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Review Research

AUGMENTATION HEAT TRANSFER IN A CIRCULAR TUBE USING TWISTED - TAPE INSERTS: A REVIEW

Sahira H. Ibrahim*, Zianab H. Naji

Mechanical Engineering Department, University of Technology, Alsinaa Street 52, 10066 Baghdad, Iraq

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Abstract: Heat transfer enhancement is the process of increasing the heat-transfer coefficient, which enhances the system's performance. Enhancing heat transfer is a major problem for saving energy and is also beneficial economically. Many passive devices are used inside tubes to improve heat transfer such as twisted tape inserts, rough parts, extended surfaces, additives for liquids wire plugs, etc. This research reviewed one of the most effective passive devices which are twisted tape inserts. Since it has many advantages such as simple fabrication, simple operation, and ease of maintenance. The twisted tape inserts generated swirl flow and vortex inside the tube. Therefore, the internal convective heat transfer process is significantly improved. The current research article provides an overview of different twisting tape inserts that can improve heat transfer rates. By reducing boundary layer thickness near tube walls. Which lead to reduce the size and cost of many industrial applications, including heat exchangers, refrigeration systems, air conditioners, reactors, thermal power plants, spacecraft, and automobiles. A summary of previous experimental and numerical studies is presented as well. The primary results indicated that the twisted tape inserts are demonstrated to be efficient in enhancing heat transfer inside the tube for laminar and turbulent flow. But during a turbulent flow, twisted tapes increased pressure loss more than laminar flow because of flow obstruction.

Keywords: *Friction losses; factor of performance; heat transfer; tape inserts; twisted strip*

1. Introduction

Improving heat transfer has become one of the most important goals in today's engineering business. The cost and size of industrial equipment including heat exchangers, refrigeration systems, air conditioners, and reactors were reduced using heat transfer argumentation techniques. Heat transfer enhancement techniques are generally divided into three categories: active, passive, and compound approaches. The active approach improves heat transfer by using an external source of power. It's indeed actually rather difficult from a design perspective. As a result of the need for external power, it is only somewhat useful. While for Passive methods, there is no external power supplied. A hybrid technique called the compound heat transfer method uses both active and passive mechanisms. That technique is highly difficult and only has a few uses. So, the most common passive method to improve heat transfer in tubes is twisted tapes inserts since twisted tape generated axial flow, which recirculates due to increased fluid mixing and a consequent significant reduction in boundary layer thickness or improved heat transfer in turbulent and laminar flow, disrupting thermal boundary layers and viscous sub layers. Twisted straps can be easily attached to tubular heat

*Corresponding Author: 20063@uotechnology.edu.iq

exchangers and are very inexpensive Dewan A et al [1] ; Eiamsa-ard S et al. [2] as shown in Fig.1. The purpose of this study was to review the many experimental and analytical studies conducted by researchers on various topics.

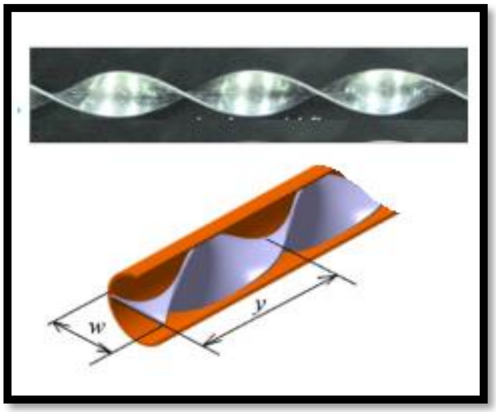


Figure. 1 shows plain Twisting tape inserts

2. Thermal performance Factor (PF)

A frequently employed metric to assess the effectiveness of various heat transfer augmentation ways is the Factor of thermal Performance (PF). It is described as the proportion of increasing heat transfer to increasing skin friction coefficient for a specified Reynolds number, at constant pumping power.

$$PF = \left(\frac{Nu_{tw}}{Nu_p}\right) \Big/ \left(\frac{F_{tw}}{F_p}\right)^{1/3} \quad (1)$$

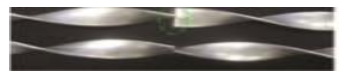
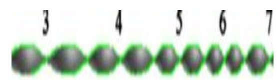
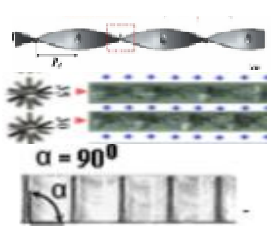
While Nu_p and F_P represent the plain tube values of the Nusselt number and friction factor, respectively Hwang SD et al. [3].

