o)}{(f/f_o)^{\frac{1}{3}}} \tag{4}$$

Different researches were carried out to investigate characteristics of thermal flow behaviour and hydrodynamic of insert various kinds of twisted in pipes as represented in next section.

1.1. Experimental Investigations

Kumar and Prasad [7] conducted influence of tape inserted on friction factor and heat performance in solar water heater. Figure 1 shows the model geometry for pipe and twisted tapes. They noticed that when using twisted insert the pressure drop augmented around 87 to 132% and heat transfer rise about 18 to 70%. Also, they found that heat losses were decreased owing to the lower plate temperature value that leads to increasing the heat performance around 30%. Figure 2 shows the impact of tape on thermal performance under different conditions and geometrical parameters. Though, previous work has mainly just concentrated on influences of the tape twisted on flow, also, no information regarding study the impact of different geometrical investigations on flow behaviour in their research.

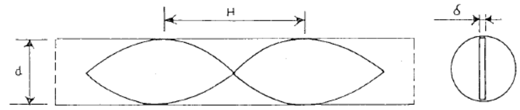

Figure 1. Geometry of tube and twisted tape [7]

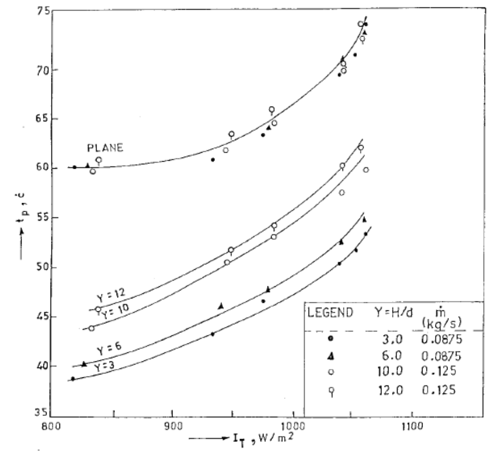

Figure 2. Influence of tape on solar water heater performance [7]

Liao and Xin [8] augmented the thermal performance in 3D pipes using insert of twisted tape. Figure 3 describes the tube with inlet diameter of 13.5 mm was tested. Their experimental work the outcomes show that improved heat transfer compound for three-dimensional pipe and tape twisted with inner surface was specific advantage to enhance the heat performance for highly viscous liquid. Stanton number was reduced from 15 to 18%. The ratio of overall performance was from 2.46 to 4.70. The same above investigation no more details regarding study the effect of different geometrical investigations on flow behaviour.

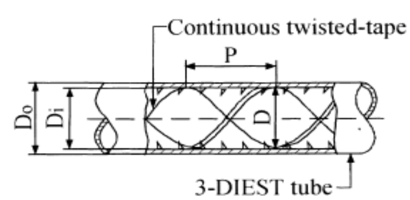

Figure 3. Pipe with twisted inserts [8]

Sarma et al. [9] studied the thermal performance with in the pipe laminar convective using twisted tape. It was noticed the influences of several contributory geometrical parameters have more impact on improvement the heat transfer. Also. using tapes inside the pipe can successfully treat the laminar flow regime for a high range for Prandtl number 3 < Pr < 400 due to increase the eddy viscosity. Ray and Date [10] investigated characteristics of friction factor and heat performance in square type duct using twisted inserts. In their work heat transfer performance was predicted at constant heat flux and axially flow conditions. Friction factor and Nu correlations were found using predicted results. The friction factor in laminar flow was for Re from 406 to 1100 with minimum to maximum Nu number ratio changing from 1.02 and 1.17 as shown in Figure 4.

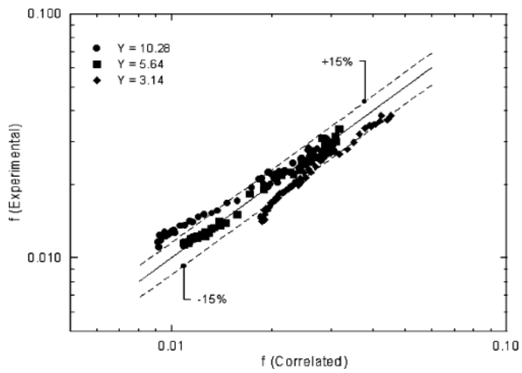

Figure 4. Comparison of correlation parameters [10]

Manglik and Bergles [11] conducted the effect the inserts of twisted tape on pressure losses and heat performance with swirl flow. It was discussed enhancement of heat transfer by swirl induced characteristic features. They observed that using twisted tapes in single-phase was quite established for regimes of turbulent and laminar. Naphon [12] investigated the thermal flow in double pipes by using twisted tape and without tape. Their test section length of 2000, outer and inner diameters were 9.54 and 8.10 mm. Twisted tape thickness was1 mm with length of 2000 mm as shown in Figure 5. their work was carried out just under various conditions, no details concerning the influence of geometrical configurations.

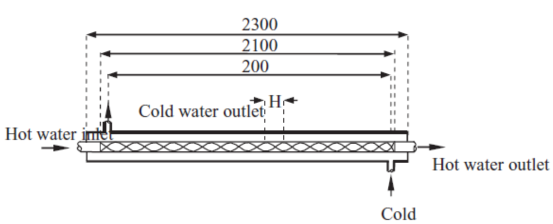

Figure 5. Experimental section schematic diagram [12]

Results indicate that using twisted tapes in pipes have important impact on pressure losses and enhancing heat transfer also they predicted different correlations equations for f and Nu as represented in Figure 6.

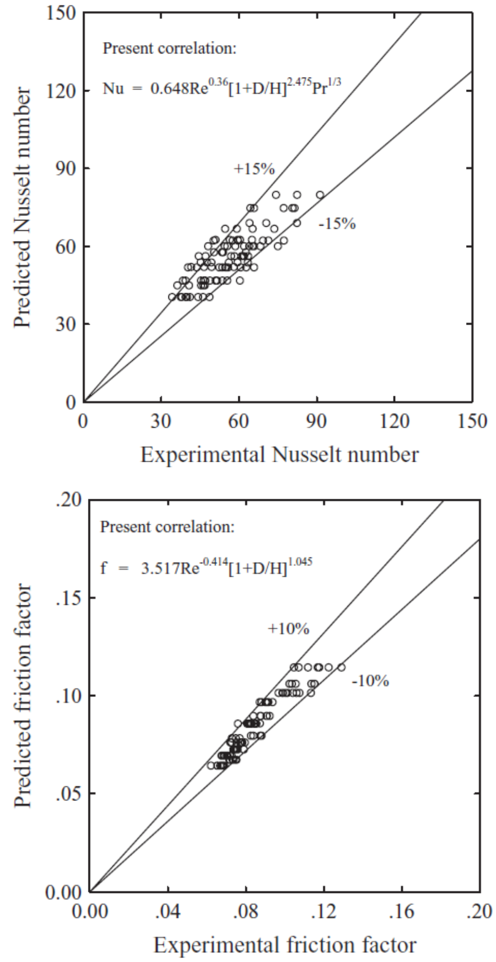

Figure 6. Correlations equations for Nu and f [12]

Eiamsa-ard et al. [13] experimentally analysed flow friction and thermal heat within pipe with elements of twisted tape. The experimental set-up schematic diagram includes a double-pipe with L=1500 mm and Di=25.8 mm as illustrated in Figure 7.

