A REVIEW ON HEAT TRANSFER AUGMENTATION USING TWISTED TAPE INSERTS HAVING DIFFERENT CUT SECTIONS IN A CIRCULAR TUBE

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ABSTRACT:

Heat transfer augmentation refers to the process of increasing the heat transfer co-efficient which leads to the improvement in the performance of the system. The twisted tape insert is a device used for increasing the heat transfer rate in the heat exchanger system due to its advantages of easy fabrication, operation as well as low maintenance. Some of the applications of heat exchangers are in process industries, thermal power plant, air conditioning equipment, refrigerators, radars for space vehicles, automobiles etc. Previously, most of the researchers focused on different types of inserts such as coil wire insert, mesh inserts, brush inserts, twisted tape insert,wire coils etc. with different geometries, slots, holes, ribs, fins, dimples and cuts. This review paper mainly focuses on the twisted tape insert with different cuts like semi-circular cut, v-cut, delta-winglet cut, rectangular cut, peripherally cut, serrated cut, elliptic cut, quadrant cuts and the effects of these cuts on heat transfer enhancement, pressure drop, friction factor and thermal performance factor characteristics in heat exchanger tubes.

1. INTRODUCTION:

Two fluids which are at different temperatures pass through a heat exchanger then hot fluid loses its heat energy and cold fluid gains the heat energy and thus exchange of heat takes place between two fluids. The effective way of exchanging heat between two fluids is the topic of much interest by the researchers. The methods which are going to enhance the heat transfer between two fluids should be cost effective, require low maintenance and easily fabricated. The aim of all the researchers is to get high thermal efficiency from the thermal systems.

There are three broad categories of heat transfer augmentation techniques.

1 .Active techniques

2. Passive techniques

3. Compound techniques

The difference between active and passive techniques is that the former one requires some external power input to have the desired flow but the passive techniques do not require the power input externally. More over active methods are complex in design compared to the passive methods due to usage of external power input.

Active heat transfer techniques:

1) Mechanical aids: In this method, the fluid is stirred by mechanical means or by rotating the surface.

2) Surface vibration: A high or low frequency is applied to create vibrations to the surface which provide higher convective heat transfer coefficients.

3) Fluid vibration: Instead of applying vibrations to the surface, pulsations are created in the fluid itself.

4) Electrostatic fields: Electric field or magnetic field or a combination of the two is applied in heat exchanger systemto have greater bulk mixing and forcedconvection to enhance the heat transfer.

5) Injection: Same or other fluid is injected into the main bulk fluid or upstream of the heat transfer section.

6) Jet impingement: Fluid is cooled or heated obliquely or perpendicularly to the heat transfer surface.

Passive heat transfer techniques:

1) Treated Surfaces: Cavities, scratches or pits are created on the surfaces of the heat transfer areas.
2) Rough surfaces: These surface modifications particularly create the disturbance in the viscous sub-layer region.
3) Extended surfaces: Plain fins and finned surfaces are the extended surfaces used in many heat exchangers dueto their ability to disturb the flow field.
4)Displaced enhancement devices: Metal licmeshes and discs, wire matrix inserts, rings or balls are the examples of the displaced enhancement devices. Fluid elements displace from the core of the channel to heated or cooled surfaces by these devices.
5) Swirl flow devices: These are the devices which create secondary or swirl flow in the tubes apart from the axial flow of the fluid. Helical twisted tapes are well known examples of swirl flow devices.
6) Coiled tubes: Secondary flows or vortices are generated due to curvature of the coils.
7) Additives for liquids: Solid particles, gas bubbles and soluble trace additives are added to the liquids to reduce the drag resistance.

Compound technique:

A compound technique is a combination of both active and passive techniques. Implementing this technique into thermal systems involves complex designs, high maintenance and they are not cost effectives too, but the heat transfer enhancement produced by this technique is obviously greater when both passive and active techniques used individually.