Nu_{tw} and F_{tw} represent the estimated values for the Nusselt number and friction factor for tubes with twisting tape inserts, respectively.

3. Effect of Twisting Ratio and Twisting Angle

Researchers have performed numerous experiments on the heat, transfer, and pressure losses characteristics of heat transfer in tape eddy flows to find the best design of tapes, which gives the least amount of friction losses in both laminar and turbulent flow for various twisting strips such as Dhumal AH et al. [4]; Chavan H V et al.[5]; and Ponnada S et al. [6]. Table.1 shows various configurations of the Twisting tape inserts. Jassim NA et al. [7] Experimented to examine the impact of twisting tape inserts in laminar tube flow heat exchangers with various pitch and twisting ratios. In comparison to plain tubes, the rate of heat transfer increased for tubes with twisted - tape from (50.54% to 52.22%) at a twisting ratio of 5, (52.42% to 55.15%) at a twisting ratio of 4.5, and (52.41% to 56.98%) at a twisting ratio. In a concentric tube heat exchanger Introduction I [8]; Meyer JP et al.[9] conducted an experimental examination utilizing twisting tapes with a ratio of (5, 7) Nusselt number increases progressively from 920 to 6700, and it is 12-15 percent higher than plain one, due to the increasing swirl degree of flow. For copper pipe with tape inserts and a square-edged intake.

Table 1. Twisted- tape configurations and shape

Sketches No	Reference	Type	sketches Configuration	Description
1	Chavan H V et al.[5]	normal Twisted tape or Typical twisted tape(TTT)		Tube and tape have the same length
2	Eiamsa-ard S et al. [15]	Short- length tape(ST)		Tape has a length shorter than the tube length
3	Tabatabaeikia S et al.[34]	alternate-axes tape (ATT)		The twisted tapes with opposite axes attaching
4	Li P et al.[51]	vary pitches twisted tape		The pitches twisted tape Changed in the axial direction
5	Bhuiya MMK et al. [40,41]; Nanan K et al. [46]	Multiple twisted tapes		Multi-twisting tapes are bundled together and utilized in a single tube.
6	Singh Suri AR et al.[39]; Kumar A [38]; Chavan H V et al.[28] ; Kumar B [31]; Lin ZM et al. [50]	Twisted tapes with Perforated, holes and cuts	perforated[22,43,41], and holes],[31,21]    cuts[22,47]	perforations, holes, and cuts in twisting tape to increase turbulence
7	Gugulothu SK [33]; Eiamsa-ard S et al. [36]; Tamna S et al. [43]	Jagged Twisted tape with attached, winglet, and baffles	winglet [36,29]  baffle[27] 	Baffles, wings, and ribs are attached to the twisted tape to get more enhancement
8	Chang SW& Guo MH[35]; Ananth J& Jaisankar S [25]	Tapes with different surface modifications Rib, edge, dimpled		Used dimpled surface material for tape fabrication

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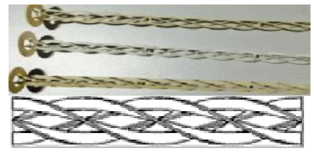
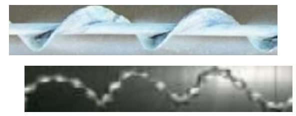
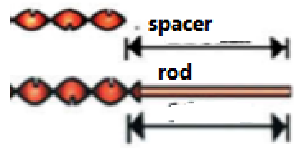
9	He Y et al.[42]; Li P et al.[51]	Hollow twisting tapes that cross each other		Twisted tape production requires the employment of many tapes.
10	Yongsiri K et al. [21]; Sivashanmugam P et al . [22]; Eiamsa-ard S et al.[20]	helically twisted tape (HTT)		The twisted tapes are shaped left–right helical
11	Gnanaraj D& Vijayan R [23]; Ananth J& Jaisankar S. [24,25]	With a bar and spacers, twisting tape		To gain greater improvement, a spacer and rod were used.

