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Review Article

NANOFLUID HEAT TRANSFER ENHANCEMENT WITH TWISTED TAPE INSERT—A REVIEW

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Heat transfer enhancement techniques are of different methods which used to increase rate of heat transfer without affecting much overall performance of the system. As these techniques are used in heat exchangers. The heat transfer enhancement can be done by using passive technique just by changing the flow geometry, boundary conditions, or by enhancing the thermal conductivity of the fluid. Much research has been takes place to increase the heat transfer rate by increasing the thermal conductivity of fluid with twisted tape type of insert. Increase in thermal conductivity can be achieved by use of nanopowder with base fluid. The present paper mainly focuses on the twisted tape heat transfer enhancement with nanofluid.

Keywords: Heat transfer enhancement, Nanofluid, Inserts, Twist ratio, Passive technique

INTRODUCTION

Heat transfer phenomenon is widely used to prevent the overheating and improvement of heat transfer rate of various applications area such as heat exchanger, transportation vehicle, process industries and various thermal systems. Heat transfer enhancement with nanofluid and twisted tape inserts has gained significant attention over the past few years. To improve the heat transfer rate in heat exchangers namely two methods are used one is active and another one is passive. Apart from nanofluid conventional fluids such as ethylene glycol, water are unable to meet increasing demand for cooling in high energy applications this all due to the fact that conventional fluids are having low thermal conductivity property. Heat transfer enhancement refers to different methods used to increase rate of heat transfer without affecting much to the overall performance. Use of twisted tape inserts with nanofluid have been widely used for enhancing the convective heat transfer in various applications it's all due to their effectiveness and low cost.

CLASSIFICATION OF ENHANCEMENT TECHNIQUES

Heat transfer enhancement techniques are classified into three different categories:

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Passive Heat Transfer Enhancement Technique: This method do not required any direct input of external power source rather this technique uses the power source from system itself which ultimately leads to an increase in pressure drop. This method generally uses surface or geometrical modifications to flow channel introducing inserts or other additional devices.

Active Heat Transfer Enhancement Technique: In this method there is a requirement of an external power input for enhancement of heat transfer, an example of active technique includes induced pulsation by cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream.

Compound Technique: This technique refers to the combination of both above two techniques, i.e., active and passive heat transfer enhancement technique. This technique involves complexity in design due to which it has limited applications.

NANOTECHNOLOGY

The word nanotechnology is new, but their existences of functional devices are not new to the world. In 1905, experimental data on diffusion theory showed that molecule has nanometer diameter, which is considered as landmark in scientific history of technology. Nanofluid is used for huge variety of industries such as transportation system, energy production and electronic system etc. Reasons of wide application of nanofluid in industries are its long term stability, increase pumping power and pressure drop, nanofluid thermal performance in turbulent and fully developed region low specific heat of nanofluid.

TERMS USED IN TWISTED TAPE

Twist Ratio: Twist ratio is defined as ratio of pitch length to inside diameter of tube.

Twisted Tape: Twisted tape is defined as a metallic strip twisted with a suitable technique with desired shape and dimensions, inserted in the flow.

Pitch: Pitch is defined as distance between two points that are on same plane measured parallel to the axis of twisted tape.

LITERATURE SURVEY

Sundar and Sharma (2010a), studied experimentally the heat transfer enhancements of low volume concentration of Al_2O_3 nanofluid and with longitudinal strip inserts in a circular tube. The main aim is to study the convective heat transfer and friction factor for Al_2O_3/water nanofluid with different aspect ratio. Experiments are conducted with water and nanofluid in the range of $3000 < Re < 22,000$, particle volume concentration $0 < u < 0.5\%$ and longitudinal strip aspect ratios of $0 < AR < 18$. The friction factor of 0.5% volume concentration nanofluid with longitudinal strip insert having AR = 1 is 5.5 times greater at 3000 Reynolds number and 3.6 times at 22,000 Reynolds number when compared to water or nanofluid flowing a tube. The heat transfer coefficient of 0.5% volume concentration Al_2O_3 nanofluid with longitudinal strip insert having AR = 1 is 50.12% and 55.73% greater at Reynolds number of 3000 and 22,000, respectively compared to the same fluid and 76.20% and 80.19% greater compared to water flowing in a plain tube.

Sundar and Sharma (2010b), studied turbulent heat transfer and friction factor of

Al_2O_3 Nanofluid in circular tube with twisted tape inserts. The main aim of this study is to determine the thermophysical properties like thermal conductivity and viscosity of Al_2O_3 nanofluid is determined through experiments at different volume concentrations and temperatures and validated. Convective heat transfer coefficient and friction factor data at various volume concentrations for flow in a plain tube and with twisted tape insert is determined experimentally for Al_2O_3 nanofluid. Experiments are conducted in the

Reynolds number range of 10,000-22,000 with tapes of different twist ratios in the range of 0 < H/D < 83. The heat transfer coefficient and friction factor of 0.5% volume Concentration of Al_2O_3 nanofluid with twist ratio of five is 33.51% and 1.096 times respectively higher compared to flow of water in a tube.