2. NOMENCLATURE:

TT	twisted tape insert
PTT	Plain twisted tape insert
VTT	V- cut twisted tape insert
STT	semi-circular cut twisted tape insert
O-DWT	oblique delta-winglet twisted tape insert
S-DWT	straight delta-winglet twisted tape insert
STT	serrated twisted tape insert
PT-A	peripherally-cut twisted tape with alternate axis insert
PT	peripherally-cut twisted tape insert
Nu	Nusselt number
Re	Reynolds number
R	cut radius, m
y	twist ratio
W	tape width, m
w	serration width, m
d	serration depth, m
w/W	serration width ratio
d/W	serration depth ratio
d/w	depth of wing cut ratio

3. REVIEW ON TWISTED TAPE INSERTSHAVING CUT SECTIONS:

P Murugesan et al. [1] have conducted experiments using v-cut twisted tape insert as shown in figure1 on heat transfer, friction factor and thermal performance factor characteristics in a circular tube for three twist ratios (y=2.0, 4.4 and 6.0) and three different combinations of depth and width ratios (DR=0.34 and WR=0.43, DR=0.34 and WR=0.34, DR=0.43 and WR=0.34). The average Nusselt number and friction factor for the tube with VTT of DR=0.43, WR=0.34 is respectively, 4.51% and 7.86% higher than those given by the tape with DR=0.34 and WR=0.34. Similarly, tube with VTT of DR=0.34 and WR=0.34 is 4.24% and 8.02% higher than those for DR=0.34 and WR=0.43.The obtained results show that the mean Nusselt number and the mean friction factor in the tube with v-cut twisted tape increase with decreasing twist ratios (y), width ratios (WR) and with increasing depth ratios (DR).From all the results obtained, the maximum value of Nusselt number is 1.36 to 2.46 times higher than the plain tube in the presence of VTT.

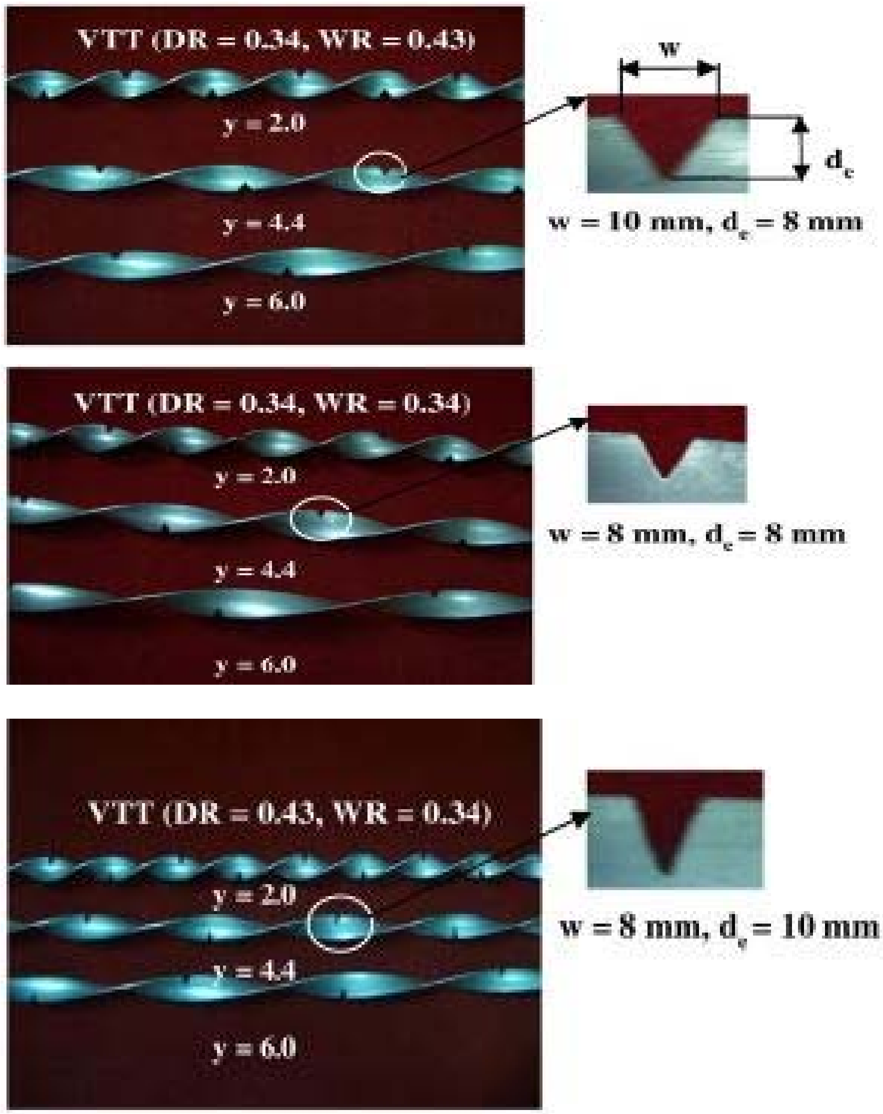
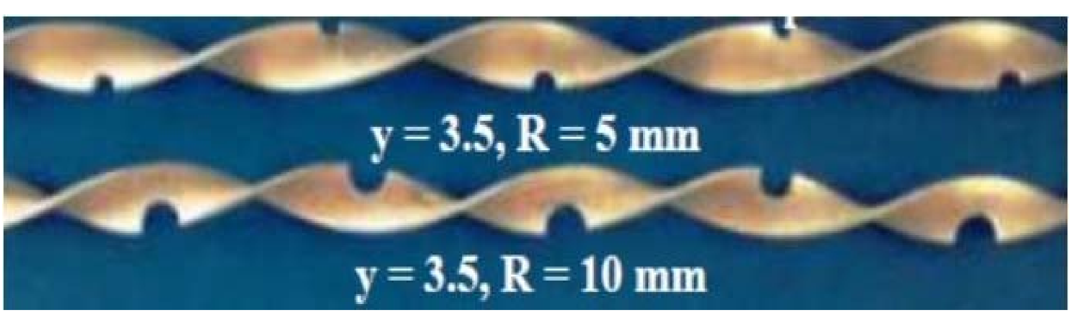