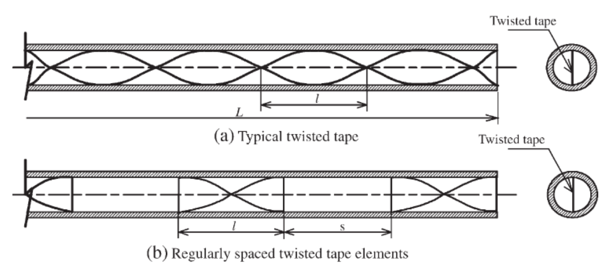

Figure 7. Experimental set-up schematic diagram [13]

Outcomes found that using twisted tape construction type can efficiently enhance rate of heat transfer also increasing friction factor, due to swirling flow and the secondary flows. Figure 8 represents the Nu number under different tape parameters. No details regarding flow pattern inside the pipe in their analyse.

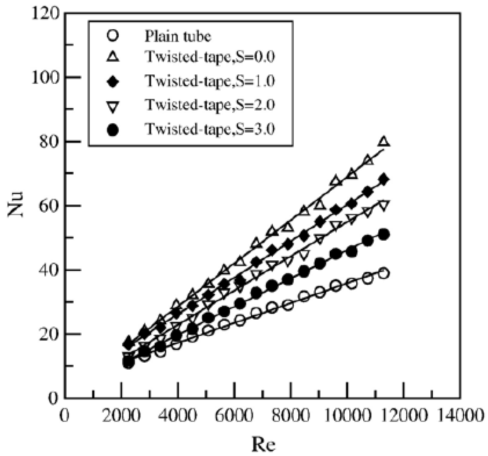

Figure 8. Changing the Nu number under different twisted configurations [13]

Promvonge and Eiamsa-ard [14] studied behaviour of heat transfer by combined twisted tape and conical ring in a pipe. Figure 9 represents test pipe with tape and turbulator of conical ring. Experimental outcomes noted that using latter devices can improve values of Nusselt number about 4 to 10%. Also, improvement heat efficiency around 4 to 8%. Rates of heat transfer using twisted tape and conical ring were found to be increases from 350% to 367%. In their two types of passive devices have been used.

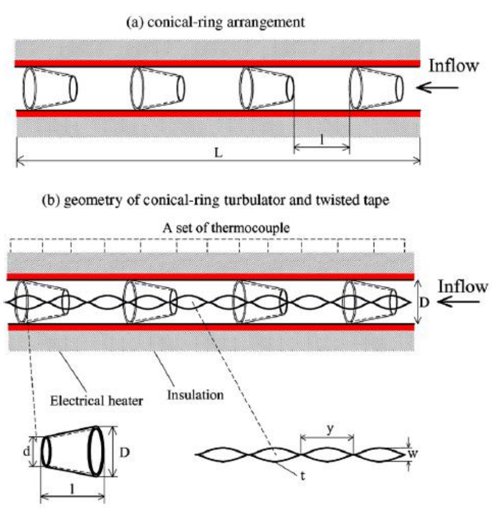

Figure 9. Schematic diagram of pipe with both devices [14]

Chang et al. [15] studied turbulent flow, pressure and thermal flow using serrated twisted tape. Figure 10 describes test section pipe containing twisted tape with length of 300 mm pipe thickness of 3 mm as well as the bore diameter of 15 mm.

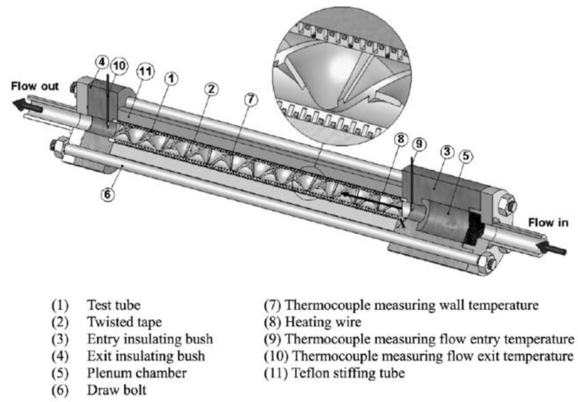

Figure 10. Experimental set up for the pipe with twisted tape [15]

In their work when twist ratio reduced the Fanning friction factor and Nu number rise. Moreover, augmentation of thermal performance attributed with tape increase in range from 250 to 480% at Re number range between 5000 and 25000. Level of heat transfer increase around 1.25–1.67 times. Figure 11 describes thermal heat transfer performance with Re number, the overall performance decreases as the Re number increases. No information results for laminar flow analysis have been provided in their work.

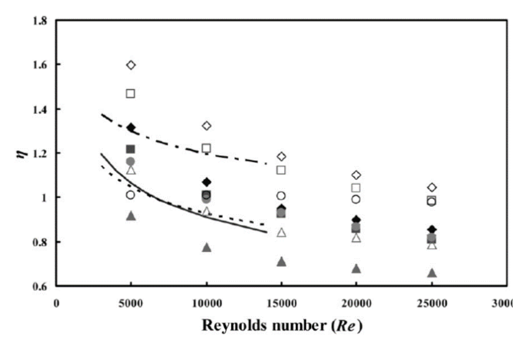

Figure 11. Thermal heat transfer performance with Re number [15]

Promvonge [16] carried out the effect of thermal augmentation using both twisted inserting tape and coil wire turbulators in circular pipe. Figure 12 depicts the experimental test section in their work.

Figure 12. Test pipe with coil wire and twisted inserts tape [16]

Outcomes noted that presence using both devices together can double rise in heat performance as compared to employ tape and coil wire alone. Also, with similar conditions with lower pitch ratios of twist and coil can provide thermal performance of about between 200 and 350%. Figure 13 illustrates thermal improvement variation factor with Re for changed turbulators parameters.

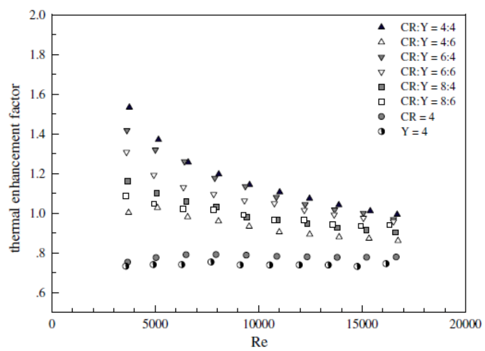

Figure 13. Thermal improvement variation factor against Re number [16]

Rahimi et al. [17] experimentally conducted characteristics of friction factor and thermal flow with twisted tapes as shown in Figure 14.

