# A REVIEW ON MODIFICATION IN TWISTED TAPE FOR HEAT TRANSFER ENHANCEMENT

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**Abstract -** The present study is considered as a review on modification of twisted tape inserts. Twisted tape insert is used as a device to enhance the rate of heat transfer. In this review, several modifications of twisted tapes are considered. This includes half-length twisted tapes, double twisted tapes, short twisted tapes, broken twisted tapes, peripheral-cut twisted tape etc. Twisted tapes can be used in combination with other mechanisms of heat transfer enhancement which includes the usage of twisted tape with combination of other techniques like using tape in dimpled tube, grooved tube, corrugated tube etc. Further, the fluid to be used for heat transfer can also be altered. A nanofluid can also be used to further enhance the rate of heat transfer. Thus, this paper will give a brief review about the works related to enhancement in heat transfer by techniques involving twisted tapes.

**Keywords -** Modified Twisted Tapes, Enhancement in Heat Transfer, Pressure Drop

## I. INTRODUCTION

Heat transfer is an important aspect of most of the processes and equipment. It governs the functioning of heat exchangers, electrical and electronic equipment, combustion engines and so many devices. Thus, addressing the heat transfer is an important factor. For the devices where heating is an issue, rate of heat transfer is needed to be increased and for this purpose, many methods are already available and studied widely. These techniques of heat transfer rate improvement are classified broadly into two categories- active techniques and passive techniques by Bergles[1,2] .

Techniques which requires external energy input are termed as Active techniques and techniques which don't require external energy inputs are termed as Passive Techniques. Concept of passive techniques deals with tempering of the boundary layer to subsequently affect the heat transfer positively. Examples of active techniques are mechanical stirring of fluid, providing vibrations to the fluid and fluid- solid interacting surface etc. On the other side, examples of passive techniques include providing roughness, mixing additives with the fluid andswirling devices in fluid flow.

## II. MECHANISMS OF HEAT TRANSFER ENHANCEMENT USING SWIRL FLOW DEVICE

In a fluid flow region inside a tube without any device, flow is along the axis of the tube and velocity profile is parabolic. Boundary layer formation takes place near the tube surface which offers resistance to the heat transfer. Also, if heating takes place from one side of tube only instead of throughout the circumference, then fluid particles on the other side of fluid doesn't participate in heat transfer actively.

To overcome this, a swirl flow device is placed inside the fluid flow to alter the flow patterns. When a swirl flow device is used, swirling component of velocity is induced in the flow and fluid starts swirling as it moves from inlet to outlet. This affects the flow patterns as flow is no longer along the axis alone and fluid particles also revolves around the axis. These swirling fluid particles helps in reducing the thickness of the boundary layer which helps in reducing the resistance to heat transfer near the wall. Also, if heating is taking place from one side of only instead of all along the periphery, swirling helps in bringing all the fluid particles in the contact with the active heat transfer region which further helps in enhancement of heat transfer. Thus, a swirl flow device provides a better rate of heat transfer.

## III. LITERATURE REVIEW

For the purpose of heat transfer enhancement, various swirl flow devices were studied in past years and some of the important studies are taken below for review:

**S Al Fahed** et al [3] studied pressure drop and heat transfer experimentally for a plain, microfins and tubes with twisted tape inserts. Twist ratio and tape widths of twisted tape were varied to observe the effect. It was concluded that as the tape width increases, both pressure drop and heat transfer increases. This can be attributed to the squeezing of fluid between the tape and tube. As the tape width increases, more squeezing will take place and more turbulence will be created which will help in more mixing subsequently. As the twist ratio ($Y = H/D_i$; where H is the wavelength of twisted tape and $D_i$ is the internal diameter of the tube) increases, more swirling will take place which will further help in thinning the boundary layer and better mixing. Hence, a tape with higher twist ratio and higher tape width should be preferred. But practically, a loose fit

