NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 4, ISSUE 3, Mar.-2017

A REVIEW OF HEAT TRANSFER ENHANCEMENT USING TWISTED TAPE WITH AND WITHOUT PERFORATION

DR. AVINASH M. PATIL
*Department of Mechanical Engineering, Padmabhushan Vasantdada Patil Institute of Technology, Sangli, India, * patilavi.karnal@gmail.com*

ABHISHEK R. PATIL
*Department of Mechanical Engineering, Padmabhushan Vasantdada Patil Institute of Technology, Sangli, India, * abhidada.nagaj@gmail.com*

PARESH M. WADEKAR
Department of Mechanical Engineering, Annasaheb Dange College of Engineering and Technology, Ashta, India, wadekar.paresh@rediffmail.com*

ABSTRACT
Energy conservation and beneficial from economic point of view heat transfer enhancement is important factor. There are many techniques to enhance the heat transfer rate through, Passive and active techniques. Passive techniques like, twisted tapes, wire inserts and roughness of element is most effective methods for heat transfer enhancement. Many studies have been carried out on different geometries of twisted tapes to increase the rate of heat transfer. Several correlations have been developed between heat transfer and friction factor for inserts of twisted tapes. In current study, a literature review of heat transfer enhancement in heat exchanger using twisted tapes has been done. Experimental and numerical studies on various twisted tapes with and without perforation are discussed based on the literature. The development in heat exchanger systems will be improved is shown in this studies. The research area in heat exchanger for enhancement in heat transfer rate is so big. Twisted tape optimum shape can also be developed based on the minimum friction factor and maximum heat transfer in fluid.

INTRODUCTION
Important requirement in energy conservation is the efficient heat transfer system [1]. Augmentation of high heat flux is occurred due to the enhancement of heat transfer. Reduction of heat exchanger size and temperature driving force etc. are other advantages of enhancement in heat transfer rate. Economic point of view the reduction in size is very important, whereas apart from this by reducing the temperature driving force leads to minimization of entropy generation or minimum energy destruction and increase in second law efficiency. Apart from this, increased heat transfer rate is beneficial due to the heat exchanger can operated at law velocity and gives considerably higher heat transfer coefficient. Also, law operating cast is achieved along with law operating pressure drop. To increase the thermal efficiency of the heat exchanger, the most important parameter is improving the thermal contact and reduction in pumping power. These factors are associated with enhancement in heat transfer forces y using different techniques to increase thermal performance of heat exchanger.

Heat exchangers are usually used in nearly all areas of industrial activities. The heat transfer enhancement concept is relatively significant and advantageous in process, power, air conditioning, refrigeration, automotive industries etc. Along with this, heat transfer augmentation methods are also becoming an important substance of interest in solar heat collectors, micro chemical processing compact heat exchanger design, electronics cooling etc. [2]. As the time progress, the matter of heat transfer enhancement has become more dynamic in all industrial applications. The classification of heat transfer enhancement techniques is generally classified into three main classes i.e., active, passive and compound methods (Figure 1). The external power is used for enhancement in heat transfer is come under active method. It is a very easy technique in some cases however it is somewhat complex from design point of view. Also, it is limited in use because of its external power requirement. As like active methods there is no requirement of external power supply in passive method for heat transfer improvement. In passive methods, it utilizes the energy associated with system which tends to increase pressure drop in fluid. The special surface utilization in geometry gives high thermal performance in system as compared to plain surface. Micro fins, twisted pates, dimples, wire coils, fins, ribs etc. are many passive devices which are used to improve the rate of heat transfer. Tube with longitudinal insert is also an effective passive technique of heat transfer enhancement [3]. Passive methods are related with the use of modified surfaces and geometries in a flow flied is association with insert. Earlier, due to fabrication difficulties and restriction it is very difficult to work with complex geometries, but now days due to advancement in manufacturing field it is now possible to adopt new geometries in heat transfer enhancement techniques. The last method for heat transfer enhancement is compound method. In compound method, the hybrid techniques involve both active and passive method. The compound method is relatively complex and having very limited applications Bergles [4] has studied on various types of developed convective heat transfer enhancement techniques. He has summarised different types of effective heat transfer enhancement techniques. Compound heat transfer enhancement methods were discussed which includes enhancement of heat transfer rate.