Piriyarungrod N et al. [10] Looked at the impact of curved twisted- tapes with four angles of (0.0, 0.3, 0.6, and 0.9) degrees, for four various ratios (3.5, 4.0, and 4.5) on heat transfer. The results that as the taper angle and twist ratio decreased, heat transfer enhancement and friction loss increased, with the tube with a taper angle of 0.9 and the twisting ratio of 3.5 supplying the superior (PF) of 1.05 at Reynolds number of 6000. Tusar M et al. [11] Estimated the impact of the tape twisting of heat transfer strips for airflow through a pipe with constant wall heat flux Reynolds numbers ranging from 3642 to 21857. The study's findings demonstrate that, at lower Reynolds numbers and twist ratios, twisting tapes improve heat transfer. The highest value is approximately 1.16 times at Re-5000, indicating that it is greater than a plain tube. Durga P V and Gupta AVSSKS [12] carried out an experimental investigation of the heat transfer of a Nanofluid inside a twisted tape insert-equipped U-tube heat exchanger. Under various operating conditions with volume fractions from 0.01% to 0.03% and twist ratios (5 – 20), the heat-transfer coefficients and related

friction factors of the heat exchangers are computed with Reynolds numbers range between 3000 to 30,000. With twisted tape inserts the Nusselt number of tube with 0.03% concentrations of Nano-fluid is increased by 31.28%, while friction factor by 1.23 times when compared with water flow. Sundar LS et al. [13] Fe O3-Oil Nanofluid flow characteristics and heat transmission were evaluated experimentally at the mass flow of (0.04 kg/s - 0.208 kg/s), fractions of (0.05% - 0.5%), and Prandtl numbers (440 to 2534). Based on the results, the Nusselt number for the 0.5% Nano fluid rate of 0.0416 kg/s and 0.208 kg/s, respectively, is raised by 8.94% and 13.48% compared to the pure fluid. For the rate of 0.208 kg/s and 0.5 vol. % Nanofluid, the friction factor consequence is 1.21 times more than the pure fluid.

4. Effect of Tape Length and Number

Several researchers Yadav AS [14]; Eiamsa-ard S et al. [15] included conducted studies to determine how the length of the twisted taps affected performance.

Yadav AS [14] Looked into how pressure loss and heat exchange in double-pipe U -bend heat exchangers are affected by half-length twisting tape inserts. Comparing half-length twisted tape inserts to a standard heat exchanger, heat transfer rates are increased by about 40%. Half-length tape inserts outperform simple heat exchangers in terms of heat transfer while the mass flow rate is the same, however smooth tubes outperform half-length twisted tapes when the pressure drops. Standard heat exchangers outperform half-length twisting tape thermally by 1.3 to 1.5 times. A fading swirl turbulent, flow created by short twisted tapes positioned in the test section's entrance with three distinct twisting ratios (3, 4, and 5) was studied analytically and empirically by Eiamsa-ard S, and Seemawute P [15]. The results demonstrate that short tape inserts have inferior thermal performance over the Reynolds number range of (5200-15,300) and at the same twist ratios as full-length tape. Gugulothu SK. [16] Analyzed a ribbed tube for various twisted tape inserts using computational fluid dynamics in the presence of uniform heat flux, in a turbulent zone, simulations have been performed by using the ANSYS Fluent (17.1). Full-length twisted tape performs better overall than half-period tape in terms of heat transfer, friction factor, and (PF). Zhu JD, and Chen H [17] recorded according to the findings, as compared to single tape inserts, the triple twisting tape can enhance resistance by 8.7–6 times while increasing heat transfer ability by 1.8–4.5 times. Promthaisong P et al. [18] Reported a study into the thermal behavior of spiraling corrugated tubes with five-channel twisting tape. Equations were used to analyze how dual twisted tape inserts with different pitches affected turbulent heat transfer and pressure loss. Aghaie A et al. [19] Used ANSYS Fluent (16.1) to study heat transfer inside a circular tube with Nanofluid under constant heat flux. For all the situations under investigation, the relative Nusselt number decreases as the Reynolds amount increases.