Fig 1. V- cut twisted tape inserts

A Pawan et al. [2] did experimental investigations using semi-circular cut twisted tape inserts (STT) for twist ratios 3.5 and 5.3 as shown in figure2 on heat transfer and friction factor characteristics in a circular tube. They found that, heat transfer rate increases with decrease in twist ratio (y) andincrease in cut radius (R). At maximum Re, friction factor decreases for STT 3.5 with cut radius of 10mm compared to STT 3.5 with cut radius of 5mm. They have concluded that, comparing with smooth tube, the tube with STT has more friction factor but for increase in cut radius, it reduces simultaneously. From all the results obtained, the maximum value of Nusselt number isachieved with STT 3.5 with cut radius of (R) 10mm.



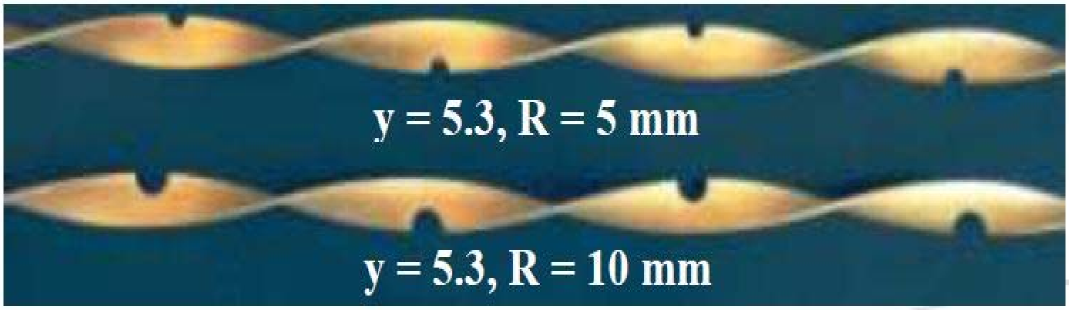


Fig 2. Semi-circular cut twisted tape inserts

S.Eiamsa-ardet al.[3] experimentally investigated the heat transfer, flow friction and thermal performance factor characteristics in a tube fitted with delta winglet twisted tape insert(DWT) as shown in figure3 having three twist ratios (y/w = 3, 4and 5) and three depth of wing cut ratios (d/w = 0.11, 0.21 and 0.32). Comparing both the oblique and straight delta winglet twisted tape arrangements, it is proved that O-DWT is giving higher turbulent effect and thus the heat transfer co-efficient obtained by O-DWT is more than S-DWT.The Nusselt numbers and friction factors for tube equipped with DWT are respectively 1.1–2.55, 1.02–1.64 and 2.5–7.02, 1.08–1.95 times of those for plain tube and tube with typical twisted tape insert. The results also show that, for O-DWT the mean Nusselt numbers and mean friction factorswith the highest depth of wing cut ratiosd/w = 0.32 are respectively 1.35–2.55 and 3.62–7 times the plain tube, 1.29–1.64 and 1.51–1.95 times the tube with typical twisted tape. For the S-DWT the mean Nusselt numbers and mean friction factors with the highest depth of wing cut ratiosd/w = 0.32 are respectively 1.25–2.16 and 3.22–5.85 times the plain tube, 1.16–1.39 and 1.31–1.63 times the tube with typical twisted tape. From all the results obtained, the maximum value of Nusselt number is 1.35 - 2.55 times higher than the plain tube in the presence of O-DWT.