tape should be preferred in case of fouling fluid for the cleani

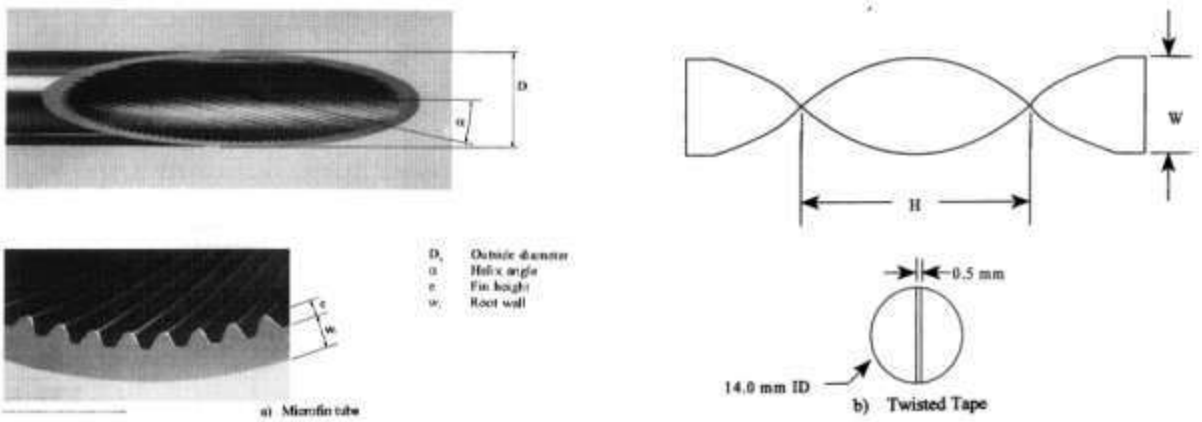


**Figure 1: Microfins and Twisted tapes used by S Al Fahed et al**

**V Zimparov** [4] further combined twisted tape inserts with corrugated tubes and studied experimentally in turbulent region (Re = 4000 to 60000). Corrugation height to diameter ratio (e/Di) and pitch (H/Di) were varied to see the effect of these parameters. It was observed that as the pitch decreases, heat transfer is enhanced due to increased swirling.

**R M Manglik** et al [5] extended research by application of twisted tape inserts inside tubular heat exchangers.

**S Ray and A W Date** [6] used twisted tape inside a square duct instead of circular tube for study in both laminar as well as turbulent region. Tape width was kept same as side length of the duct. When the tape was kept inside duct touching the sides of square duct, no swirl motion was seen as the flow couldn't get from one side of the tape to the other side. But when the tape was rotated at its axis such that it was some space was there between tape and duct, heat transfer enhances. It was observed that as the Reynolds number and Prandtl number increases, Nusselt number increases subsequently.

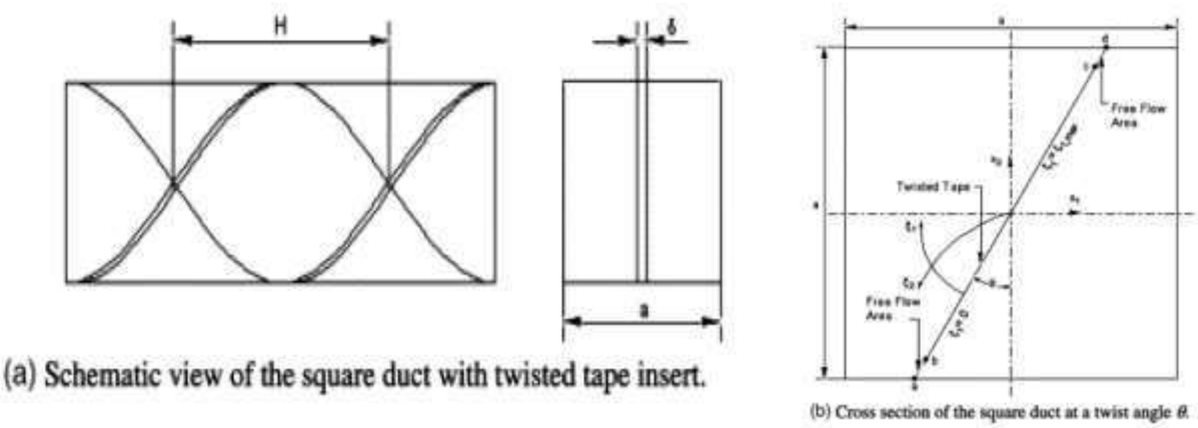


**Figure 2: Twisted tape in square duct used by S Ray and A W Date (2002)**

**P K Sarma** et al [7] investigated laminar convective heat transfer in a tube inserted with twisted tape. Nusselt number was kept between 91 and 5700, Prandtl number was kept between 7 and 60 and H/D ratio was kept between 4.5 and 9.4. It was concluded that eddy viscosity dominated over kinematic viscosity in case of flow with twisted tap tube flow which subsequently helps in increased Nusselt number.