5. Effect of Tape Surface Shape

Experimental research on the helically twisted tape was done by Eiamsa-ard S. et al. [20]; Yongsiri K [21] evaluated three twisting ratios of helical tape of 2, 2.5, and pitch ratios of (1, 1.5, and 2), with Reynolds numbers ranging from 6000 to 20,000. As the tape twisting ratio and helical pitch ratio decreased, the heat transfer coefficient, and friction, factor increased. At Reynolds number 6000 the thermal performance exhibits the reverse pattern, and a maximum (PF) of 1.29 is attained with a twisting ratio of 3 and a spiral pitch ratio of 2. Sivashanmugam P, and Nagarajan PK [22] Examined helical screw inserts of various lengths with various twisting ratios, as well as a full-length helical screw component with various twist ratios. According to the research, right-left helical screw inserts enhance heat transmission rate more than straight helical twists do for a given twist ratio, maximum performance ratios of 2.85 and 2.97 were obtained from the findings of performance analysis, respectively. Many researchers, including Gnanaraj D et al.[23]; Ananth J et al.[24]; Ananth J et al.[25]; Hajare O et al.[26]; Gawande KR et al.[27];and Chavan H V et al.[28] were investigated twisted tape inserts with Variety-shaped holes, including rectangular, elliptical, and square holes, and twisting tape with a rod and spacer. Another researcher looked at twisting tapes with cuts like those in Hasanpour A et al.[29]; Sarviya RM and Fuskele V [30]; Kumar B et al. [31]. Additionally, several scientists, including Abeens M et al.[32]; Gugulothu SK [33]; Tabatabaeikia S et al.[34]; Chang SW and Guo MH [35] explored twisted tape inserts with stripes and ribs or baffled, and Eiamsa-ard S et al. [36]; Uzagare N and Bansod P [37] studied twisted tapes with wings. Kumar A [38]; Singh Suri AR et al. [39]; Bhuiya MMK et al. [40,41,44]; He Y et al. [42]; and Tamna S et al. [43] investigated the impact of cross-hollow twisting tape and multi-twisted tapes on the improvement of thermohydraulic efficiency. Many other researchers like Salam B et al.[45]; Nanan K et al.[46]; Patil S V et al. [47]; Eiamsa-ard S et al. [48]; and Patel MJ et al.[49] were investigated by compound twisted tape and other heat transfer enhancement technologies. Lin ZM et al. [50] Created a computer model to simulate turbulent flow through a heat exchanger tube with two V-cut twisting inserts. For the Reynolds number range of 5000 -15000 and cut ratios (0. 6-1. 8), the results indicated an improvement in the thermal performance, Nusselt number due to greater vortex flow in the V-cuts, which disrupts thermal viscous layers more effectively and speeds up heat transfer. Li P et al. [51] unique idea known as the centrally hollow thin twisted tape was examined in laminar flow conditions. When compared to conventional twisted tape, the new type of tape performs overall heat transfer 28.1 percent better. According to the US National Institute of Standards and Technology, the cross-hollow twisted tape is suitable for laminar flow situations. Saysroy A, and Eiamsa-ard S. [52] Simulated three dimension tube flows with square-cutout twisted tapes at constant heat flux-wall. Kumar A et al. [53] Twisted tape was used to evaluate the heat transfer characteristics in a heat exchanger with two pipes. The average Nusselt number index rose by 85% and 34%, respectively, while the pressure decrease is larger for twisted tape with holes. Mashoofi N et al. [54] Used numerical techniques to decrease pressure loss and increase a heat transfer performance factor for axial perforated twisting tape with various hole diameters. Zheng L et al. [55] examined numerically by using CFX15.0 the influence of dimpled tape on heat transmission of Nanofluid with different constrictions the result indicated that The usage of dimples increases convective heat transfer by 25.53 % when compared to smooth tape, and the maximum rise is 58.96 %. Eiamsa-ard S et al . [56] Investigated different materials: twist ratio, tube dimple angles, and TiO2-water Nano fluid constriction. According to the experimental findings, twisted tapes and dimpled tubes produced higher heat transfer rates than dimpled tubes alone. The results also showed that the dimple angle, twist ratio, and concentration of the TiO2-water Nano fluid had a significant impact on thermo-hydraulic performance. The greatest increase in heat transfer was produced with a dimple angle of 45 degrees. With a declining twist ratio and rising Nano fluid concentration, the Nusselt number increased. The maximum thermo-hydraulic performance of 1.258 over the studied range was attained by using Nano fluid with = 0.15

Saysroy A, and Eiamsa-ard S. [57] Compared numerically the heat transfer and thermal performance of square cut twisted tapes placed into a circular tube to typically twisted tapes inserted into the same tube. The influence of square cut twisted-tape geometries. The primary findings are that when the perforated width-to-tape width ratio and perforated length-to-tape width ratio decrease, heat transfer and pressure loss increase, whereas the thermal performance factor increases as perforated width-to-tape width ratios increase.