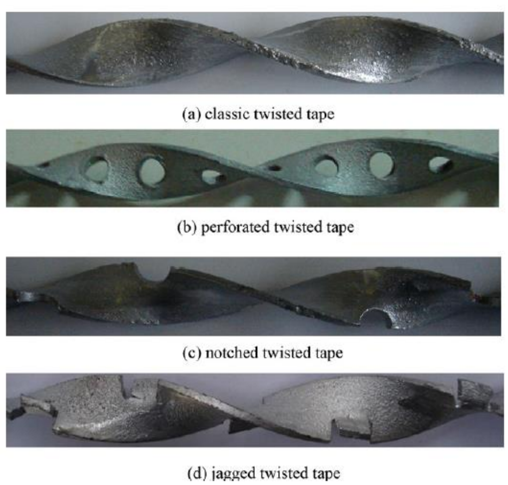

Figure 14. Used different twisted tapes configurations in tube [17]

Outcomes reveal that that heat performance and value of Nu number using tapes were larger than other ones. The percentage of Nu and performance were increased by 31% and 22%. The main reason for these higher values observations was due to more of fluid turbulence intensity occurrence near pipe wall. Bharadwaj et al. [18] carried out the influence of tape on heat performance in spirally grooved pipe experimentally. Figure 15 represents the grooved pipe with twisted tape, the experimental test section made from copper with Di = 14.8 mm, Do= 15.88 mm and 1040 mm length long. More investigation work need to provide good knowledge.

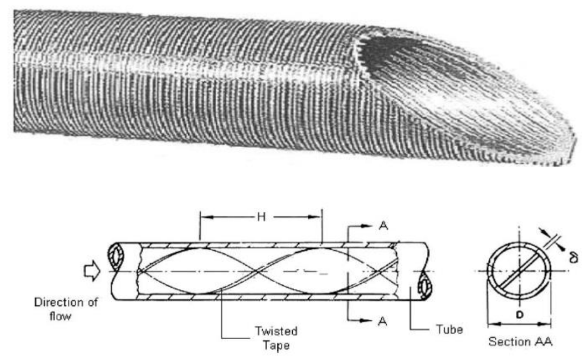

Figure 15. Grooved pipe with twisted tape model [18]

It was noticed that the anticlockwise and clockwise twist direction highly effected on the characteristics of thermo-hydraulic fluid within a pipe. Heat transfer performance was considerably increased in both laminar and turbulent flows with variety of Re numbers range as describes in Figure 16.

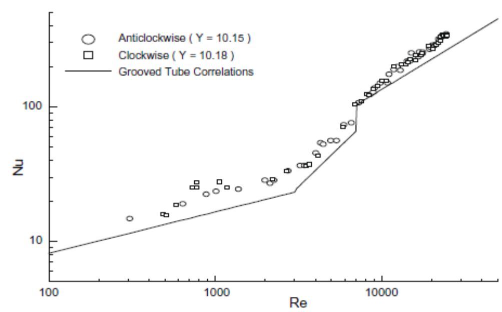

Figure 16. Nu number value for grooved pipe using inserting of tape [18]

Eiamsa-Ard et al. [19] stated the influence of insert a short twisted tape length on convective heat performance as shown in Figure 17. Using this type can introduce more swirling flow and produce highly mixing flow. Also, results found that full-length type was generate a highly swirling flow in whole pipe. Result for length ratios were increased values of friction factor by 21%, 15.3% and 10.5%, and heat performance around 14, 9.5 and 6.7% respectively. Figure 17 illustrates changing in thermal performance with different tapes configurations. Though, previous work has mainly just concentrated on consequence of tape on the thermal performance, also, no information regarding conducted impact of different geometrical investigations on thermal flow behaviour in their research.

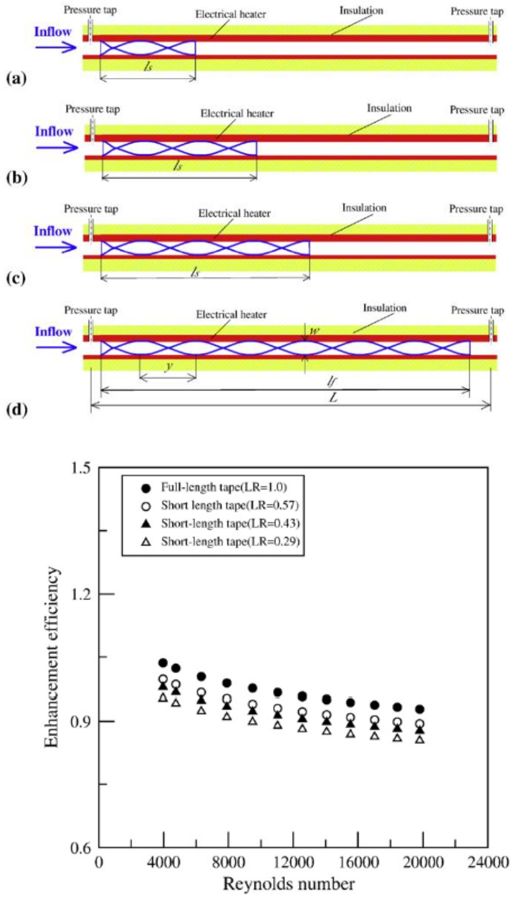

Figure 17. Inserts of short twisted tape length in a test section with various ratios of tape length and thermal performance variations [19]

Eiamsa-Ard and Promvonge [20-24] analysed characteristics of thermal performance round pipe with serrated inserting of twisted tapes. Figure 18 illustrates pipe test in experimental work, it was consisting of length of 1250 mm inlet and outlet pipe diameters were 47 and 50 mm with 1.5 mm thickness. Outcomes illustrate that the rate of heat transfer for (Nu number,) was rises as depth ratio increase. Nevertheless, it was reducing as width ratio increases. Rate of heat transfer was from 27% to 72% respectively. Moreover, average Nu with dual twisted tapes were increased up to 140%. Just the effect of width ratio has been investigated in their work.

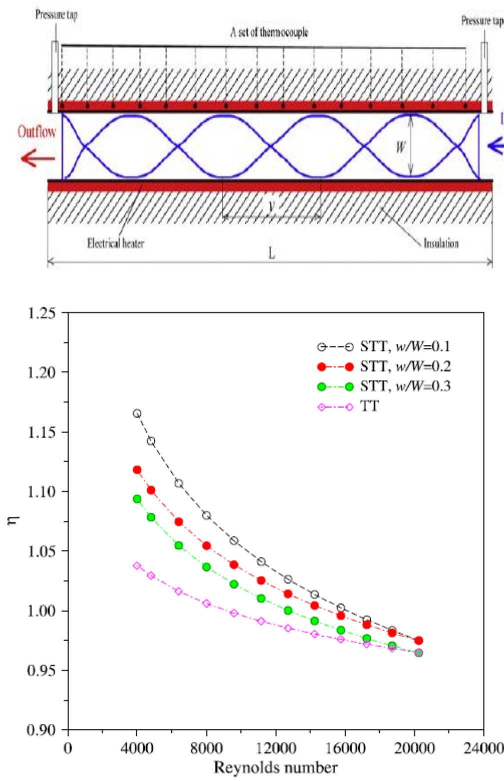

Figure 18. Test pipe section model and overall thermal performance for system [20]

Wongcharee and Eiamsa-Ard [25 -26] enhanced heat transfer using twisted tape and nanofluid type CuO/water. It was found that as nanofluid concentration and Re number increasing the Nu number rises. Nu numbers increase up to 12.8 times with compared to plain pipe. Moreover, higher thermal performance value was at concentration of CuO/water nanofluid equal to 0.7% as depicted in Figure 19.