Sundar and Ravi Kumar (2012), studied Effect of full length twisted tape inserts on heat transfer and friction factor enhancement with Fe_3O_4 magnetic nanofluid inside a plain tube:An experimental study. The main aim to study turbulent convective heat transfer and friction factor characteristics of magnetic Fe_3O_4 nanofluid flowing through a uniformly heated horizontal circular tube with and without twisted tape inserts. Experiments are conducted in the particle volume concentration range of 0 < u < 0.6%, twisted tape inserts of twist ratio in the range of 0 < H/D < 15and Reynolds number range of 3000 < Re < 22000. Heat transfer and friction factor enhancement of 0.6% volume concentration of Fe_3O_4 nanofluid in a plain tube with twisted tape insert of twist ratio H/D = 5 is 51.88% and 1.231 times compared to water flowing in a plain tube under same Reynolds number. Heat transfer enhancement is observed with twisted tape inserts into plain tube. Under 0.6% volume concentration of Fe_3O_4 nanofluid in plain tube with twisted tape insert, H/D = 5 is 16.06% and 18.49% at Reynolds number 3000 and 22,000, respectively compared to the same volume concentration of fluid flowing in plain tube without insert. In the similar way,the heat transfer enhancement of 0.6% nanofluid in plain tube with twisted tape insert, H/D = 5 is 43.37% and 51.88% compared to water flowing in a plain tube without inserts at Reynolds number 3000 and 22,000, respectively.

Sharma *et al.* (2009), studied Estimation of heat transfer coefficient and friction factor in the transition flow with low volume concentration of Al_2O_3 nanofluid flowing in a circular tube and with twisted tape insert. The aim of this study is to evaluate heat transfer coefficient and friction factor for flow in a tube and with twisted tape inserts in the transition range of flow with Al_2O_3 nanofluid. The heat transfer coefficient of nanofluid flowing in a tube with 0.1% volume concentration is 23.7% higher when compared with water at number of 9000. Heat transfer coefficient and pressure drop with nanofluid has been experimentally determined with tapes of different twist ratios and found to deviate with values obtained from equations developed for single-phase flow. The heat transfer enhancement of Al_2O_3 nanofluid in circular tube with 0.1% volume concentration is 13.77% at 3000 Reynolds number and 23.69% at 9000 Reynolds number when compared to water.

Mohammed *et al.* (2013), studied Heat transfer enhancement of nanofluids in a double pipe heat exchanger with louvered strip inserts. The main aim to study. The effect of using louvered strip inserts placed in a circular double pipe heat exchanger on the thermal and flow fields with various types of nanofluids. Two different louvered strip insert arrangements are used in this study with a Reynolds number range of 10,000 to 50,000. Four different types of nanoparticles, Al_2O_3, CuO, SiO_2, and ZnO with different volume fractions in the range of 1% to 4% and different nanoparticle diameters in the range of 20 nm to 50 nm, dispersed in a base fluid are used. The maximal skin friction coefficient of the enhanced tube is around 10 times than that of the smooth tube. It is found that SiO_2 nanofluid has the highest Nusselt number value, followed by Al_2O_3, ZnO, and CuO while pure water has the lowest Nusselt number.

Darzi Rabienataj *et al.* (2012), studied Turbulent heat transfer of Al_2O_3-water nanofluid inside helically corrugated tubes: Numerical study. The main aim to study turbulent heat transfer in heated helically corrugated tube was investigated numerically for pure water and water–alumina nanofluid using two phase approach. The study was carried out for different corrugating pitch and height ratios at various Reynolds numbers ranging from 10,000 to 40,000. Results show that the heat transfer enhancement is promoted extremely by increasing the volume fraction of nano-particles. Adding 2% and 4% nano-particles by volume to water enhances the heat transfer by 21% and 58%, respectively. Result shows that adding 4% nanoparticles by volume causes to enhance the heat transfer of corrugated tube by a factor of 1.58. The overall enhancement of heat transfer using nano-particles and helical corrugation roughness can promote this factor up to 3.31.