Also, several researchers such as Abeens M et al. [58]; and Salman SD et al. [59] studied twisted tape inserts with strips and baffled. Table.2 shows the summary of the literature work on the thermal-hydraulic performance of the twisted tape inserts.

Table 2. Summary of literature for thermo hydraulic performance of twisted-tapes

NO	Author	Research type	Condition	Tape dimensions	Observation and results
1	Dhumal et al. [4]	Experimental	Re=20000-40000 Water	Typical twisted tape(TTT) y/w = 4.2, 5.3,6.4	Nusselt Number reduced as the twist ratio increased, but the pressure drop lowers as well.
2	Chavan et al.[5]	Experimental	Re=5000-25000 Air	Typical twisted tape(TTT) y/w =3.7, 3.8,4.2	For twisted tape inserts with twist ratios of 3.78, 3.89, and 4.22, the Nusselt number and friction factor increased.
3	Sivashanmugam [6]	Experimental	Re=200-3000 y/w=2.93–4.89 Water	equal-length right-to-left screw inserts	For a specific twist ratio, R-L screw inserts improve the heat transfer more than regular screw twists d. The highest performance ratios of 2.85 and 2.97 were achieved for 300 R and 300 L type inserts, and 400 R and 200 L type inserts, respectively.
4	Jassim et al. [7]	Experimental	Re=300-1100 Water	Typical twisted tape(TTT) y/w=3.5,4,4.5,5	When compared to a simple tube, there is a rise in heat transfer rates that vary from (50.54%- to 52.22%) at the twisted tape of 5, (52.42% – 55.15%) at the twisting of 4.5, and (52.41% -to 56.98%) at 3.5. .
5	Meyer & Abolarin [9]	Experimental	Re= 400 - 11400 Water	Typical twisted tape(TTT) y/w= 3, 4, 5	When both the twist ratio and the Reynolds number were constant, it was discovered that increasing the heat flux reduced the friction factor.
6	Piriyarungrod [10]	Experimental	Re= 6000 - 20000 Air	Tapered twisted tape with θ = 0.0, 0.3, 0.6, 0.9 y/W=3.5, 4.0,4.5	At Reynolds number 6000 tapered twisted tape, the taper angle of 0.9° and twisting ratio of 3.5 provided the greatest thermal performance efficiency of 1.05
7	Tusar M et al.[11]	Experimental	ANSYS Fluent (SST) k-ω Re= 3642 - 21857 Air	Typical twisted tape(TTT) inserts y/w= 2.93, 3.91,7.6	Nusselt values, friction factors, and TPF are raised by 20% -to -62% and 185% -to -245 percent, and 0.9 - 1.2 respectively, with twist ratios of 3.46. But At a twist ratio of 7.6, it was noted that grew by 10 to 30 percent, 128% -to 183%, and (0.95-1.05), respectively.
8	Durga Prasad P V [12]	Experimental	(3000 < Re < 30000) Water-Al2O3 concentration range of 0.01, and 0.03	twisted-tape inserts with y/w=5,20	For vol. 0.03 percent, there is a 31.28% rise in the Nusselt number of complete pipes. When compared to water, also has however .1.23 times more friction
9	Continuous Sundar et	Experimental	Re=50-350	Typical twist-	The Nusselt value is improved by