These twisted tapes were modified by P Promvonge et al [8] as double twisted tapes. Experimental study was carried out in a double tube heat exchanger witha helical ribbed tube. Vortex was created inside the tube by using double twisted tape having twist ratio between 2.17 and 9.39. It was observed that ration of friction in case of twisted tape to the friction in caseof plain tube (f/f0) declines linearly with higher twist ratio. Thus, a larger twist ratio can help in reducing the pressure drop. At the same time Nusselt number increases till twist ratio of 8.09 only. Hence, it can be concluded that a twisted tape with larger twist ratio should be preferred but twist ratio should be keptbelow 8.09 only for best results. It was also observed that using a twisted tape along with helically ribbed tube gives a better performance than standalone twisted tape or helically ribbed tube only.

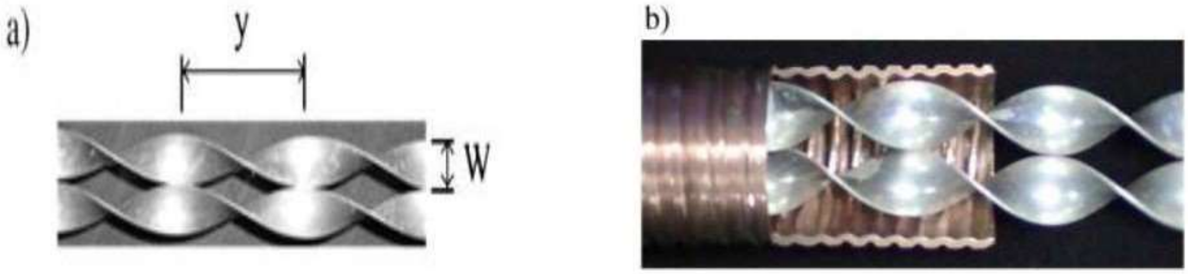

**Figure 3: Double twisted tapes used by P Promvonge et al**

**X Zhang** et al [9] further used a modified twisted tape. Instead of using a single twisted tape, multiple twisted tapes were used. Authors performed numerical studies to evaluate the heat transfer and pressure drop. It was concluded that on the use of these multiple twisted tubes (triple and quadruple tapes), heat transfer enhances significantly but pressure drop is relatively lesser as compared to the full length single twisted tape. Thus, it is advised to use regularly spaced multiple tapes than using a single continuous twisted tape.

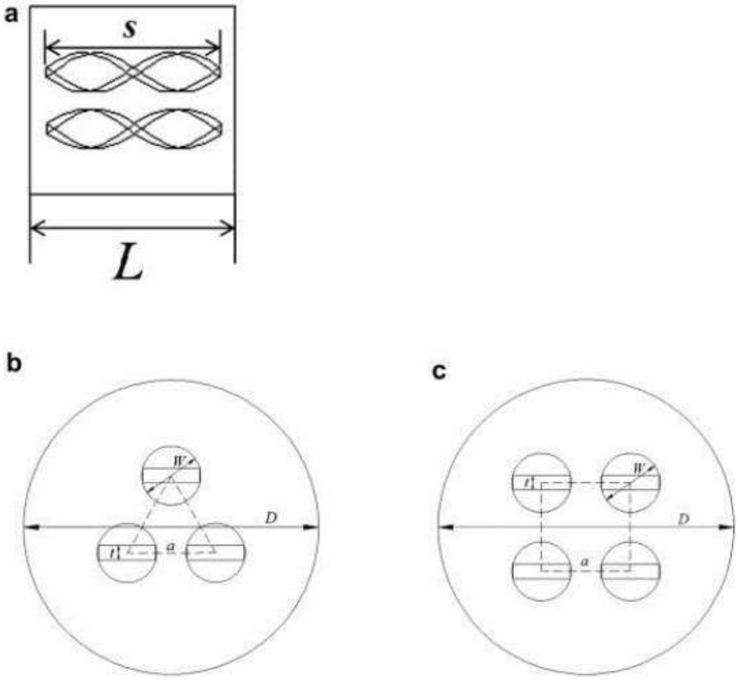

**Figure 4 : Triple and Quadruple twisted tapes used by X Zhang et al**

The next modification on the use of twisted tape was done by using nanofluid instead of plain fluid. L.Syam Sundar et al [10] performed experimental studies on flow in tube with twisted tape with Fe3O4 nanofluid as fluid. The studies were completely performed in turbulent region. It was concluded that higher rate of heat transfer was observed in case of using nanofluid as fluid. But more importantly, in case of using twisted tape with nanofluid, heat transfer further increases as compared to the using nanofluid in plain tube. As the Reynolds number is increased, this enhancement increases further.