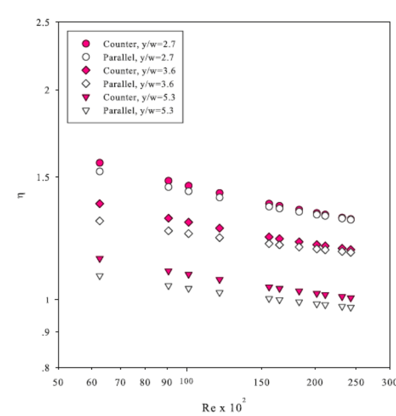

Figure 19. Thermal performance with different Re numbers [26]

Bhuiya et al [27 -29] studied characteristics of thermal performance in heat exchanger pipes with inserts type of triple twisted tape as represented in Figure 20.

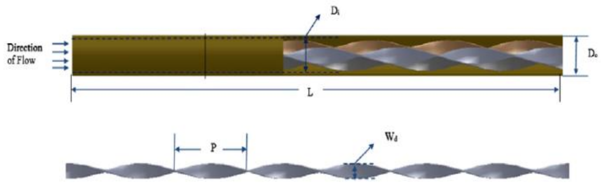

Figure 20. Pipe test model with twisted tape [27]

It was observed that using triple twisted tapes inside a pipe led to increase pressure and rate of thermal performance over the plain pipe. Also, both friction factor and Nusselt number were increased up to 4.2 and 3.85 times when compared to plain pipe. thermal performance was noticed around 1.44 as shown in Figure 21.

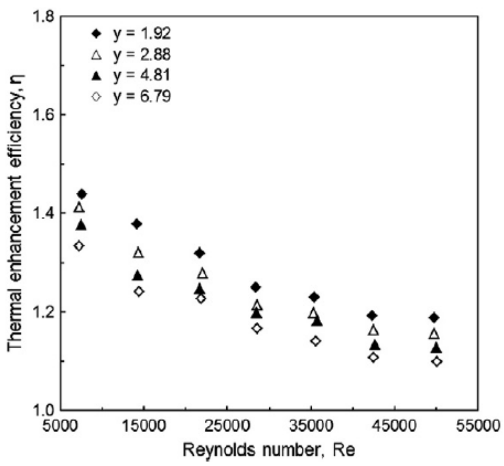

Figure 21. Thermal performance for the system [28]

Piriyarungrod et al. [30] investigated improvement of thermal by using tape type tapered. It was found that friction loss and improvement of heat performance were increased as both twist ratio and taper angle decreasing. In addition, as ratio of tape twist decreasing and taper angle increasing the tended of thermal performance increasing, the higher thermal performance value was equal to 1.05 as depicted in Figure 22. No information results have been provide concerning the impact of twisted geometrical on flow and thermal performance.

Chu et al. [31] researched enhancement of thermal flow using twisted type V-cut. It was noted that the fraction factor increases from 6.7 to 11.6%. Nu number increases as Re number increases. Meanwhile, maximin thermal performance was up to 1.10 with different twisted configurations as depicted in Figure 23.

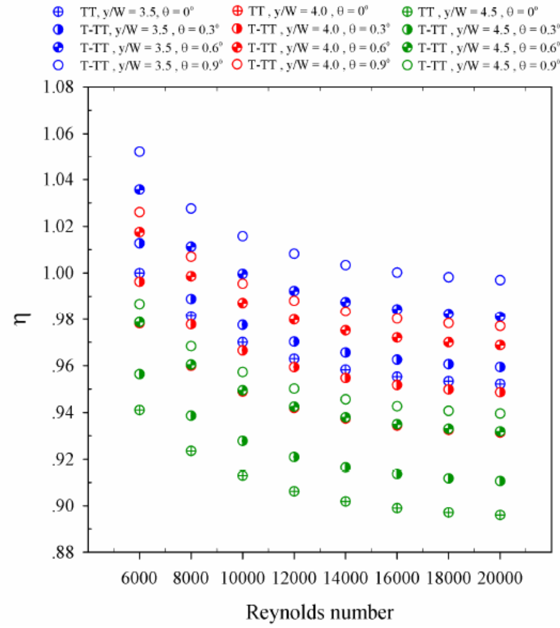

Figure 22. Thermal performance with different twist ratios and taper angles [31]

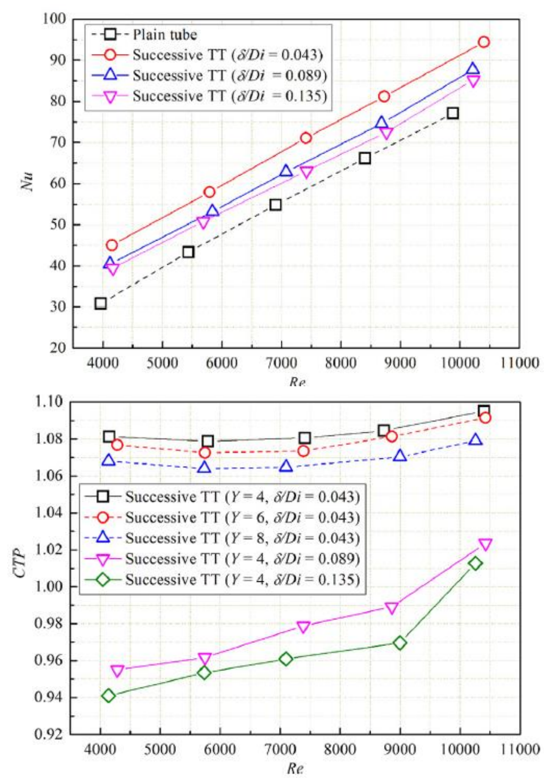

Figure 23. Variations in Nu and performance factor with Re number [39]

For more details Table 1 summarises all above studies with authors, year, twisted type and main results.