	al. [13]		Pr= (440 to 2534) Gr= (500 to 3000) Fe3O4+ oil	tape (y/w = 5, 10 and 15).	23.86%, for the 0.5% Nano fluid when applying twisted tape inserts of 5. As compared to the basic fluid, the impact of .friction factor cost is 1.44 times higher.
10	Yadav [14]	Experimental	Turbulent u-tube oil mass flow rate 4, 8, 12,18,24,30	Half-length twisted tape y/w=7 (2-piece)	When compared to a simple heat exchanger, half-length twisted tape inserts enhance the heat transfer coefficient by 40%, and smooth tube heat transfer performance is superior to half-length twisted tape based on unit pressure drop. Plain heat exchangers' thermal performance exceeds half-length twisted tape by 1.3-1.5 times.
11	Eiamsa-ard & Seemawute [15]	Experimental &numerical l	Re=5200-15300 Water	Short-tape (STT) y/w=3, 4, 5	The full-length tape ones with y/w=4 and 5 gave higher TPF, because of the large improvement in heat transmission compared .to the rise in friction factor.
12	Gugulothu SK et al. [16]	Numerical	ANSYS Fluent Turbulent Air Re= 25000 - 110000	Full &half length twisted tape y/w=0.14, 0.27 & 0.36	When compared to half-length twisted tape. The numerical results demonstrate that full-length twisted tape has greater heat transfer, friction factor, and enhancement efficiency, in the range of Reynolds numbers 25000 to 110000.
13	Zhu JD et al.[17]	Numerical	ANSYS K-ε turbulent model Air Re= 2000-20000	Double, triple twisted tapes	The tube with triples twisted tapes can enhance the heat transfer ability by 1.8-4.5 times and the resistance can be increased by 8.7-6 times compared with the single tape and14.4-9.4 times compared with the double tape inserts.
14	Pitak Promthaisong[18]	Numerical	ANSYS Fluent Realizable k-ε Air Re= 5000-15000	Five channel twisted tape y/w= 0.10,0.20,0.30,0.40,0.44	Heat transfer enhancement was about 1.34-3.22 times than the plain tube and pressure loss was about 2.82-21.34 times. The thermal performance factor for a spiral corrugated tube without twisted tape, combined with five-channel twisted tape gives the maximum value about 1.16 times at Re-5000, indicating higher performance over the smooth tube.
15	Aghaie A et al. [19]	Numerical	ANSYS Fluent K -ε (RNG) Al2O3/water Re 5000 - 20000	Single &double twisted tape y/w=2,3,4	When dual twisted tapes are inserted, the increase in heat transfer is greater than when single twisted tapes are inserted. At low Reynolds numbers, the highest improvement of heat transfers by inserting single and dual inserts is 290 and 595 percent, respectively.

Continuous

16	Eiamsa-	Experimental	Re=6000-	Helically tape	

	ard et al. [20]		20000 Air	H-T y/W= 2, 2.5, 3 for helical pitch ratios p=1, 1.5 , 2	The TPF of 1.29 is obtained by using the tape with the highest twisting ratio of 3 and helical pitch ratio of 2.
17	Yongsiri [21]	Experimental	Re=6000-20000 Air	Helically tape H-T H-TA alternate axis, P/d = (1.0-2); alternate length to y/w=3	H-TA has greater heat transfer and thermal TPF than H-T of roughly 14.1 percent and 1.9 percent. Because the H-TA has Stronger swirl intensity and, as a result, improved fluid mixing towards the tube wall, leading to a larger contact surface area.
18	Gnanaraj & Vijayan [23]	Experimental	Re=200-1750 double glazing solar water heating system y/w=3 Water	Cut-wing twisted tapes with rod or spacer	The Nusselt value for horizontal wing-cut twisted tapes with a rod or spacer at the ends is greatest when compared to complete straight wing-cut twisted tapes. In comparison to horizontally wing-cut twisted tapes with rod or space, complete forms have a lower friction factor. .
19	Ananth [24]	Experimental	Re=200-1200 Water	Thermosyphon solar left-right tube insert regularly spaced with rod and spacer y/w=30	When compared to a simple tube collector, twists reduce the pressure drop by 47.2 percent to 8.9 percent and enhance the total instantaneous thermal efficiency by 53.3 percent to 38.7 percent.
20	Ananth [25]	Experimental	Re=400-1200 Water	Thermo syphon solar heater twist with rod and spacer of various lengths y/w=30	When compared to full-length twist, the Nusselt number reduces as rod and spacer length increases, but the pressure drop increases as rod and spacer length decreases.
21	Hajare et al. [26]	Experimental	Re=7500 - 13000 Air	Twisted tapes with rectangular hole (W/D) of 0.35, 0.44, 0.53, 0.62 and 0.71 y/w=2.5	The twisted tape without the rectangular hole enhanced convective heat transfer performance by 1.40 while lowering flow friction. The thermal performance of the twisted tape with a rectangular hole is around 1.50 times that of the ordinary twisted tape.
22	Gawande & Deshmuk [27]	Experimental	Re=10000-19000 Air	Twisted Tape with rectangular Hole	When compared to a smooth tube, Nusselt values in the tube of rectangular-hole twisted tape inserts increased by 2.3 - 2.9 times at the cost of increased friction values by 1.4 - 1.8 times.
23	Hasanpour et al.[29]; Hisham [60]	Experimental	Re=5000-15000 Water	corrugated tube V-cut twisted tape and U-cut twisted tapes y/w=3.5,7	The V-cut TT in the corrugated tube is greater than that of the conventional TT (from 1.15 to 1.40) and empty corrugated tube (from 1.50 to 2.2) in the experiments.

