International Journal of Advances in Engineering Research http://www.ijaer.com

(IJAER) 2018, Vol. No. 16, Issue No. II, August e-ISSN: 2231-5152, p-ISSN: 2454-1796

REVIEW ON HEAT TRANSFER ENHANCEMENT USING NANO FLUID WITH TWISTED TAPE IN LAMINAR AND TURBULENT FLOW IN A CIRCULAR PIPE HEAT EXCHANGER

Jitendra S. Pachbhai[1], Swarup Y. Vaidhye[2], Ankush M. Hattimare[3], Vikas D. Vaidya[4], Sushil Shahare[5].

[1]*Asst. Professor, Department Of Mechanical Engineering*
J D College of Engineering and Management Nagpur- 441501, Maharashtra.
[2,3,4]*UG Scholar, Department Of Mechanical Engineering,*
J D College of Engineering & Management, Nagpur- 441501, Maharashtra.

ABSTRACT

Nanofluidsare used in broad range of engineering applications due to their improved thermo-physical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficient. In this paper heat transfer enhancement is carried out by using nano fluid and by inserting twisted tape plate in heat exchanger. The aim of this present work is to enhance thermal performance characteristics in a heat exchanger tube by studying: multiple twisted tapes in different arrangements and Al2O3 nanoparticle with different concentration as the working fluid. The tube inserted the multiple twisted tapes showed superior thermal performance factor when compared with plain tube or the tube inserted with a single twisted tape, due to continuous multiple swirling flow and multi longitudinal vortices flow along the test tube. The higher number of twisted tape inserts led to an enhancement of thermal performance that resulted from increasing contact surface area, residence time, swirl intensity and fluid mixing with multi-longitudinal vortices flow. The tube inserted with Al2O3/water nanofluid at different concentrations increase heat transfer rate.

INTRODUCTION

The double pipe heat exchangers are commonly used as heat transfer equipmentin industrial applications because of small size, compactness and easy manufacturing. The most commonly used fluids are water, ethylene glycol, propylene glycol and engine oil. The heat transfer of these fluids is limited because of their low thermal conductivity values. Choi[1] and his team develop nanofluids, which is prepared by dispersing nanometer size solid particles in water, ethylene glycol, propylene glycol and they observed increased thermal conductivity values compared to base fluids.These enhanced thermal conductivity values make the use of nanofluids in heat exchange devices highly desirable.Sudarmadjietal.[2] prepared Al2O3/water nanofluids with particle volume concentrations of 0.15, 0.25 and 0.5; they conducted heat transfer experiments for these nanofluids flowing in a tube and they observed Nusselt number increment of 40.5% compared to pure water under 0.5% volume concentration. Duangthongsuk and Wongwises [3] observed heat transfer enhancement of 11% at 0.2% volume of TiO2/water nanafluids flow in a horizontal double tube counter flow heat exchanger under turbulent flow conditions.

For further convective heat transfer enhancement, Turbulent promoters(twistedtape, longitudinal stripe, helical tape, screw tape, etc.) are generally used inside the fluid flow. The twisted tape are one of turbulent promomoters, which are used for further heat transfer enhancement. The concept of twisted tape inserts was used Manglik and Bergles [4,5], Lopina and Bergles [6], Thorsen and Landis[7], for single phase fluid flow in a tube and they develop nusselt number and friction factor correlations. After that, nanofluids flow in a tube with twisted tape inserts whereanalyzed by Sunder and Sharma[17]. They considered Al2O3 nanofluids flow in a tube with twisted tape insert and develop nusselt number and friction factor correlations.Wongcharee and Eiamsa-ard [18], conducted heat transfer, friction and thermal performance characteristics of CuO /water nanofluid flow in a tube with twisted tape with alternate axis and obtained that, the nusselt number increase upto 12.8 and 7.2 times of the plane tube and further increases to 13.8 with twisted tape insert at 0.7% volume concentration and at Reynolds number of 1990.

TWISTED TAPE

The pipe in flow to spiral along the tube length the tape is inserted generally do not have good thermal contact with tube wall, so the tape does not act as fin, The corrugation channel are used in this paper and twisted tape have been investigated for circular tube this may increased the heat transfer rate and also give increase in pressure drop.