**F T Kanizawa** et al [11] used twisted taped for study in two-phase flow. R134a was used as fluid. Twist ratios were kept as 3, 4, 9 and 14. Flow patterns were observed. When twist ratio is decreased and flow velocity is increased, earlier transition to flow patterns were observed which was characterized by wet tube perimeter. It was observed that as the twist ratio decreases and mass velocity of two-phase flow increases, pressure drop increases. This frictional pressure drop was observed to be hugely dependent on vapor quality in two-phase flow. At lower content of vapor, mass velocity governs the pressure drop, specifically at lower twist ratios.

**J Guo** [12] modified conventional twisted tape to center-cleared twisted tape. This study was performed numerically in laminar region and results were compared with short width twisted tape. A short width tape is modified tape by cutting the edges of the conventional tape. This affects the thermohydraulic performance of the tape adversely.

On the other side, heat transfer can be enhanced when a center clearance ratio provided. This can be attributed to the fact that in laminar region, boundary layer is disturbed by this central-cleared twisted tape. No resistance is offered due to twisted tube at the center portion as it is cut out. Thus, this helps in reducing frictional pressure drop relatively. A central-clear twisted tape performs 7-20% better than conventional twisted tape. At higher Reynolds number, thermal efficiency increases significantly.

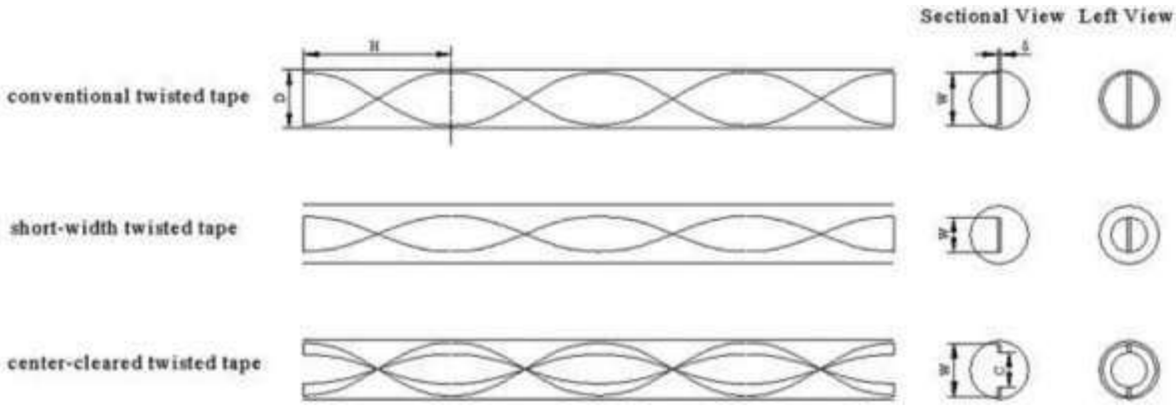


**Figure 5: Modified twisted tapes by J Guo et al**

**P Bhardwaj** et al [13] studied twisted tape inserts in a 75-start spirally clockwise grooved tube. Flow range was kept wide ranging from both laminar as well as turbulent. Three twist ratios were considered as 3.4, 7.95 and 10.15. Both clockwise and counterclockwise twists were provided and authors observed that direction of twisting also affects the thermohydraulic performance of tapes. Studies shown that twisted tape in laminar region performs better than same in case of turbulent region. This is due to the fact that laminar flow offers resistance throughout the cross-section but on the other hand, turbulent flow offers resistance near the wall only. A twisted tape affects the flow almost throughout the cross-section. Hence, twisted tape performs better in case of laminar region comparatively. It was also concluded that thermohydraulic performance increases up to 120% when twisted tape was used in plain tube but in case of twisted tape was used with grooved tube, thermohydraulic performance increases up to 180%.