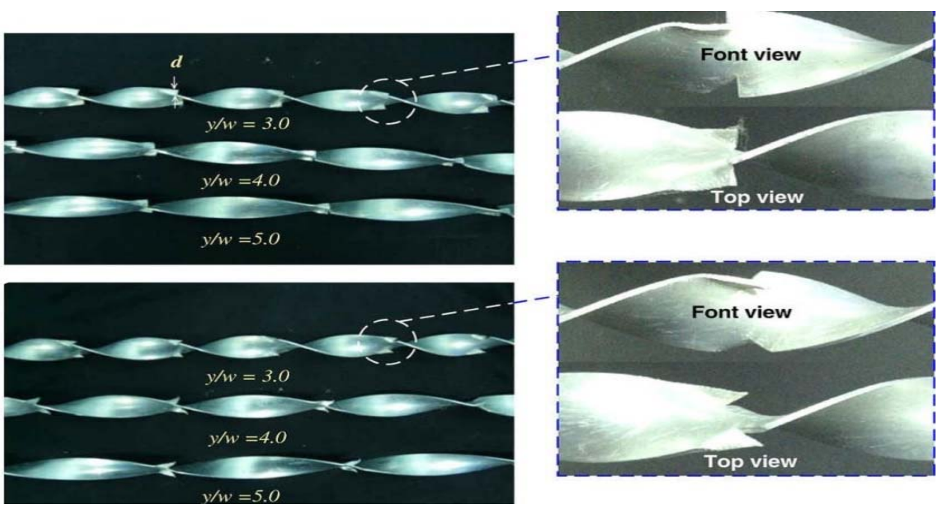


Fig 3.Delta-winglet cut twisted tape inserts

Salam B, Biswaset al.[4]conducted experimental investigations for measuring tube side heat transfer coefficient, friction factor and heat transfer enhancement efficiency of water for turbulent flow in a circular tube fitted with rectangular-cut twisted tape insert as shown in figure 4. For tube with rectangular-cut twisted tape insert for Reynolds number (Re) = 10116, Nusselt numberwas found to be 125 and for Re = 19070, Nusselt number was increased to 309. It is found that,heat flux increases with the increase in Reynolds numberand rectangular-cut twisted tape insert provided higher heat fluxes than those for smooth tube as the Reynolds number increases. From all the results obtained that, the maximumenhancement in heat flux is 68% higher than the smooth tubein the presence of rectangular-cut twisted tape insert.

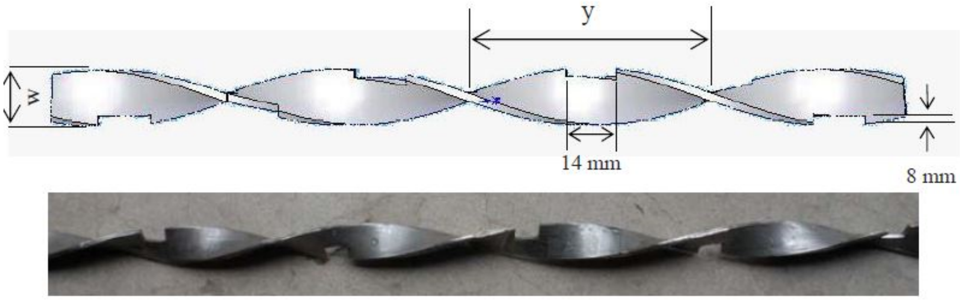


Fig 4.Rectanglecut twisted tape inserts

S Eiamsa-ard et al.[5] have conducted experimental investigations on the heat transfer, flow friction and thermal performance factor behaviors in a constant heat fluxed tube using twisted tape with serrated-edge insert as shown in figure5 has different serration width ratios (w/W= 0.1, 0.2, 0.3) and depth ratios (d/W= 0.1, 0.2, 0.3). Under the experimental conditions, the mean heat transfer rate and mean friction for tube fitted with STT are found to be about 42.2%, 36.7%, 32.7% and 148%, 194%, 233% higher than those of the plain tube for w/W = 0.1, 0.2, 0.3 respectively. In the similar way the mean heat transfer rate and mean friction factor for tube fitted with STT are found to be about 11.3%, 7%, 4% and 17.5%, 10.2%, 5.5% higher than those of the TT for w/W=0.1, 0.2, 0.3 respectively.The results show that,Nusselt number increases with the rise in the depth ratio but decreases with increase in width ratio. It is interesting to note that the smaller width ratio (w/W=0.1) yields higher heat transfer rate than the larger ones (w/W= 0.2, 0.3). From all the results obtained, maximum heat transfer enhancement is 42.2% higher than the plain tube in the presence of STT.