1.Terminology used in Twisted Tape

1.1. Thermo hydraulic performance

For a particular Reynolds number, the thermo hydraulic performance of an insert is said to be good if the heat transfer coefficient increases significantly with a minimum increases in friction factor Thermo hydraulic performance estimation is generally used to compare the performance of different inserts under a particular fluid flow condition.

1.2. Overall Enhancement ratio

The overall enhancement ratio is defined as the ratio of the heat transfer enhancement ratio to the friction factor ratio.

1.3. Reynolds Number

The Reynolds number is the ratio of the inertia force to the viscous force within a fluid which is subjected to relative internal movement due to different velocities, in what is known as a boundary layer in the case of a bounding surface such as the interior of a pipe.

1.4 Nusselt Number

The Nusselt Number is a measure of the convective heat transfer occurring at the surface and is define as **hd/k,** where **h** is the convective heat transfer coefficient, **d** is the diameter of the tube and **k** is the thermal conductivity.

1.5 Prandtl Number

The Prandlt Number is define as the ratio of molecular diffusivity of the momentum of the molecular diffusivity of heat.

Pitch

The Pitch is define as the distance between two points that are on same plane, measure parallel to the axis of a twisted tape.

1.6 Twist Ratio

The Twist Ratio is the define as the pitch length to the inside diameter of the tube.

1.7 Pressure Drop

Pressure Drop is the define as the difference in total pressure between two points of a fluid carrying network. Pressure drop occurs when the frictional forces, caused by the resistance to flow, act on a fluid as it flows through the tube.

2.Following are the different types of twisted tape arrangement, such as **Plane Twisted Tape(PTT), Modified Twisted Tape(MTT), Modified Geometry Twisted Tape (MGTT).**

2.1 Plane Twisted Plane

a) Behabadi [10] experimental investigated heat transfer coefficients and pressure drop during condensation of HFC – 134a in a horizontal tube fitted twisted tapes. The refrigerant flows in the inner copper and the cooling water flows in annulus. Also imperical correlation where develop to predict smooth tube and swirl flow pressure drop.

b) Syamsunder and Sharma [11] in investicated the thermo physical properties like thermal conductivity and viscosity of Al_2O_3 nanofluid is determine through the experiments at different volume concentrations and temperatures.from the result it is observed that, heat transfer coefficients and friction factor is higher when compared to water in a plane tube. Also a generalised regression equation is developed with the experimental data for the estimation of the friction factor and the nusselt number.

c) Promvonge [12] experimentally investicated the heat transfer rate, friction factor and thermohydraulic efficiency of the combined devices of the twisted tapes and wire coil. The experiment carried out by arranging in two different forms:(1) decreasing coil and (2) decreasing / increasing coil while the twisted tape was prepare with two different twist ratios.

2.2 Modified Twisted Tape

a) Yadav [13] experimentally investigated on the half length twisted tape in insertion on heat transfer and pressure drop characteristics in a U- bend double pipe heat exchanger. The experimental result revealed that the increase in heat transfer rate of the twisted tape inserts is found to be strongly influenced by tape- induced swirl.

b)Eiamsa-ard [14] an experimental study on the mean nusselt number, friction factor and thermal performance factor in a round tube with sort – length twisted tape insert. the full – length twisted tape inserted into the tested tube at a single point where pitch ratio(y)=4.0.while the short- length tapes mounted at the entry test section. The experimental result indicates that the presence of the tube with short- length twisted tape insert yield higher heat transfer rate.

c) Saha[15] experimentally investigated heat transfer enhancement and the pressure drop characteristics in the tube with regularly spaced twisted tape element. From the result, it is the observed that pinching of tape rather than in connecting the tape element with rods is be twisted tapers proportion from thermohydraulic point of view.

d) Mengna[16] investigated experimentally the pressure drop and compound heat transfer characteristics of a converging-converging tube with evenly spaced twisted tape(converging-diverging tube).swirl cause generated by evenly spaced twisted- tape elements which vary in twist ratio and rotation angle.

e) Tromvonge and Eiamsa-ard[17] investigated thermal characteristics in a circular tube fit twisted taped with conical – ring and a twisted tape swirl generator. The experimental result reveal that the tube fit twisted taped with conical – ring and twisted tape provides Nusselt values of around 4 to 10% and enhancement efficiency of 4 to 8% higher than that with the conical ring alone.