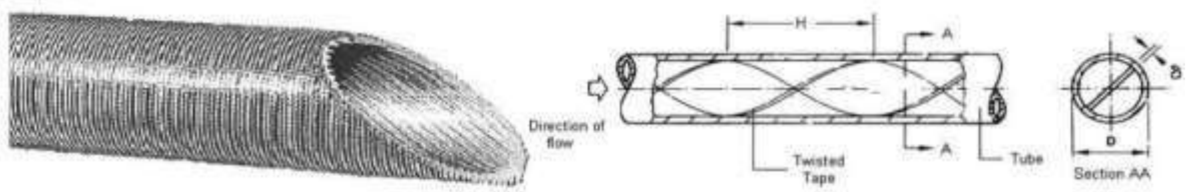


**Figure 6: Grooved tube and twisted tape used by P Bhardwaj et al**

**S Eiamsa-ard** et al [14] modified conventional twisted tape to peripheral-cut twisted tape insert. Total 9 different peripheral-cut twisted tapes were studied by varying twist ratios with varying tape widths in a Reynolds number range of 1000 to 20000. It was concluded that in case of laminar region, heat transfer as well as friction factor increases significantly when a peripheral-cut twisted tape was used as compared to conventional twisted tape but in case of turbulent region, the increase is not as significant as in laminar region, though both pressure drop and heat transfer still increases.

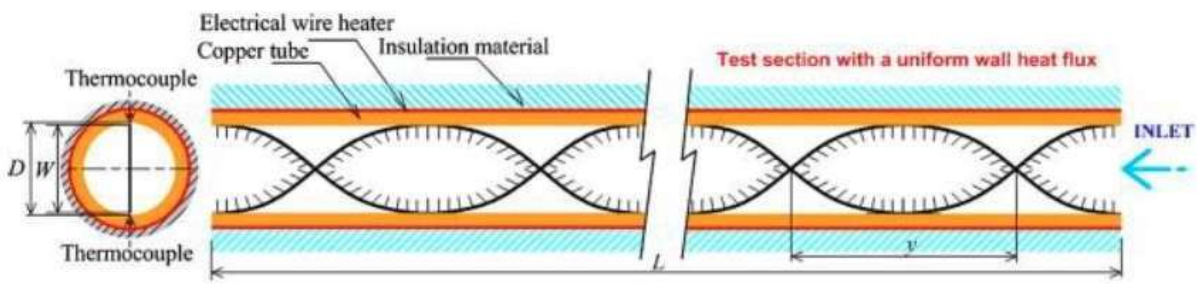


**Figure 7: Peripheral-cut twisted tapes used by S Eiamsa-ard et al**

**Shyy WoeiChang** et al [15] used a broken twisted tape first time. A broken twisted tape is modified conventional twisted tape which generates swirl with better mixing of fluid Experimental studies were performed in Reynolds number range 1000 to 40000 with broken twist tape of twist ratio 1, 1.5, 2, 2.5 and ∞. A regular twisted tape generates swirl which, though results in higher rate of heat transfer, also increases pressure drop significantly. A broken twisted tape helps in weakening of swirl, hence reducing the frictional pressure loss. Results obtained by broken twisted tape shown that Nusselt number increases by 630-950% as compared to in case of plain tube.