Table 1. Summarises experimental investigation in this review study

Authors	Year	Twisted tape	Working fluid	Results
Kumar and Prasad	2000	twisted tape inserted solar water heaters	water	They noticed that when using twisted insert the pressure drop augmented around 87 to 132% and heat transfer rise about 18 to 70%.
Liao and Xin	2000	twisted-tape in pipe	water	Stanton number was reduced from 15 to 18%. The ratio of overall performance was from 2.46 to 4.70.
Sarma et al.	2003	twisted-tape in pipe	water	using tapes inside the pipe can successfully treat the laminar flow regime for a high range for Prandtl number 3 < Pr < 400 due to increase the eddy viscosity.
Ray and Date	2003	twisted tape insert in duct	air	The friction factor in laminar flow was for Re from 406 to 1100 with minimum to maximum Nu number ratio changing from 1.02 and 1.17
Manglik and Bergles	2003	Twisted inserting tape	water	It was discussed enhancement of heat transfer by swirl induced characteristic features.
Naphon	2006	Twisted inserting tape	water	using tapes in pipes have significant effect on pressure and enhancing perfotmnace
Eiamsa-ard et al.	2006	regularly twisted tape	water	using tape construction type can efficiently enhance rate of heat transfer also increasing friction factor
Promvongeand Eiamsa-ard	2007	combined tape insert with conical ring	water	using twisted tape devices can improve values of Nusselt number about 4 to 10%. Also, improvement heat efficiency around 4 to 8%.
Chang et al.	2007	tube fitted with serrated twisted tape	water	augmentation of heat transfer attributed with twisted tape increase in range from 250 to 480% at Re number range between 5000 and 25 000. Level of heat transfer increase around 1.25–1.67 times.
Promvonge	2008	tape with wire coil	water	using tape and coil wire with lower pitch ratios of twist and coil can provide rate of performance of about from 200 to 350%.
Rahimi et al.	2009	modified inserting twisted tape	water	heat performance and value of Nu number using tapes were larger than other ones. The percentage of Nu and performance were increased by

				31% and 22%.
Bharadwaj et al.	2009	tape insert with spirally grooved	water	anticlockwise and clockwise twist direction highly effected on the characteristics of thermo-hydraulic fluid within a pipe.
Eiamsa-Ard et al.	2009	short-length twisted tape insert.	water	Using this type can introduce more swirling flow and produce highly mixing flow.
Eiamsa-Ard and Promvonge	2010	serrated tape insert	water	full-length type was generate a highly swirling flow in whole pipe.
Eiamsa-Ard et al.	2010	dual twisted tape elements	water	Outcomes noted that rate of performance for (Nu number,) was rises as depth ratio increase.
Eiamsa-Ard and Promvonge	2010	alternate twisted-inserting tape	water	as width ratio increases performance was from 27% to 72% respectively.
Eiamsa-ard et al.	2010	tape insert type peripherally	water	average Nu with dual twisted tapes were increased up to 140%.
Eiamsa-Ard et al.	2010	tape inserts combined with non-uniform coil wire	water	Using two types of tape inserts and coil wire were highly effect on thermal performance
Wongcharee and Eiamsa-Ard	2011	Tape insuring with alternate flow axis	nanofluid type CuO with water	as nanofluid concentration and Re number increasing the Nu number rises. Nu numbers increase up to 12.8 times with compared to plain pipe.
Wongcharee and Eiamsa-ard	2012	twisted tape equipped with corrugated pipe	nanofluid type CuO with water	Max. heat performance value was at concentration of CuO/water nanofluid equal to 0.7%
Bhuiya et al.	2013	tape inserts type triple twisted	water	using triple tapes twisted led to increase pressure and rate of performance over the plain pipe.
Bhuiya et al.	2013	perforated inserting tape	water	both f and Nu were increased up to 4.2 and 3.85 times when compared to plain pipe TPF was found to be 1.44
Bhuiya et al.	2014	double counter twisted tape inserts	water	Using this type of twisted tape can highly impact on flow and heat performance

1.2. Numerical Investigations

Guo et al. [32] numerically studied characteristics of f and performance for laminar flow with tape inserting. Figure 24 shows geometry model of pipe with twisted of centre cleared and short width tapes.

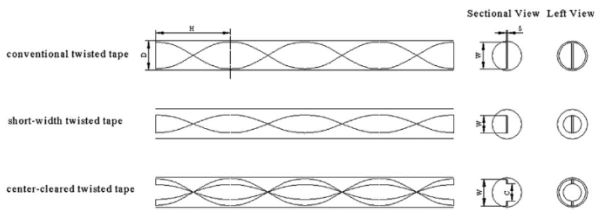

Figure 24. Geometry of pipe with twisted of centre cleared and short width tapes [32]

In their work, flow resistance can be changed using twisted type centre cleared and short width tapes. Characteristics of f and thermal flow features were various from each other. The factor of thermal performance in pipe with twisted tapes type center-cleared improved from 7 to 20%. Figure 25 depicts variations in velocity and temperature fields using both enhancement methods. Though, previous work has mainly just concentrated on impact of tape on flow performance, also, no information regarding reported influences of different geometrical investigations on flow behaviour in their research.

Mwesigye et al. [33] carried out entropy generation and heat in parabolic shape using inserts tape type wall tape as shown in Figure 26.

It was noticed that heat transfer performance considerable increase by 169%. Decrease in pipe absorber circumferential temperature change about 68% then thermal efficiency rise more than 10%. Also, as the Re number rises the width ratios reducing and twist ratio increasing. The higher entropy generation reduction was around 58%. Figure 27 describes the changing in velocity contours due to the effect of twisted type wall detached. No information results have been shown in their reported to investigate impact of various types of passive devices such as dimple or corrugation configurations.

Akbari et al. [34] investigated the fraction nanoparticles flow volume with aspecting ratio in the pipe using inserting tape the test pie was described in Figure 28.

Outcomes indicate that using solid nanoparticle in turbulent flow with higher volume fractions can enhance performance in pipe as compared in laminar fluid flow, Nu number amount was changed as twisted ratios change from 3.5 to 4. In addition, the changing in thermal boundary layer can sufficient increase heat transfer between fluid and tube.

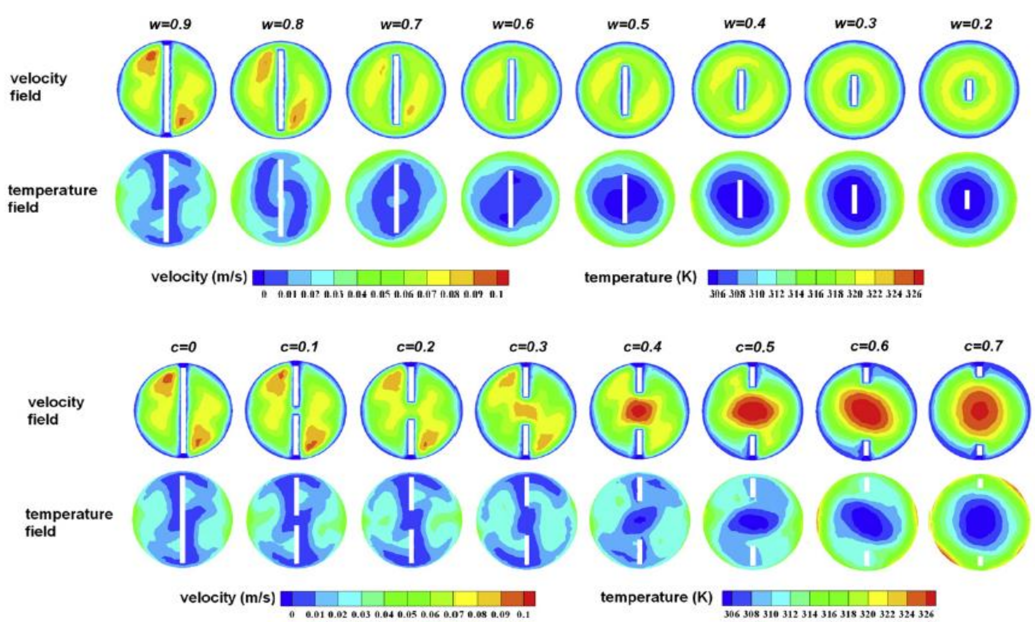

Figure 25. Changing in velocity and temperature for both methods [32]

Figure 29 represents the changing in temperature under different tape configurations. Though, previous work has mainly just concentrated on impact of tape on thermal performance.