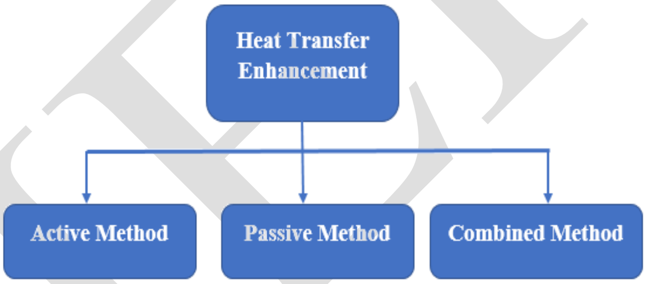

Figure 1 Heat Transfer Enhancement Methods

The most important passive methods for heat transfer improvement is use of twisted tapes. The twisted tapes are just a metal strip which are twisted in some desirable shapes and dimensions and inserted in flow field. This are also worked as swirl generator and creates turbulence in flow to impart swirl on it, which leads to increase in heat transfer coefficient. The ratio of pitch to twist is important parameter while study the effect of twisted tapes for performance improvement. The pitch of tape is the length between two points on a plane parallel to the axis of the tape. The twist ratio of the twisted tape is the ratio of pitch to inside diameter of the tube. Numerous experimental and numerical studies have been conducted by various researchers on heat transfer enhancement using twisted tapes. Some review studied have been also described on twisted tapes however it is still need to summarise all previous works and latest techniques and modification in geometries required to increase the performance of twisted tapes. In the present paper, an attempt has been carried out to review various analytical, experimental studies done on twisted tapes with and without peroration.

HEAT TRANSFER ENHANCEMENT USING TWISTED TAPES

Heat transfer improvement is always an central matter of concern since the improvement of heat transfer rate leads to increase the performance of system which is fairly significant in many heat transfer applications. The most popular and effective device for heat transfer enhancement is twisted tapes and also many correlation of heat transfer and pressure drop has been developed for different geometries of twisted tapes. The improvement in heat transfer is obtained by developing turbulence into the fluid flow, which increases the velocity of fluid near to the boundaries and better fluid mixing is obtained which cause to increase heat transfer rate. In heat transfer system with twisted tapes, the rate of heat transfer and pressure drop is governed by twist ratio of twisted tapes. The clearance between twisted tape and tube boundary is also important parameter while selecting the width of twisted tape. The moderate clearance should be provided between the twisted tape and tube otherwise if clearance is more bypass flow may occur which reduces the performance.

The use of inserts in flow like twisted tapes causes flow blockage, induction of secondary flow and flow portioning. The flow blockage reduces the free flow area and also reduces the of pressure drop and viscous effects are also reduced. Along with this flow velocity also increases and in some cases secondary flow is generated. The generated secondary flow produces turbulence and gives required effective mixing of fluid in flow region which ultimately improve temperature gradient and tends to increase in heat transfer coefficient [5].

Kumar et. al. [6] presented a study on the heat transfer improvement using various twisted tapes. The conclusion of study is in laminar flow the performance of twisted tapes is more effective. As due to the turbulence pressure drop occurs in case of turbulence flow the performance may decrees. The increased heat transfer rate in laminar and turbulent flow there with some friction factor occurred due to the twisted tapes with modified geometry.

Patil et. al. [7] conducted a study on heat transfer improvement in a square duct and circular tube using screw tape and twisted tape inserts. The study exposed that use of screw tape and twisted tape is an economical solution for heat transfer augmentation. The passive methods which are used to increase the heat transfer were found advantageous as compared to active methods. The study also shows that as compared to circular tube increase of heat transfer in square duct is higher due to high surface to volume ratio of square duct.

New method of determining heat transfer coeffient in a tube fitted along with twisted tape insert is determine by Sarma et. al. [8]. Based on wall share and temperature gradient through friction coefficient correlation which leads to enhancement of heat transfer through the wall of tubes. The previous developed correlations for twisted tapes were compared with this current developed theory. Afterward the theoretical results were presented in the form of correlations.

The generalised correlations for convective heat transfer and friction coefficients for a tube equipped with twisted tapes for a wide range of Prandtl and Reynolds number is given by Sarma et. al. [9]. The twisted tapes inserts is transfer the flow from laminar to turbulent in form of monoatomic transition is discussed in this study. For Reynolds number 200e5 and twist ratio 2-10 combined solution from theoretical approach was discussed. Heat transfer coefficient by theoretical prediction was also discussed for all range of Reynolds number. While predicting the above theoretical fact there is a absence of transition and regimes of laminar and turbulent flow. There is good agreement between therotical prediction and previous correlations. Deviation between Nusselt number and friction factors is found less than 7.12%.