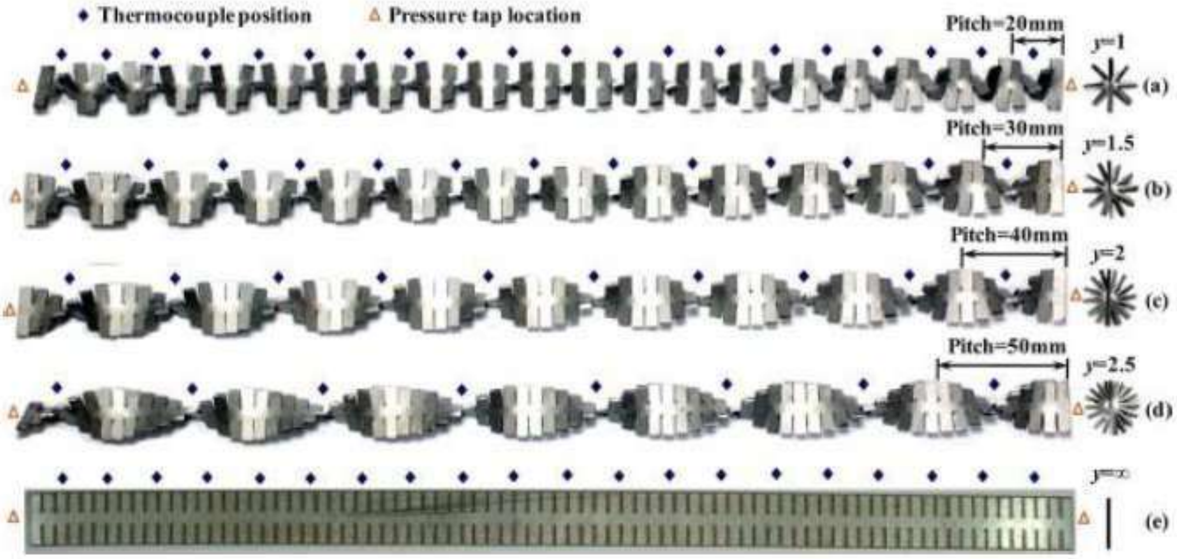


**Figure 8: Broken twisted tapes used by Shyy WoeiChang et al**

**C Thianpong** et al [16] used dimpled tube in place of plain tube with twisted tape insert. Authors performed studied on two dimpled tubes having pitch ratios of 0.7 & 1 and three different twist ratios of 3, 5 and 7. This investigation reported that thermohydraulic performance is better while using twisted tape with dimpled tube as compared to using standalone dimpled tube, plain tube and twisted tape. It was also observed that as the twist ratio and pitch ratio is decreased, both frictional loss and heat transfer coefficient increases.

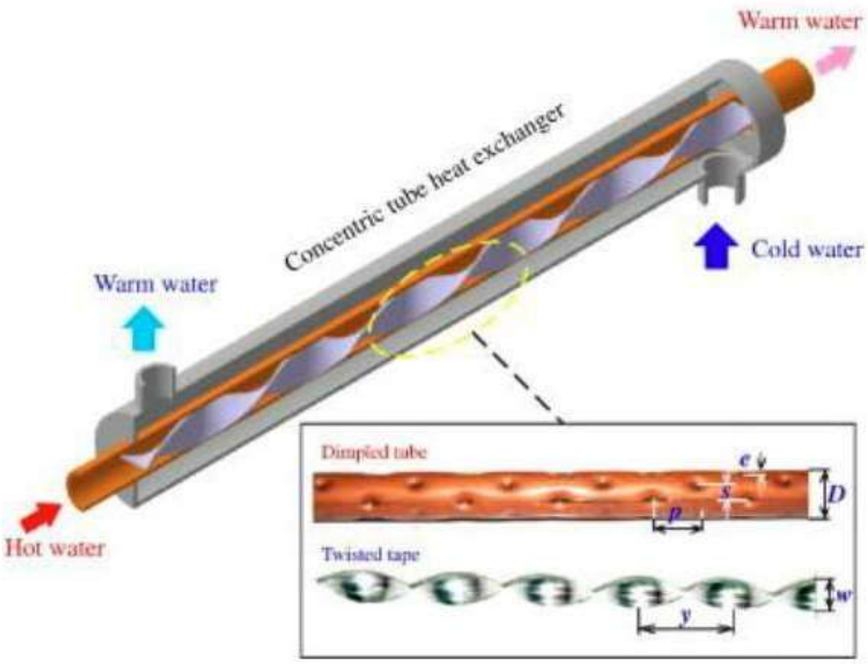


**Figure 9: Twisted tape insert and dimpled tube used by C Thianpong et al**

**P. Murugesan** et al [17] further modified conventional twisted tape as square-cut twisted tape. Authors studied both plain twisted tape (PTT) and square-cut twisted tape (STT) in Reynolds number range of 2000 to 12000 (turbulent region) with varying twist ratios as 2, 4.4 and 6. It was concluded that pressure drop and Nusselt number are higher by up t0 125% in case of square-cut twisted tape as compared to Plain twisted tape. Authors have also developed empirical correlations to estimate pressure drop and Nusselt number.