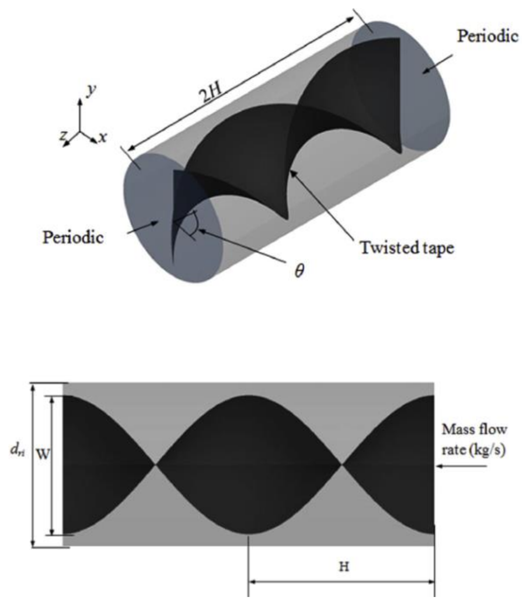

Figure 26. Pipe section with twisted type wall detached [33]

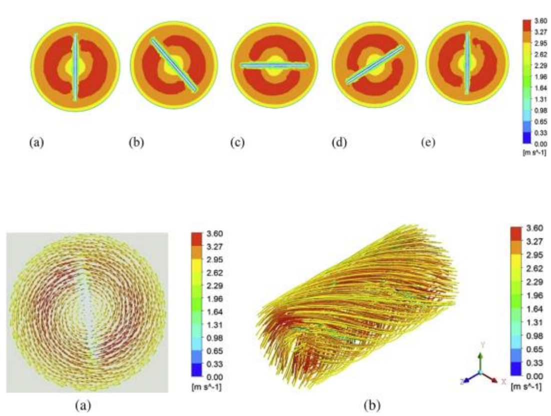

Figure 27. Velocity variations contours in pipe using the twisted tape [33]

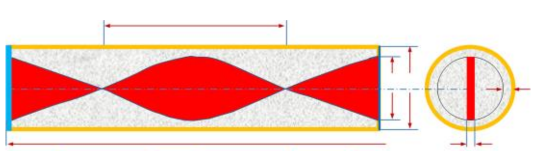

Figure 28. Pipe section with twisted tape schematic geometrics [34]

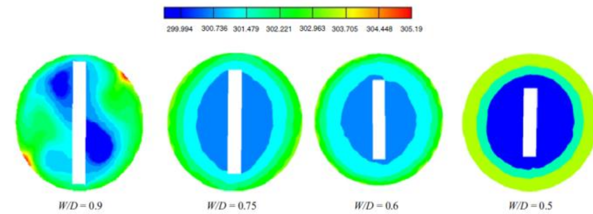

Figure 29. Changing in temperature field (K) with various tape parameters [34]

Hosseinnejad et al. [35] reported the influence of tape inserting in tubular heat exchanger. Outcomes showed that at constant Re number with tapes unaligned orientation and decreasing the twisted torsion ratio led to rises in Nu number. Twisted with aligned orientation has high performance enhancement. Resulted noted that more generated mixing, swirl and secondary flows when used this type of twisted tape as represented in Figure 30.

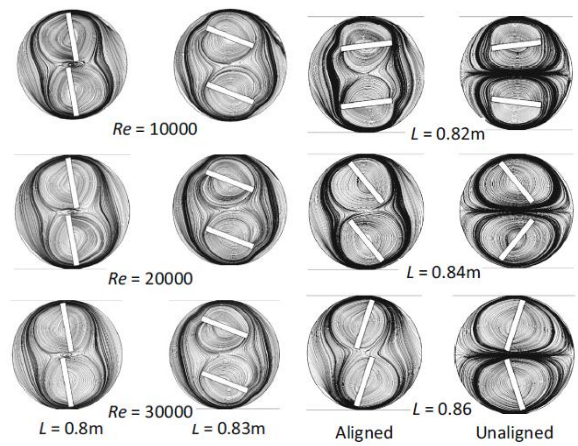

Figure 30. Velocity variations under different tapes geometrical configurations [35]

Al-Obaidi [36 -38] analysed flow behaviour and improvement of thermal heat in pipe. It is noted that a high mixing flow and secondary flow owing to twisted tape can cause more improvement in heat performance. Nevertheless, twisted cause extremely increases in pressure drop across the pipe. Furthermore, results display that twisted insertion can improve system thermal performance. Numerical observation found different changing in velocity field due to the twisted tape inserts inside a pipe as depicted in Figure 31.

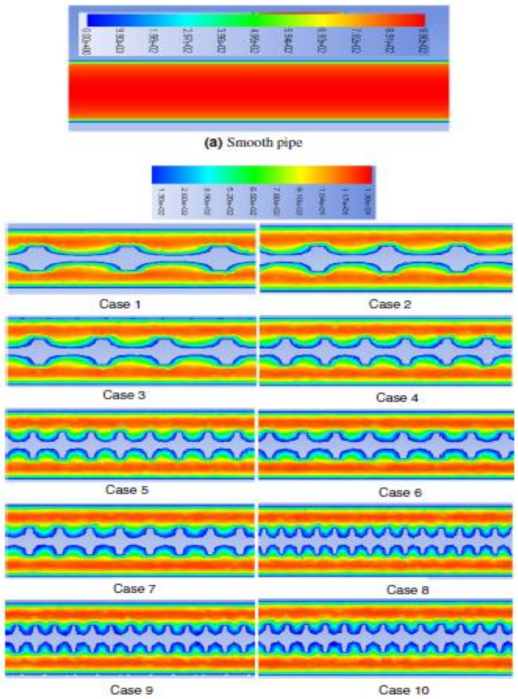

Figure 31. Velocity field with and without twisted tape in the pipe [36]

Meng et al. [39] numerical evaluated the turbulent flow characteristics and heat performance using twisted tape as shown in Figure 32.