EXPERIMENTAL STUDIES ON TWISTED TAPES:

Many researchers have been carried out experimental studies for improvement in heat transfer by using twisted tapes insert. Agrawal et. al. [10] conducted an experiment study to determine the characteristic of friction and heat transfer for heating and cooling of Servo herm oil under uniform wall temperature with twisted tapes inserts. In experiment two double pipe heat exchangers is used, one pipe for hot and other is for cold in series. The prediction of isothermal friction factor and Nusselt number is given by new correlation for uniform wall temperature of viscous liquids when twisted tapes of twist ratio is less than or equal to 5. The results showed a growth in isothermal friction factor which was 3.13–9.71 times the values of plain tubes whereas at constant pumping power and constant flow rate increase in Nusselt number were found to be 1.21–3.70 and 2.28–5.35 respectively times the plain tube values. The relationship was developed to predict isothermal friction factor for (Re/y) ¼ 9-1000.

Al-Fahed et. al. [11]carried out an experimental investigation to study the effect of clearance between tube and tape on heat transfer characteristics for fully developed turbulent flow through a horizontal isothermal tube. The experimentation is conducted for fifteen different twisted tapes. 3.6, 5.4 and 7.1 these three different twist ratios were selected with five different widths of 10.8 mm, 11.4 mm, 12.0 mm, 12.6 mm and 13.2 mm. The results showed that with decrease in tube- tape clearance the enhancement of heat transfer rate increases. Result Also shows that, for twist ratio 3.6 and tape width 10.8 mm, heat transfer enhancement was nearly equal to 13.2 mm width of same twist ratio. Almost 17% difference in heat transfer enhancement was obtained from different widths with twisted tape of twist ratio 3.6, and same difference in heat transfer improvement for twisted tapes of twist ratio 5.4 and 7.1 was 9% and 5% respectively. The study concluded that with small twist ratio and tight fit tape are desirable to achieve high heat transfer improvement for turbulent flow in practical design of thermal systems.

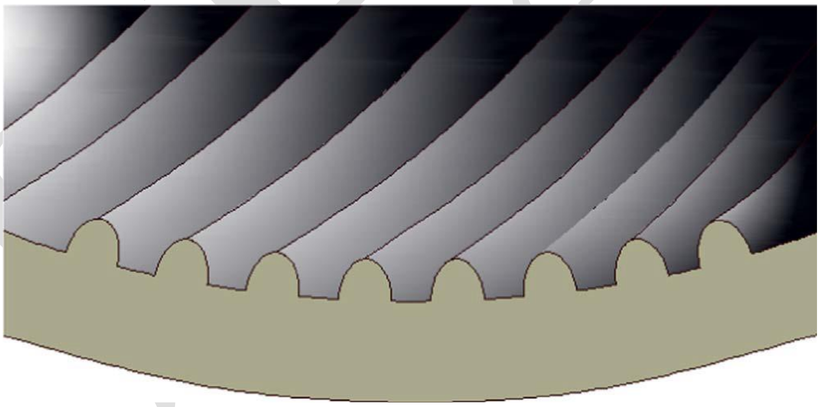

Figure 2 Macro Fin

Al-Fahed and Chamra L.M. [11]conducted an experimental study to study and compare heat transfer coefficients and pressure drop for a plain, twisted tape inserts and microfin in laminar flow region. The analysis of microfin tube is shown in Figure 2. By using a single shell and tube heat exchanger tThe experiments were performed, were steam as a heating source and oil was used as a working fluid. The twisted tapes of three different twist ratios 3.6, 5.4 and 7.1 for and two widths ratio 0.95 and 0.77 were selected in the study. The study shows that from the results that the use of twisted tapes is most effective method to improve heat transfer rate. It was also found that heat transfer rate increases with decreasing twist ratio. Higher values of heat transfer were obtained by using tight fit tapes for twist ratios 3.6 and 5.4 than loose fit tapes. But the high heat transfer rate was obtained by loose fit tapes than tight fit tapes for twist ratio of 7.1. The comparison of friction factor of microfin tube with that of plain tube was done using Friction Loss Ratio. The friction loss ratio of microfin tube was approximately unity due to which pressure drop in microfin tube was almost same as that of plain tube. A small increase in heat transfer and pressure drop coefficients was obtained by using microfin tubes over the plain tubes therefore, the studied microfin tubes were not found useful for laminar flow.