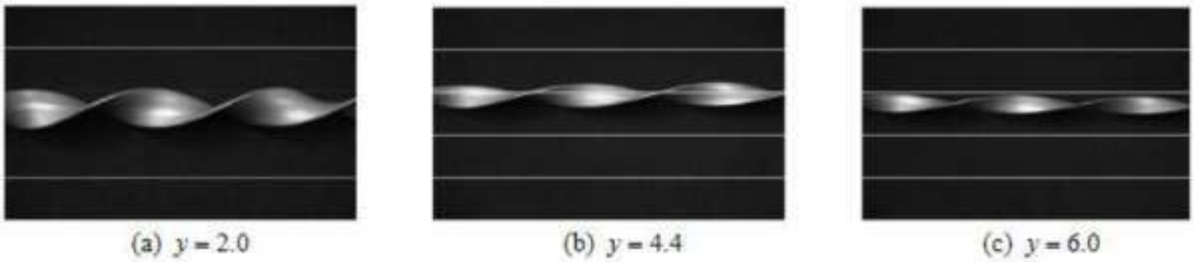


**Figure 10 (a) Plain Twisted Tape**

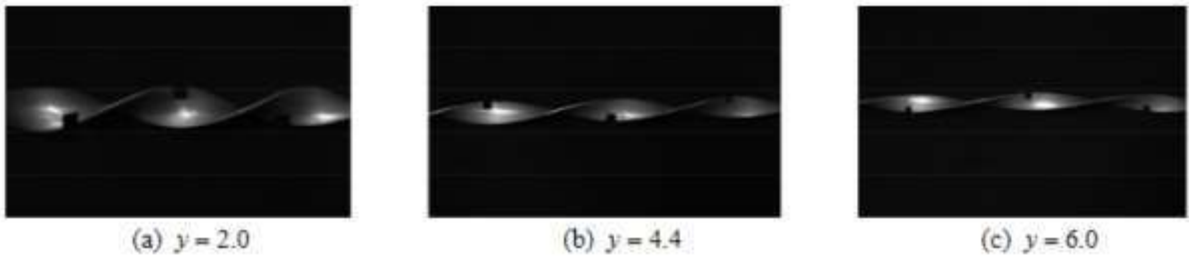


**Figure 10 (b) Square-cut twisted tapes used by P. Murugesan et al**

**R Yadav** and **A. S. Padalkar** [18] used half-length upstream twisted tape (HLUTT) and half-length downstream twisted tape (HLDTT) along with full length twisted tape (FLTT) and plain tube (PT) for their numerical investigation. Different twist parameters as 0.14, 0.27 and 0.38 were used. The heat transfer coefficient and pressure drop in the tubes with the FLTT were found to be 1.29 to 1.86 times and 2.03 to 6.23 times higher, respectively, than in the tubes without inserts. In case of HLUTT, heat transfer occurred to be 1.08 to 1.37 times higher and pressure drops occurred to be 1.36 to 1.7 times higher while for HLDTT, these came out to be 1.09 to 1.47 times and 1.31 to 1.44 times higher respectively.

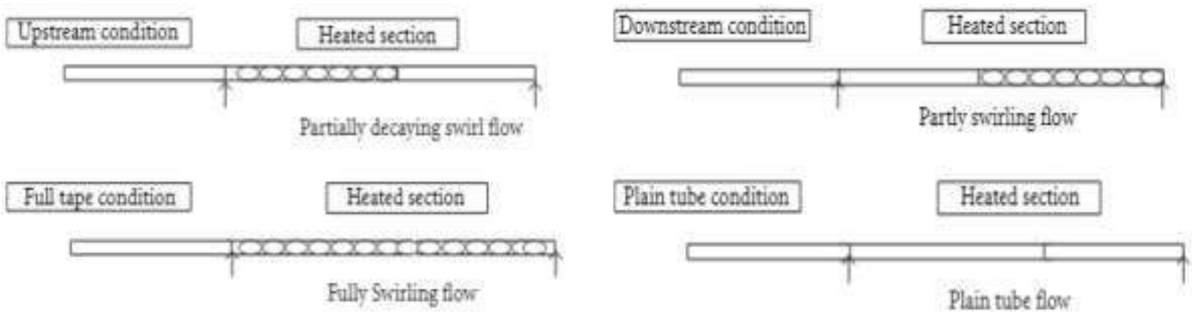


**Figure 11: HLUTT, FLTT, HLDTT and PT used by R Yadav and A. S. Padalkar**

## IV. CONCLUSION

The literatures about various modifications to the twisted tapes were discussed and combination of other mechanics of improving heat transfer along with twisted tape were reviewed. Heat transfer increases by all the methods discussed above but pressure drop also increases as penalty. So, some of the methods like half-length upstream and half-length downstream twisted tapes or broken twisted tapes can prove to be having better thermohydraulic performance. Further, using a combination of the mechanics like using dimpled tube with twisted tape can prove to be better in case of higher heat transfer requirements.

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