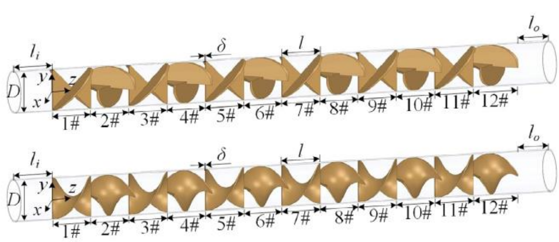

Figure 32. Pipe test section geometric constructions [39]

It was found that Nu rises as the Re increasing from 37 to 47%, Darcy friction factor rise about 82%. The factor of thermo-hydraulic performance values decreases as Re increasing. Numerical outcomes noted that the velocity and temperature fields were highly changed as the twisted tape geometrical parameters change as shown in Figure 33. In this analysis one twisted tape has been used to show the impact of this type on flow and thermal performance.

Samruaisin et al. [40] stated the impact of multiple-transverse insert type on enhancement of heat as shown in Figure 34.

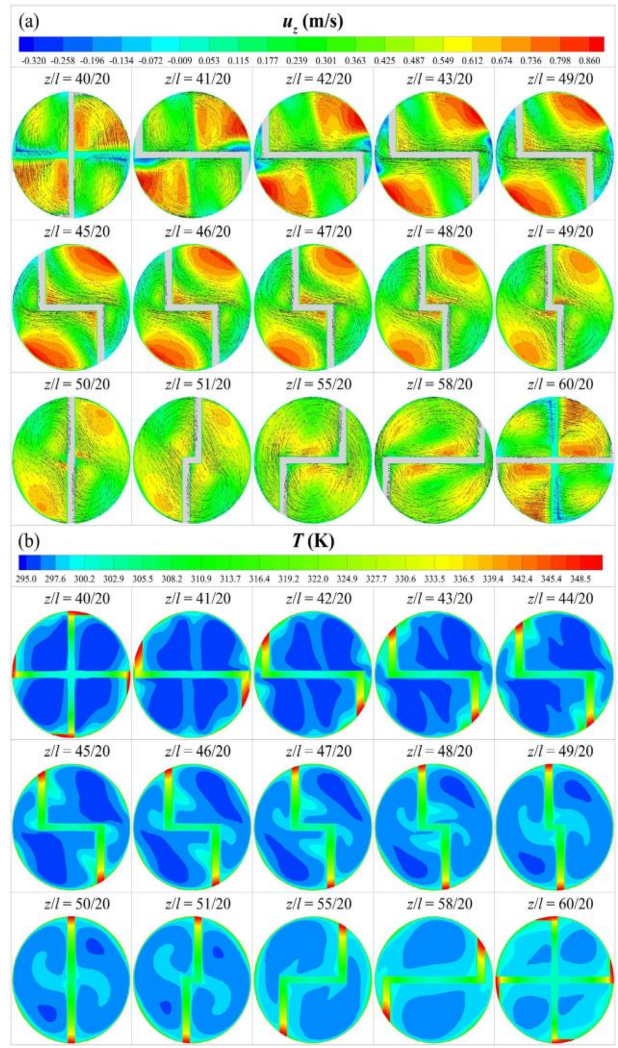

Figure 33. changing in velocity and temperature field due to tape geometrical [39] configurations

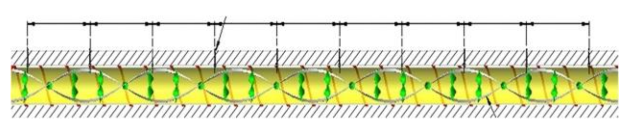

Figure 34. Test copper pipe with multiple transverse inserting twisted tape [40]

The outcomes presented that the twisted baffles type has more effect on friction factors, rate of thermal performance improvement. Tape inserts can cause more swirl flow and secondary flow and leads to enhance heat in pipe. At a Re of 6000 the system has higher thermal performance (η) of 1.3 as depicted in Figure 35.

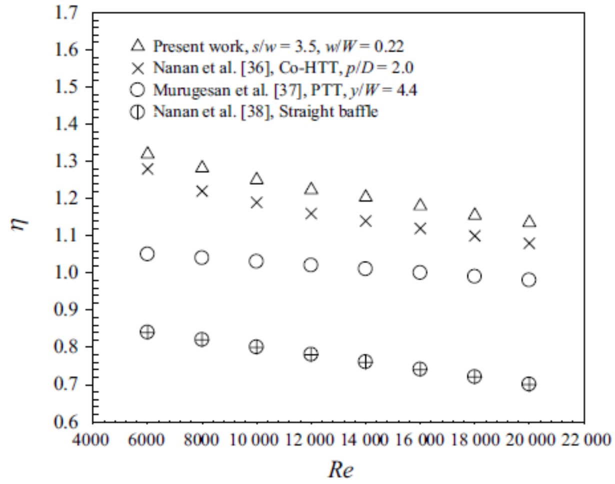

Figure 35. Overall system thermal performance with Re number [40]

Outokesh et al. [41] evaluated the impact of using twisted tape by curved profile on flow and enhancement of heat transfer. Outcomes revealed that the twisted tape with curved of 7 mm has about 35% thermal performance more than base case. Also, as the pitch ratio from 5 to 15 have higher thermal performance as compared to normal tube as represented in Figure 36.

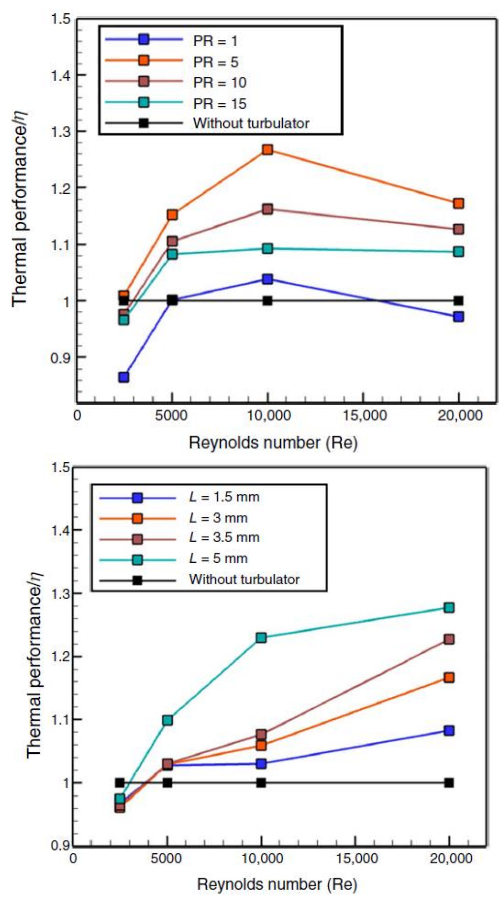

Figure 36. Thermal performance with different twisted configurations [41]

He et al. [42] stated impact of tape by using nanofluid as a working liquid on characteristics of flow and heat transfer. It was notice that the higher performance efficiency in a pipe using just one twisted tape was around 2.18 at Re of 36,000. Whereas, using two twisted tapes with similar conditions, it was about 2.04. Therefore, based on their analysis using one tape was more effective to enhance the thermal performance. Kurnia et al. [43] studied using twisted tape in helical tube under laminar flow. It was observed that applying twisted tape in this type of pipes can improve heat performance about more than 4 times when compared to normal pipe, with higher pressure drop. Moreover, lower twisted tape ratio can increase the enhancement of heat transfer due to it generate more secondary flow. Furthermore, with low Pr the ratio of heat performance enhancement rises when the Re was raised. Figure 37 depicts the change in flow pattern due to the use of twisted tape in pipe.