2.3 Modified Geometry Twisted Tape

a) Wei Liu et al. [18] investigated numerically the Heat exchanger and friction factor characteristics of laminar flow in a tube with short-width and centre cleared twisted tape. It is given that centre cleared twisted tape is good technique in lamina flow and the heat transfer can be enhanced with a change in central clearance ratio.

b) Eiamsa-ard and wongcharee [19] experimentally investigated heat exchanger, friction factor and thermal performance factor characteristics of CuO/water nanofluid and modified alternate axis twisted tape. The use of nanofluid with the alternate axis twisted tape provides considerably higher Nusselt number and thermal performance factor than that of nanofluid with the plain twisted tapes. .

c) Murugesan et al. [20] investigated experimentally the heat exchanger, friction factor and thermal performance factor characteristics of tube fit tapered with v cut twisted tapes. The obtained results show that the mean Nusselt number and the mean friction factor in the tube with v cut twisted tapes increases with in decrease pitch ratio.

d) Radhakrishnan. et al. [21] made experimental investigation on heat exchanger, friction factor and thermal performance factor of thermosyphon solar water heater system fit tapered with full- length twist, twist fit tapered with rod and spacer fit tapered at the trailing edge. Conclusions made from the results show that heat exchanger in twisted tapes collector is higher than the plain tube.

e) Bharatdwaj [22] experimentally determined pressure drop and heat transfer characteristics of flow of water in a 75 start spirally grooved tube with twisted tape insert are presented. It is found heat exchanger in spiral tube is higher when compared to plain tube.

f) Eiamsa-ard [23] investigated the Effects of plain twisted tapes insert on heat transfer, friction factor and thermal performance factor characteristics in a round tube. Nine different plain twisted tapes with pitch ratio, different Depth Ratio and different width ratio were tested. From the result, it is revealed that Nusselt number, friction factor and thermo hydraulic performance are found to be increased with depth ratio and width ratio.

g) Chang [24] experimentally examined the turbulent heat transfer in a swinging tube with a serrated twisted tapes insert under seagoing conditions. This swirl tube swings about two orthogonal axes under single and compound rolling and pitching oscillations. Synergistic effects of compound rolling and pitching oscillations with either harmonic or non-harmonic rhythms improve heat transfer performances.

h) Chang et al. [25] experimental study that comparatively examined the spiky twisted-tape insert (swirl tube) placed in a tube. The dispersed rising air bubbles in the plain tube and the centrifugal-force induced coherent spiral stream of coalesced bubbles in the swirl-tube core considerably modify the pressure-drop and heattransfer performances from the single-phase conditions.

3.Nanofluid

PREPARATION OF NANOFLUID

Selection of nanoparticles and then making it ready for experimentation is one of the primary tasks. This procedure involves procuring nanoparticles preparing the nanofluid after mixing it with the base fluid and most significantly characterization of the nanofluid. In this study silica and tungsten oxide nanoparticles were procured from Sigma Aldrich Technologies Corporation USA.

3.1 Selection of nanoparticles

The thermal conductivity of heating or cooling fluids is a very important property in the development of energy efficient systems. The thermal conductivity of the fluids is one of the basic properties taken into account in designing and controlling the process. Materials used for nanoparticlesinclude chemically stable metals (e.g., Aluminium, Gold, Silver, Copper), metal oxides (e.g., Alumina, Copper oxide, Zirconia, Silica, Titanium) and carbon in various forms (e.g., Diamond, Graphite, Carbon nanotubes etc). Prime factors to be considered are ease of availability, costs, thermal conductivity, tendency of the particles to hold them into the base fluid with negligible agglomeration etc. Even though metal particles have better thermal conductivity, they have more inclination to agglomerate compared to metal oxides. Present in this work Silica and Tungsten oxide were used.

3.2 Details of the Nanoparticles Procure

The nanoparticles were procured from Sigma Aldrich Technologies Corporation the details are given below.