Liao et. al. [13] carried out an investigation on tubes with three dimensional internal extended surfaces as shown in Figure 3. Experiments were performed to investigate heat transfer and friction characteristics for ethylene glycol, water, and ISO VG46 turbine oil with laminar, transitional and turbulent flow through four tubes with three dimensional internal extended surfaces and copper continuous or segmented twisted tape inserts. On three copper, continuous twisted tapes insert the experiments were conducted with twist ratio 5, 10 and15 along with two copper segmented twisted tape inserts with a twist ratio of 10 and 15. The range of Prandtl number (Pr) and Reynolds number (Re) was 5.5–590 and 80–50,000 respectively. The results showed that by using 3 DIEST tubes technique with twisted tape inserts to increase heat transfer rate is suitable for laminar flow of highly viscous fluid flowing through tube. Also, there was found a small increase in heat transfer for transitional and turbulent flow but friction factor increases considerably.

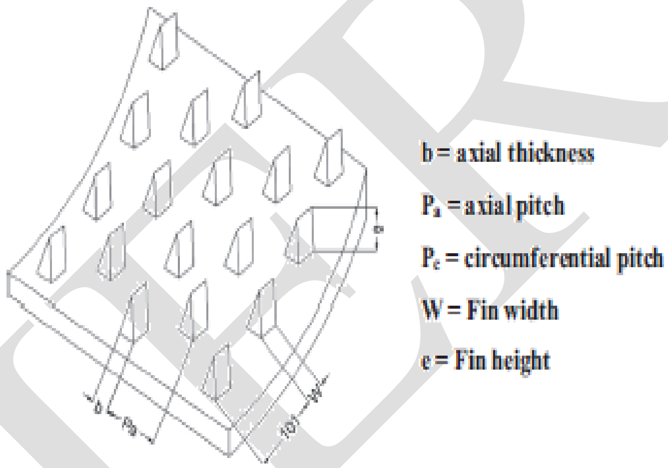

Figure 3 Three dimensional internal extended surface.

Saha et al. [14]carried out an experimental study was carried out by to investigate pressure drop and heat transfer characteristics in a circular tube equipped with regularly spaced twisted tape inserts. Viscous fluid having laminar swirl flow was used with an intermediate Prandtl number range of 205 < Pr < 518. The twisted tapes of different rod diameters, tape width and phase angle between successive tapes element with regularly spaced were used to produce swirl. The result obtained for small width twisted tapes is not satisfactory, heat transfer rate improvement in such cases is not enough. Results shows that increase of phase angle between to adjacent tapes do not improve result but increases complexities in manufacturing.

Ujhidy A. and Nemethe J. [15] studied experimentally the laminar flow through coils and helical static elements and tube having twisted tapes. There is an existence of secondary flow in between surface of the helical element and tube wall. Laser technology is used for flow visualisation analysis and measurements. A good match was found between measured data and data obtained from numerical calculations. Also, a modified Dean Number was proposed to study comparison between the flow pattern of developed secondary stream lines in coils and flow patterns in tubes equipped with twisted tapes and helical static elements.

HEAT TRANSFER ENHANCEMENT USING TWISTED TAPES WITH PERFORATIONS

C. Thianpong et. al [16] conducted an experimental investigation for heat transfer and pressure drop analysis for turbulent flow with perforated twisted tapes in heat exchanger. The experimentation is carried out for perforated twisted tapes of having hole diameter ration d/W is 0.11, 0.33 and 0.55 with wing depth ratio w/W is 0.11. 0.22 and 0.33. Experimental result shows that the heat transfer enhancement in perforated twisted tube and twisted tube is be up to 208% and 190% as compared to plain tubes. Perforated twisted tube with same pumping power having d/W ratio 0.11 and 0.33 gave the maximum thermal performance factor of 1.33 at Reynolds number of 5500. The empirical relations for friction factor, heat transfer and thermal performance for perforated twisted tube were also developed.