Continuous

24	Kumar et	Experimental	Re=2700-	V cuts	The maximum thermo-hydraulic

	al.[31]		23400	perforated twisted with y /w=2 -6 Air	performance parameter is found to be 1.58. The maximum enhancement in the Nusselt number is found to be 2.99.
25	Gugulothu [35]	Experimental	Re= 4000-36000 Water	-Typical tape TTT -perforated PTT -baffled bTT y/w = 3.69, 4.39, and 5.25)	When the taper twist ratio is reduced, the thermal performance factor tends to increase. In the case of baffled tape and perforated baffled tape, the highest increase in Nusselt number and friction factor was observed.
26	Nivedita & Bansod [37]	Experimental	Re=6000-13000 Air	V-Jagged Twisted Tape (Copper And Aluminum)	In comparison to plain tube, the heat transfer coefficients for V-Jagged Twisted Tape increase by 52 percent to 90 percent for copper and 50 percent to 75 percent for aluminum, while the friction factor decreases.
27	Suri et al. [39]	Experimental	Re=5000 - 27000 Air	-multiple square wings perforated twisted tapes(4)	The maximum enhancement in the Nusselt number and friction factor is observed to be 6.96 and 8.34 times that of the plain circular tube, respectively. Correlations between the Nusselt number and friction factor are established
28	Bhuiya et al. [41]	Experimental	Re= 7200 - 50200 Air	double perforated counter twisted tapes porosities of Rp = 1.2, 4.6, 10.4 18 and 18.6%	The heat transfer rate and friction factor were found to be 80 to 290 percent greater and 111 to 335 percent higher, respectively, than those of plain tube values. Thermal enhancement efficiency of 1.44 was achieved using constant blower power.
29	Bhuiya et al. [44]	Experimental	Re=7200 - 50200 Air	Triple twisted tapes twist ratios y/w = 1.92, 2.88, 4.81 and 6.79	When compared to the plain tube, the Nusselt number and friction factor of utilizing triple twisted tape inserts were found to be 3.85 and 4.2 times higher, respectively, and the performance factor was 1.44. For Nu, f, several connections were developed.
30	Lin ZM et al[50]	Numerical	Re=50 - 600 Air CFD	Twisted tape with parallelogram winglet	Nusselt and friction values rise by about 76.4%, and 289.1%, respectively, whereas the related TPF factor ranges from 1.25 - 1.85.
31	A Kumar et al. [56]	Numerical	ANSYS 14.5 K-ε turbulent model Water	A twisted tape with holes	The average heat transfer coefficient has increased by 82% compared with the bare tape. Similarly the average pressure drop for the holed twisted tape they are 8.7%, 9.1%, and 10.02% for 1 mm, 3 mm, and 5 mm holes respectively higher than the normal twisted tape.

Continuous

5. Conclusions

Twisted tape produces swirling flow, increasing turbulence and mixing inside the tube. This is the main influencing factor for increasing heat transfer. Twisting inserts are beneficial for enhancing heat transfer in Nanofluids with high viscosity, however, it has been discovered that they are more effective in laminar and transitional flow. It suggests that these more efficient techniques can increase heat transfer while keeping constant pumping in a laminar flow regime. However, due to flow obstruction in turbulent flow, twisted tapes increased pressure loss more than in laminar flow; as a result, the thermal Performance Factor decreased with increasing Reynolds number, while pressure drop increased with twisting tapes. The smaller twisting ratios enhance heat transfer more than larger ones. Tape inserts with surface modifications like wings, cuts, baffles and dimples, and others, have better thermal-hydraulic performance than ordinary twisting tapes. In addition, the employment of twisted tapes with Nanofluids has been proven to be quite effective. However, an additional future study in this field will be highly essential in creating this technology and obtaining more broad useful connections.

Author Contribution Statement

All authors contributed to writing and editing this manuscript. Author Ibrahim S. proposed the research problem and Author Naji Z. developed the introduction and the manuscript pattern. All authors discussed the results and contributed to the final manuscript.

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Abbreviations

Nu Nusselt number

F Friction factor

Y Pitch length (mm)

w tape width (mm)

Y/w twisting ratio

Subscript symbols

t_w tubes with twisting tape

P plain tube

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