Properties of nanoparticles

Items Aluminium Oxide

Content ≥ 99% purity ≥ 99% purity

Average particle size; 12nm 100nm

Specific surface area; 160m2/g 210m2/g

Density (ρ); 2220kgm-3 4157 kgm-3

3.3 Base fluid and Nanoparticle materials

Numerous and various nanoparticle materials are used for nanofluid preparation. Al2O3, TiO2, CuO, Au, TiC, Ag, SiC, Cu and Fe nanoparticles are generally used in nanofluid study. Carbon nanotubes are also utilized due to their very high thermal conductivity in the longitudinal way. Conventional base fluids typically used in the making of nanofluids are the universal functional fluids of heat transfer applications such as ethylene glycol water and engine oil. To expand the durability of nanoparticles inside the conventional base fluids some additives are added to the combination in small amount.

Nanoparticle sizes

Nanoparticles used in nanofluids preparation usually have diameters below 100nm.Particles as small as 10nm, 12nm, 20nm, 25nm, 30nm, 40nm, 50nm, 100nm has been used in nanofluids study. The nanoparticles are not spherical but rod or cylindrical shaped the diameter is quit less than 100nm, but length of the nanoparticles might be in the order of micrometers, it should also be remembered that due to the clustering fact, particles may form clusters with sizes by the order of micrometers. Nanoparticle shape Spherical shaped particles are widely used in nanofluids. However, rod shaped, tube shaped and disk shaped nanoparticles are also used. While, the clusters formed by nanoparticles may fractal like shapes.

3.4 Preparation of nanofluid process

In this work to prepare the nanofluid with desired concentration, nanoparticles were equivalently dispersed into pure water. The characteristics of nanofluids are governed by not only the type and size of the nanoparticles but also their dispersion status in the pure water. Appropriate care was taken to make sure complete dispersion. After weighing the solid nanoparticles were mixed with pure water in a flask, and then Each time, To mix the nanoparticles uniformly vibrating machine was used for about 3 – 4 hrs. Noconsiderable sedimentation was observed for the range of concentrations tested even after 24 hrs. Preparation of nanofluid is the starting step in experimental research with nanofluids. Nanofluids are not just diffusion of solid particles in a fluid. The primary desire that nanofluids must accomplish is smooth and permanent suspension, significant agglomeration of particles, no chemical variation of the particles or fluid, etc. Nanofluids are formed by dispersing nano size solid particles into conventional base fluids such as ethylene glycol, water, transformer oil, etc. In the production of nanofluids, agglomeration is a most important problem. There are mainly two techniques of nanofluids production, namely two-step technique and single-step technique. In the two-step technique, the first step is the production of nanoparticles and the second step is the mixing of the nanoparticles in a conventional base fluid.

3.4.1 Two – step technique

Two- step technique is extensively used method for preparing nanofluids. Nanoparticles, nanotubes, nanofibers and other nonomaterials used in this technique are first formed as dry powders by physical and chemical methods. Then the nano sized gauge powder will be spread into a base fluid in the second dispensation step with the help of exact magnetic force trouble, ultrasonic shake up, high shear mixing, homogenizing and ball milling. Two-step technique is the most cost-effective method to generate nanofluids in big scale, nanoparticles can be prepared in enormous quantities by utilizing the method of inert gas condensation. The main drawback of the two-step technique is that the nanoparticles form clusters during thepreparation of the nanofluids which avoids the correct mixing of nanoparticles inside the conventional base fluid . Due to high surface action and surface area, nanoparticles have the tendency to summate. The popular method to increase the stability of nanoparticles in conventional base fluids is the use of surfactants. But, the operational of the surfactants under high temperature is too a big problem, particularly for high temperature situations. Due to the difficulty that occurred in preparing steady nanofluids by two-step technique, more than a few advanced techniques are used to produce nanofluids including single-step technique.