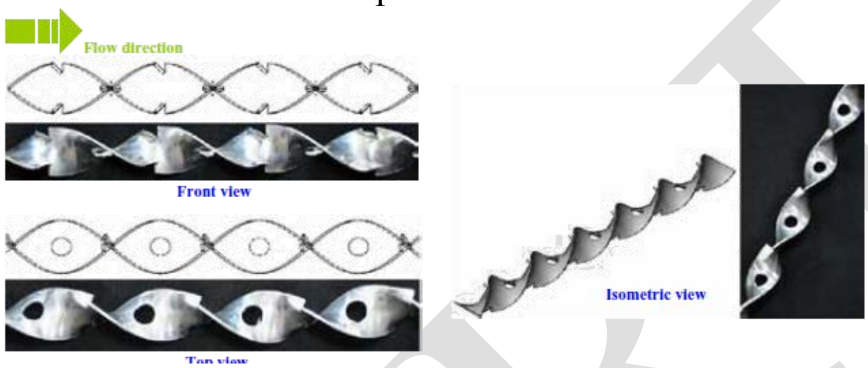

Figure 4 Photograph and Sketch of Perforated Twisted Tape with parallel wings

Bodius Salam et. al. [17] carried out experiments for measuring tube side heat transfer, friction factor, heat transfer enhancement using twisted tapes with rectangular cut. A stainless-steel tape with rectangular cut with twist ratio 5.25 is used as insert in tube heat exchanger. The rectangular cut had 8 mm depth and 14 mm width. The experimentation is carried out for uniform heat flux which is maintained with the help of nichrome wire. The heat flux variation 14 to 22 kW/m2 for smooth tube, and 23 to 40 kW/m2 for tube with insert with varring Reynolds numbers between 10000-19000. Nusselt numbers obtained from smooth tube were compared with Gnielinski correlation and errors were found to be in the range of -6% to -25% with r.m.s. value of 20%. Nusselt numbers in tube with rectangular-cut twisted tape insert were enhanced by 2.3 to 2.9 times at the cost of increase of friction factors by 1.4 to 1.8 times compared to that of smooth tube as compared to Reynolds number. Heat transfer enhancement efficiencies were found to be in the range of 1.9 to 2.3 and increased with the increase of Reynolds number.

Sombat Tamna et. al. [18] conducted an experimental work on heat transfer enhancement in a round tube by insertion of 300 V-shaped ribs on twisted tapes. The working fluid is air in test tube having a constant wall heat-flux with Reynolds number varies between 5300 to 24000. Thermal characteristics of V-ribs parameter such as relative rib height having dimensions BR= b/D= 0.07, 0.09, 0.14 and 0.19 along with relative rib pitch PR=P/D=1.9. at 300 attack angle is investigated. The experimental results shows that pressure drop and heat transfer enhancement in terms of friction factor and Nusselt number in V-ribbed twisted tapes increases as increase in Reynolds number and Blockage ratio (BR). the highest heat transfer and friction factor occurs for BR=0.19, but the maximum thermal enhancement is about 1.4 for the V-ribbed twisted tape having BR=0.09 as compared to no rib tapes which having thermal enhancement 1.09.

K. Nanan [17] studied the impact of perforated helical twisted-tapes (P-HTTs) on the thermal performance characteristics, friction loss and heat transfer under a uniform heat flux condition is reported. The P-HTTs were obtained by punching typical helical twisted-tapes (HTTs) with a prospect to reduce the friction loss of fluid flow. The P-HTTs' having three different diameter ratios (d/w) of 0.2, 0.4 and 0.6 were used for experiments, along with three different perforation pitch ratios (s/w) of 1, 1.5 and 2. The ratio of helical pitch and twist were fixed at P/D = 2 and y/w = 3. The experiment is carried out for Reynolds number ranging between 6000 and 20,000. The experiments for comparison are carried out using the plain tube and the tubes with HTTs for assessment. The experimental results shows that the use of P-HTTs leads to the decreases the friction loss as compare to that of HTT. Heat transfer, friction loss and thermal performance factor increase as d/w decreases and s/w increases. The maximum thermal performance factor of 1.28 is obtained by using the P-HTT with d/w = 0.2 and s/w = 2.0 at the Reynolds number of 6000. The empirical correlations for thermal performance factor, friction factor and Nusselt number give accurate predictions within ±3%, ±6% and ±4%, respectively.