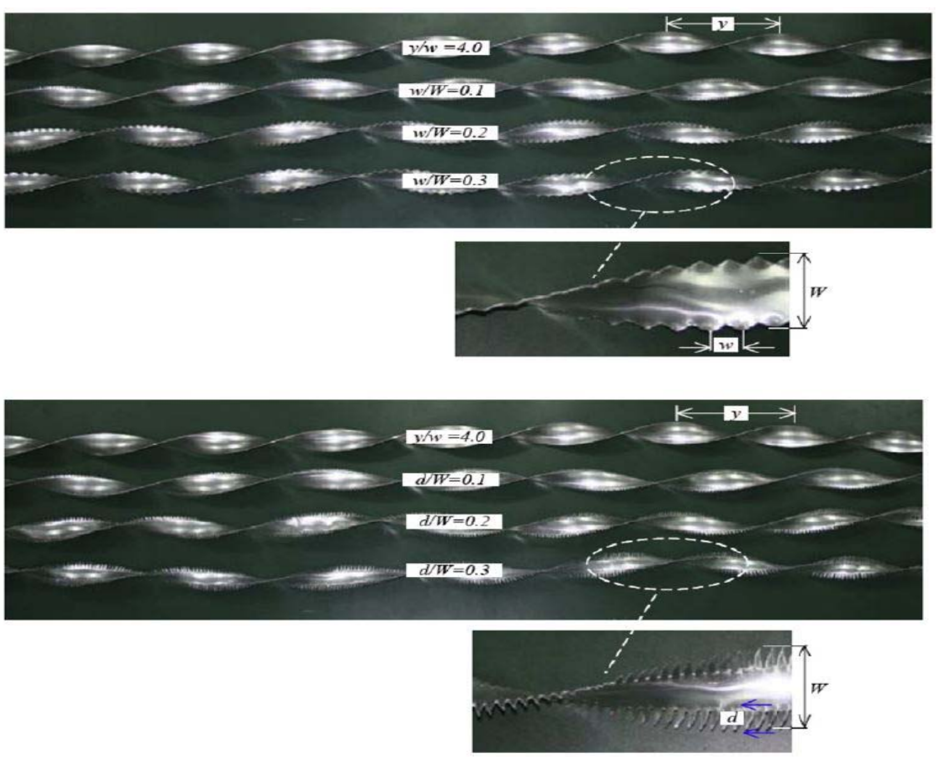


Fig 5.Serratedcut twisted tape inserts

P Seemawute et al. [6] have studied the effect of peripherally-cut twisted tape with alternate axis (PT-A) as shown in figure 6 on the fluid flow and heat transfer enhancement characteristics in a uniform heat flux circular tube. The heat transfer rates in the tube equipped with the PT-A are 13 to 38%, 17 to 81% and 50 to 184% greater than those in the tube fitted with the PT, TT and plain tube alone.Friction factor in the tube with the PT-A is increased up to 1.7, 2.1 and 7.7 times compared to those in the tube with PT, TT and plain tube respectively.From all the results obtained, the maximum heat transfer enhancement is 184%, 102% and 57% higher than the plain tube in the presence of PT- A, PT and TT.