3.4.2 Single – step technique

The single step technique concurrently used makes and disperses the nanoparticles straight into a conventional base fluid best for metallic nanofluids. Several different techniques have been tried to fabricate dissimilar kinds of nanoparticles and nano suspensions. The preliminary materials tried for nanofluids were oxide particles, primarily because they were easy to produce and chemically stable in solution. Various investigators have produced CuO, FeO and Al_2O_3 nanopowder by an inert gas condensation process and establish to be 20 -200 nm sized particles. The spreading features of nanofluids formed with single step method are better than those produced with two step method.

(IJAER) 2018, Vol. No. 16, Issue No. II, August **e-ISSN: 2231-5152, p-ISSN: 2454-1796**

The major disadvantage of single step method is that they are not good for mass production which restricts their commercialization. The fore most problem with this technique is its affinity to form clusters and its incompatibility to fabricate pure metallic nano powders. The problem of clustering can be compact to a good degree by using a direct evaporation condensation method.

CONCLUSION

In this work ,we examined a few theories published in the literature explaining the heat transfer enhancement due to adding a small percentage of nano-particles to a fluid and by using different type of twisted plate. The combination of nano fluid and twisted plate without using conventional fluid and double pipe heat exchanger definitely enhance heat transfer due to their different properties.

This review has considered heat transfer and investigations of thenano fluid and various twisted tape placed in heat exchangers. Almost all possible research subjects have been summarized on the case in the literature, such as heat transfer and studies according to plain twisted tape, modified twisted tape, and modified twisted tape geometry. A twisted tape and modified twisted tape inserts mixes the bulk flow well and therefore performs better in laminar flow, because in laminar flow the thermal resistant is not limited to a thin region. The result also shows twisted tape insert is more effective in laminar flow, and pressure drop penalty is created during turbulent flow. In case of twisted tape with modified geometry, more turbulence is created during the swirl of fluid and gives higher heat transfer rate compared to plain twisted tape and modified twisted tape. The result shows that for modified twisted tape geometry, the heat transfer rate is higher with reasonable friction factor for both laminar and turbulent flow. These conclusions are very useful for the application of heat transfer enhancement in heat exchanger networks.

REFERENCE

[1] Proceedings of the 1995 ASME International Mechanical Engineering Congress andExposition San Francisco, CA, USA, 1995.

[2] S. Sudarmadji S. Soeparman, S. Wahyudi, N. Hamidy, Effects of cooling process ofAl2O3-water nanofluid on convective heat transfer, Fac. Mech. Eng. Trans., 42,2014,pp.155–161.

[3]W.Duangthongsuk, S. Wongwises, Heat transfer enhancement and pressure dropcharacteristics of TiO2–water nanofluid in a double-tube counter flow heat ex-changer, Int. J. Heat Mass Transf., 52,2009,pp. 2059–2067.

[4] R.M. Manglik, A.E. Bergles, Heat transfer and pressure drop correlations for twistedtape inserts in isothermal tubes: part I–laminar flows, J. Heat Transf. 115 (1993),pp.881–889.

[5] R.M. Manglik, A.E. Bergles, Heat transfer and pressure drop correlations for twisted-tape inserts in isothermal tubes: part II—transition and turbulent flows, J. HeatTransf. 115 (1993),pp. 890–896.

[6] R.F. Lopina, A.E. Bergles, Heat transfer and pressure drop in tape generated swirlflow of single phase water, J. Heat Transf. 91 (1969),pp. 434–442.

[7] R. Thorsen, F. Landis, Friction and heat transfer characteristics in turbulent swirlflow subjected to large transverse temperature gradients, J. Heat Transf. 90 (1968),pp.87–98.

[8] L.S. Sundar, K.V. Sharma, Turbulent heat transfer and friction factor of Al2O3 nanofluid in circular tube with twisted tape inserts, Int. J. Heat mass transfer 53 (2010) ,pp.1409-1416.

[9] K. Wongcharee, S. Eiamsa-erd, Enhancement of heat transfer using CoO/water nanofluid and twisted tape with alternate axis, Int. Commune. Heat Mass Transfer 38 (2011) ,pp.742-748.

[10] V. Hejazi, M.A. Akhavan-Behabadi and A. Afshari, Experimental investigation of twisted tape inserts performance on condensation heat transfer enhancement and pressure drop, International Communications in Heat and Mass Transfer, Vol. 37 (2010), pp. 1376–1387.