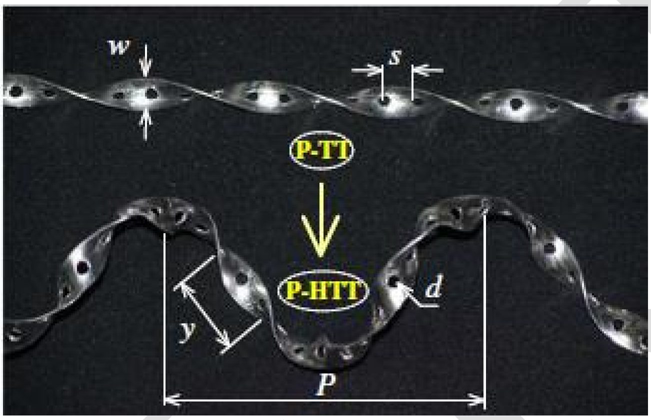

Figure 5 Perforated Twisted Helical Tape

Bhuiya M. M. K [18] presented the study which explored the effect of perforated double countered twist tape on heat transfer and friction characteristics in heat exchanger. The twisted tapes with different percentage of porosities RP= 1.2, 4.6, 10.4 and 18.4 were used as a contour flow generation. The experimentation is conducted for Reynolds number ranging from 7200 to 50000 in turbulent flow region using air as working fluid at constant wall heat flux. The experimental result shows that the friction factor, thermal enhancement efficiency and Nusselt number is increases with decreasing porosities except at 1.2%. the result is also shows that the heat transfer rate of tube with twisted tapes is increases with increase in friction factor. In the range of the present study, friction factor and heat transfer rate were obtained to be around 111 to 335% and 80 to 290% more than those of the plain tube values, respectively. The highest thermal enhancement efficiency of 1.44 was achieved for constant blower power. In addition, the empirical correlations of Nusselt number, friction factor and thermal enhancement efficiency were developed based on the experimental data.

DISCUSSIONS

The thermohydraulic performance of twisted tapes with and without perforation was studied by various investigators in different flow characteristics i.e. laminar and turbulent flow and the performance in laminar flow was found more effective than turbulent flow. Also, the study is conducted for twisted tape with and without perforation. More pressure drop was associated with the use of twisted tapes in turbulent flow. Studied is carried out on rectangular and square duct alog with circular pipes. The more improvement is obtained in rectangular and square duct due to increase in contact area. The study also shows that heat transfer enhancement is more in case of smaller twist ratio. As the Reynolds number increases the increase in friction factor, heat transfer rate is also obtained. Twisted tapes with perforation works more efficiently as compared to twisted tape without perforation and plane inserts. Also, the rate of decrees in pressure drop is relatively less due to reduction in friction factor.

Twisted tapes work relatively better in laminar flow due to efficient mixing of bulk flow. The decreased in friction factor is obtained at low range of Prandtl number, and significantly decreases of Nusselt number. Many studied shows the comparison between short length and full length twisted tapes. This shows that short length twisted tapes gives better performance for constant pumping power. Twisted tapes are not performed well in case of turbulent flow for wide range of Reynolds number. Use of twisted tapes create large pressure drop due to blockage of flow in tube in case of without perforation twisted tapes, but in case of twisted tapes with perforation has less pressure drop due to presence of perforation.

There are some other passive techniques like wire dimple fins rib, coil inserts etc. for heat transfer improvement but these are found efficient in turbulent flow only. Wire coil inserts work better in turbulent flow and having better thermohydraulic performance than twisted tapes. However, in laminar flow the performance of wire coil inserts depends on Prandtl number.

CONCLUSION

It is observed from the earlier studies that use of twisted tapes in heat exchanger systems is quite effective method of heat transfer improvement. Increase of Nusselt number, thermal performance and friction factor is reported by using twisted tapes inserts but accompanied with some pressure drop. Plenty of experimental and numerical research studies have been performed on heat transfer improvement using twisted tape inserts. Different types of geometries have been tested to check the heat transfer augmentation and many useful correlations to determine heat transfer and friction characteristics were developed. Geometry of pipe and twisted tapes, size of perforation, flow characteristics are the major factors to control the thermohydraulic performance.

Some new techniques like perforation on twisted tapes, broken twisted tapes, introduction of nanofluids etc. are also being introduced by the researchers to develop and promote the twisted tape with and without perforation techniques. Studies have also been reported the use of twisted tapes in areas like refrigeration, solar thermal technologies etc. Twisted tapes are also found useful in microfiltration of milk where they found as low pressure loss turbulence promoter. In addition to this, the use of twisted tapes with nanofluids and other geometries is also found very useful. How- ever, more future work in this area will be very effective to develop this technology and more generalised useful correlations will be obtained.