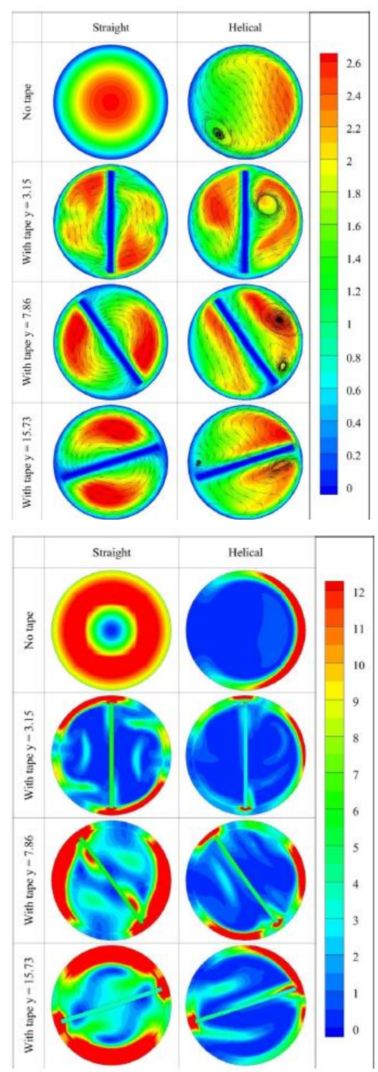

Figure 37. Velocity and entropy generation variations under different twisted parameters [43]

Liuet al. [44] analysed the internal flow and heat enhanced in pipe by segmented tape. It is indicated that tape configuration parameters such as twisted ratio plays important role in enhancement of heat performance. Whereas, the length twisted ratio also has significant effect. Outcomes depicted that using segmented tape could rise overall thermal performance by around 24% as well as increases the friction factor (f) more than 235%. Moreover, the improvement in pipe was 2.8 times more than normal one. Figure 38 describes how the swirl flow generate due to the effect of twisted tape.

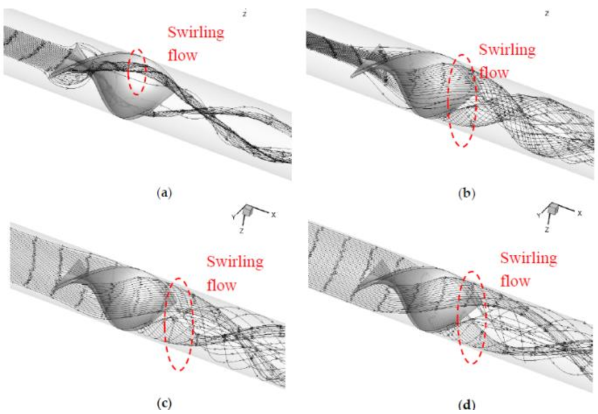

Figure 38. Flow pattern and generation of swirl flow [44]

Table 2 summarise all above studies with main results.

2. Conclusions

In current years, improvement techniques for twisted tape inserts were wieldy used to obtain better thermal performance in both turbulent and laminar flows. Passive procedures were extensively used in different domestics and industries for their easy setup, low maintenance requirements and cost saving. Based on above review investigations, it can be found that:

1. Improvement of thermal happens owing to decrease in pipe cross area, leads to rise in mixing flow, turbulence flow and then the rise in swirl flow through different kinds of twisted inserts. Studies found that twisted tape geometrical parameters can considerably impact on enhancement of heat transfer.

2. Twist direction was significant parameter on flow behaviour inside the pipe. Most of investigations revealed that the important role by using inserts were to increase the mixing flow and turbulence intensity. Some studies have employed perforated twisted and regularly spaced tapes the outcomes found that using perforation type had overall thermal performance more than regularly spaced. Investigations noted that for regularly spaced tape it was better to utilise full length tape.

3. The Nu increases with Re number increases and the factor of thermal performance was decreased with Re number increases. As air was employed as a working flow the twisted insert was not performed well. Due to the high liquid density for nanofluid and water were utilised as working flow. the twisted insert where performs well.

4. Consequently, using liquids as a working fluid with twisted tape cam produced more swirl flow and hence that led to increase in the Thermal performance factor (TPF).

5. Based on above investigations using variety of inserts twisted tape were effective technique to enhance the thermal flow in heat exchanger pipes. Changing in twist geometrical configurations tends to rise the pressure losses. Type of V-cut twisted can provide higher Nu number and hydraulic thermal heat performance when compared with plain pipe (smooth). Additionally, the effect of ratio of depth twisted was more dominant than the ratio of width twisted as compared other parameters. Furthermore, using any twisted tape type can leads to improvement of thermal hydraulic performance.

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Table 1. Listed numerical investigations

Authors	Year	Twisted tape	Working fluid	Results
Guo et al.	2011	tape type center cleared	water	The thermal performance in pipe with twisted tapes type center-cleared improved from 7 to 20%.
Mwesigye et al..	2016	tape wall- twisted inserts	water	performance considerable increase by 169%. Decrease in pipe absorber circumferential temperature change about 68% then thermal efficiency rise more than 10%.
Akbari et al.	2017	twisted tape	water	using solid nanoparticle in turbulent flow with higher volume fractions can enhance heat transfer in the pipe
Hosseinnejad et al.	2019	twisted tape	water	Twisted with aligned orientation has high performance enhancement. Resulted noted that more generated mixing, swirl and secondary flows when used this type of twisted tape
Al-Obaidi and Sharif	2020	Different twisted tape	water	It was observed that a high mixing flow and secondary flow owing to twisted tape can cause more improvement in heat performance.
Al-Obaidi	2020	dimple with internal twisted-tape	water	twisted cause extremely increases in pressure drop across the pipe. Furthermore, results display that twisted insertion can improve system thermal performance.
Meng et al.	2020	twisted tape	water	Nu rises as the Re increasing from 37 to 47%, Darcy friction factor rise about 82%. The factor of thermo-hydraulic performance values decreases as Re increasing.
Samruaisin et al.	2020	multiple-transverse - baffles	water	The tape inserts can cause more swirl flow and secondary flow and that leads to enhance heat in pipe. At a Re of 6000 the system has higher thermal performance (η) of 1.3
Outokesh et al.	2020	twisted tape with curved profile	water	Outcomes revealed that the twisted tape with curved of 7 mm has about 35% thermal performance more than base case.

He et al.	2020	twisted-tape	water	the higher performance efficiency in a pipe using just one twisted tape was around 2.18 at Re of 36,000.
Kurnia et al.	2020	helical tube with twisted tape	water	twisted tape in this type of pipes can improve heat performance about more than 4 times when compared to normal pipe
Liu et al.	2020	segmented twisted tape	water	that using segmented tape could rise overall thermal performance by around 24% as well as increases the friction factor (f) more than 235%.

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