[11] L. Syam Sundar and K.V. Sharma, Turbulent heat transfer and friction factor of Al2O3 Nanofluid in circular tube with twisted tape inserts, International Journal of Heat and Mass Transfer, Vol. 53 (2010), pp. 1409–1416.

[12] S. Eiamsa-ard, P. Nivesrangsan, S. Chokphoemphun and P. Promvonge, Influence of combined non-uniform wire coil and twisted tape inserts on thermal performance characteristic, International Communications in Heat transfer, Vol. 37 (2010), pp. 850–856

[13] Anil Yadav, Effect of half length twisted tape turbulator on heat transfer & pressure drop characteristics inside a double pipe U-bend heat exchanger, Jordan journal of Mech. & Industrial engg., Vol. 3 No.1 (2009), pp. 17-22.

[14] S. Eiamsa-ard, ChinarukThianpong, PetpicesEiamsa-ard and PongjetPromvonge, Convctive heat transfer in a circular tube with short-length twisted tape insert, International communication in Heat and Mass Transfer, Vol. 36 (2009), pp. 365-371.

[15] Saha, S. K, Dutta, A. and Dhal, S. K., Friction and heat transfer characteristics of laminar swirl flow through a circular tube fitted with regularly spaced twisted-tape elements, International Journal of Heat and Mass Transfer, Vol. 44 (2001), pp. 4211-4223.

[16] HONG Mengna, DENG Xianhe, HUANG Kuo and LI Zhiwu, Compound heat transfer enhancement of a convergingdiverging tube with evenly spaced twisted-tapes, Chinese Journal of Chemical Engineering, Vol. 15 No.6 (2007), pp. 814—820.

[17] P. Promvonge and S. Eiamsa-ard, Heat transfer behaviors in a tube with combined conical ring and twisted-tape inserts, International Communications in Heat and Mass Transfer Vol. 34 (2007), pp. 849–859.

[18] Jian Guo, Aiwu Fan, Xiaoyu Zhang and Wei Liu, A numerical study on heat transfer and friction factor characteristics of laminar flow in a circular tube fitted with center-cleared twisted tape, International Journal of Thermal Sciences Vol. 50 (2011), pp. 1263-1270.

[19] K.Wongcharee and S. Eiamsa-ard, Enhancement of heat transfer using CuO/water nanofluid and twisted tape with alternate axis, International Communications in Heat and Mass Transfer Vol. 38 (2011), pp. 742–748.

[20] P. Murugesan, K. Mayilsamy, S. Suresh and P.S.S. Srinivasan, Heat transfer and pressure drop characteristics in a circular tube fitted with and without V-cut twisted tape insert, International Communications in Heat and Mass Transfer Vol. ,38 (2011), pp. 329–334.

[21] S. Jaisankar, T.K. Radhakrishnan and K.N. Sheeba, Experimental studies on heat transfer and friction factor characteristics of thermosyphon solar water heater system fitted with spacer at the trailing edge of twisted tapes, Applied Thermal Engineering Vol. 29 (2009), pp. 1224–1231.

[22] Bharadwaj, A.D. Khondge and A.W.Date, Heat transfer & pressure drop in spirally grooved tube with twisted tape insert, J. Heat Transfer, Vol. 52 No.5 (2009), PP. 1938-1944.

[23] S. Eiamsa-ard, PanidaSeemawute and K. Wongcharee, Influences of peripherally-cut twisted tape insert on heat transfer and thermal performance characteristics in laminar and turbulent tube flows, Experimental Thermal and Fluid Science, Vol. 34 (2010), pp. 711–719.

[24] S.W. Chang, Tong-MiinLiou, JinShuenLiou and Kun-Tse Chen, Turbulent heat transfer in a tube fitted with serrated twist tape under rolling and pitching environments with applications to shipping, Journal of Ocean Engineering, Vol. 35 (2008), pp. 1569-1577.

[25] S.W. Chang, Arthur William Lees and Hsien-Tsung Chang, Influence of spiky twisted tape insert on thermal fluid performances of tubular air–water bubbly flow, International Journal of Thermal Sciences Vol. 48 (2009), pp. 2341– 2354.