REFERENCES

1) E. S. G. B. R. T. J. Hojjat M, "*Turbulent forced convection heat transfer of non-Newtonian nanofluids," Exp Therm Fluid Sci, vol. 35, pp. 1351-1356, 2011.*

2) F. D. F. H. B. S. Geyer P E, *"Laminar flow and hea ttransfer in a periodic trapezoidal channel with semi-circular cross section," Int J Heat Mass Transfer, pp. 3471-3480, 2007.*

3) H. I. Hsieh SS, "*Heat transfer and pressure drop of laminar flow in horizontal tubes with/without longitudinal inserts.," J Heat Transf (ASME), pp. 465-475, 2000.*

4) Arthur E. Bergles, "*Ex HFT for fourth generation heat transfer technology," Exp Thermal Fluid Science, pp. 335-344, 2002.*

5) M. P. S. R. K. S. K. P. Dewan A, "*Review of passive heat transfer augmentation techniques," Proc IMechE Part A: J Power Energy, vol. 269, pp. 209-214, 2004.*

6) M. P. Kumar CN, "*Review on twisted tapes heat transfer enhancement," Int J Sci Eng Res, pp. 1-9, 2012.*

7) B. P. Patil SV, "*Heat transfer augmentation in a circular tube and square duct fitted with swirl flow generators: a review," Int J Chem Eng , pp. 326-331, Appl 2011.*

8) S. T. K. P. R. V. D. S. K. Sarma P K, "Laminar convective heat transfer with twisted tape inserts in a tube," Int J Therm Sci , pp. 821-828, 2003

9) K. P. D. R. V. S. T. Sharma PK, " *A combined approach to predict friction coefficients and convective heat transfer characteristics in A tube with twisted tape inserts for a wide range of Re and Pr.," Int J Therm Sci, pp. 44-53, 2005.*

10) R. R. M. Aggarwal SK, "*Heat Transfer Augmentation for the flow of a viscous liquid in circular tubes using twisted tape inserts," Int J Heat Mass Transf , pp. 3547-3557, 1996.*

11) C. W. Al-Fahed Sami, "*Effect of tube-tape clearance on heat transfer for fully developed turbulent flow in a horizontal isothermal tube," Int J Heat Fluid Flow, pp. 173-178, 1996.*

12) C. L. C. W. Al-Fahed S, "*Pressure drop and heat transfer comparison for both micro fin tube and twisted tape inserts in laminar flow.," Exp Therm Fluid Sci, pp. 323-333, 1999.*

13) X. M. Liao Q, "*Augmentation of convective heat transfer insides tubes with three dimensional internal extended surfaces and twisted tape inserts," Chem Eng J, pp. 95-105, 2000.*

14) D. A. D. S. Saha SK, "*Friction and heat transfer characteristic of laminar swirl through a circular tube fitted with regularly spaced twisted-tape elements," Int J Heat And Mass Transf , p. 4211–23., 2001.*

15) N. J. S. J. Ujhidy A, "*Fluid flow in tubes with helical elements," Chem Eng Process, pp. 1-7, 2003.*

16) P. E.-a. P. P. S. E.-a. C. Thianpong, "*Effect of perforated twisted-tapes with parallel wings on heat transfer enhancement in a heat exchanger tube," 2nd International Conference on Advances in Energy Engineering (ICAEE), pp. 1117-1123, 2011.*

17) S. B. S. S. M. M. K. B. Bodius Salam, "*Heat transfer enhancement in a tube using rectangular-cut twisted tape insert," 5th BSME International Conference on Thermal Engineering, pp. 93-103, 2013.*

18) Y. K. S. S. b. Sombat Tamna, "*Heat transfer enhancement in tubular heat exchanger with dubble V-ribed twisted tapes," Case StudiesinThermalEngineering, pp. 14-24, 2016.*

19) C. T. P. P. S. E.-a. K. Nanan, "*Investigation of heat transfer enhancement by perforated helical twisted tapes," International Communications in Heat and Mass Transfer, pp. 106-112, 2014.*

20) A. A. M. C. M. S. M.M.K. Bhuiya, "*Heat transfer augmentation in a circular tube with perforated double counter twisted tape inserts," International Communications in Heat and Mass Transfer, 2016.*