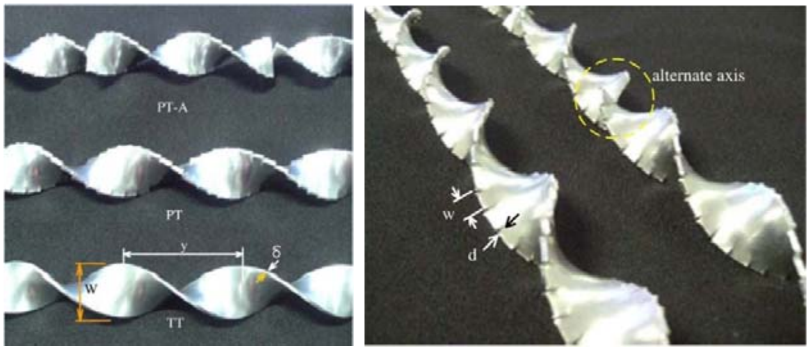


Fig 6.Peripherallycut twisted tape inserts

Sami D. Salaman, Abdul Amir H. Kadhum et al.[7] using CFD package (FLUENT-6.3.26)conducted heat transfer analysisin circular tube inserted by Elliptic cut twisted tape and classical twist tape insert with twisted ratios (y= 2.93, 3.91, and 4.89) and cut depths (w= 0.4, 0.8, and 1.4 cm) as shown in figure 7 in laminar flow conditions. The simulated results show that the elliptic-cut twisted tape with twist ratio (y = 2.93) and cut depth (w = 0.4 cm) offered higher heat transfer rate and friction factor compared to the plain tube and other twisted tape. The influence of the cut depth (w = 0.4 cm) was more dominant than that of the cut depths (w= 0.8 and 1.4 cm) for all the Reynolds numbers.

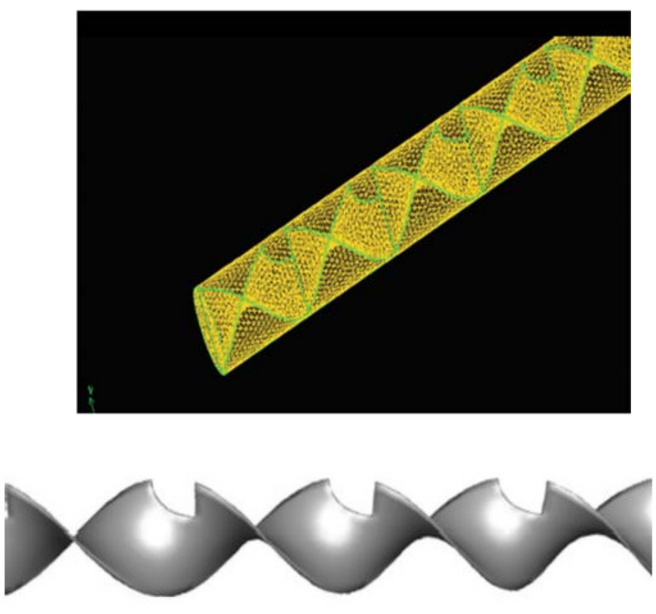


Fig 7. Ellipticcut twisted tape insert

Sami D. Salaman, Abdul Amir H. Kadhum[8] used a commercial CFD package, FLUENT 6.3.26 to study the 3D models for circular tube fitted with classicaland quadrant-cut twisted tape (QCT) inserts with three twist ratios (y= 2.93, 3.91, and 4.89) and different cut depths (w= 0.5,1.0, and 1.5 cm) as shown in Figure .8.They have concluded that, over the range of Reynolds number considered, thetube equipped with the quadrant-cut twisted tape with y= 2.93 and cut depth of 0.5 cm offered the best heat transfer performance as compared to the plain tube and other twisted tapes used.

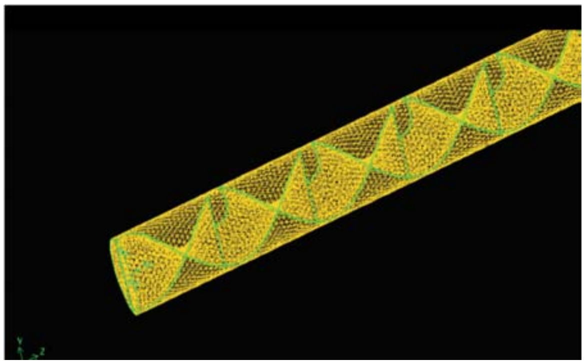


Fig 8. Quarant cut twisted tape insert

From the literature review, it is observed that among all the passive techniques available for increasing the heat transfer rate, insertion of twisted tape opposite to the flow passage is the most economic, easily fabricated and low maintenance technique. Further heat transfer augmentation could be obtained by using twisted tape inserts with v-cut, semi-circular, delta-winglet, rectangular, serrated, peripheral, elliptic and quadrant cuts provided on the twisted tape inserts.

CONCLUSIONS

Twisted tape generates swirling flow which causes higher turbulence and greater mixing in the tube. This is the major influencing factor for heat transfer augmentation. In all the experimental investigations mentioned it is proved that as Reynolds number increases, Nusselt number increases and friction factor decreases. For all tapes irrespective of their geometry and shape as the twist ratio of the tape increases both Nusselt number and friction factor increase. Heat transfer rate is higher when cuts are provided on the twisted tape insert compared to the plain twisted tape insert and plain tube without insert.

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