Naik *et al.* (2013), studied Experimental investigation of heat transfer and friction factor with water-propylene glycol based CuO nanofluid in a tube with twisted tape inserts. The main aim to study Convective heat transfer and friction factor characteristics of water/ propylene glycol based CuO nanofluids flowing in a plain tube are investigated experimentally under constant heat flux boundary condition. Experiments are conducted using CuO nanofluids with 0.025%, 0.1% and 0.5% volume concentration in the Reynolds numbers ranging from $1000 < Re < 10000$. The effect of twisted tape inserts with twist ratios in the range of $0 < H/D < 15$ on nanofluids is studied and further heat transfer augmentation is noticed. The convective heat transfer coefficient increased up to 27.95% in the 0.5% CuO nanofluid in plain tube and with a twisted tape insert of $H/D = 5$ it is further increased to 76.06% over the base fluid at a particular Reynolds number. The friction factor enhancement of 10.08% is noticed and increased to 26.57% with the same twisted tape, when compared with the base fluid friction factor at the same Reynolds number.

Suresh *et al.* (2011), studied Comparative study on thermal performance of helical screw tape inserts in laminar flow using Al_2O_3/water and CuO/water nanofluids. The main aim to study a comparison of thermal performance of helical screw tape inserts in laminar flow of Al_2O_3/water and CuO/water nanofluids through a straight circular duct with constant heat flux boundary condition. The helical screw tape inserts with twist ratios $Y = 1.78$, 2.44 and 3 were used in the experimental study using 0.1% volume concentration Al_2O_3/water and CuO/water nanofluids. Both Al_2O_3/water and

CuO/water nanofluids for a low volume fraction of 0.1% show a very high enhancement in heat transfer rate. The greater enhancement shown by CuO/water nanofluid compared to Al_2O_3/water nanofluid may be because of the greater surface to volume ratio and higher thermal conductivity of CuO nanoparticles compared to Al_2O_3 particles.

Chandrasekar *et al.* (2010), studied Experimental studies on heat transfer and friction factor characteristics of Al_2O_3/water nanofluid in a circular pipe under laminar flow with wire coil inserts. The main aim to study fully developed laminar flow convective heat transfer and friction factor characteristics of Al_2O_3/water nanofluid flowing through a uniformly heated horizontal tube with and without wire coil inserts. For this purpose, Al_2O_3 nanoparticles of 43 nm size 0.1% volume concentration of nanoparticles are used. Dilute Al_2O_3/water nanofluid having a very low volume concentration of 0.1% increased the Nusselt number by 12.24% at Re = 2275 compared to that of distilled water. Further enhancements in Nusselt numbers is observed when Al_2O_3/water nanofluid is used with wire coil inserts. Nusselt numbers were increased by 15.91% and 21.53% when Al_2O_3/water nanofluid is used with wire coil inserts WC2 and WC3 respectively at Re = 2275 compared to those of distilled water.

Suresh *et al.* (2012), studied A comparison of thermal characteristics of Al_2O_3/water and CuO/water nanofluids in transition flow through a straight circular duct fitted with helical screw tape inserts. The main aim to study a comparison of thermal characteristics of Al_2O_3/water and CuO/water nanofluids in transition flow through a straight circular duct fitted with helical screw tape inserts. The helical screw tape inserts with twist ratios Y = 1.78, 2.44 and 3 with 0.1% volume concentration Al_2O_3/water and CuO/water nanofluid. The average increase in Nusselt number corresponding to the twist ratios of 1.78, 2.44 and 3 were 166.84%, 128.67% and 89.22% respectively for Al_2O_3/water nanofluid. In the case of CuO/water nanofluid, the enhancements in Nusselt number were 179.82%, 144.29% and 105.63% for twist ratios 1.78, 2.44 and 3 respectively. The thermal performance factor varies between 1.22 and 1.14 for twist ratio Y = 1.78, between 1.15 and 1.02 for twist ratio Y = 2.44, and between 1.07 and 0.94 for twist ratio Y = 3 when used with 0.1% CuO/water nanofluid. When used with Al_2O_3/water nanofluid of 0.1% volume concentration, the corresponding ranges of thermal performance factor are 1.2 to 1.02 for Y = 1.78, 1.13 to 0.95 for Y = 2.44, 1.06 to 0.87 for Y = 3.

Nasiri *et al.* (2011), studied experimental heat transfer of nanofluid through an annular duct. The nanofluids were Al_2O_3 and TiO_2 with water as the base fluid. The range of the Reynolds number for both the nanofluids were 4000 and 13000. The volume concentration for both fluids was 0.1, 0.5, 1.0, and 1.5% of Al_2O_3 and TiO_2. Both nanofluids shows higher Nusselt number than those of the base fluids and enhancement increases with the particle concentration. At Peclet number about 24400, the enhancement of Nusselt number for Al_2O_3/H_2O nanofluid with concentration of 0.1%, 0.5%, 1.0%, 1.5% are 2.2%, 9%, 17% and 23.8% respecitively. For TiO_2/H_2O nanofluid, at Peclet number 53200 the increment in the Nusselt number with particle concentration of 0.1, 0.5, 1.0, and 1.5% are

1%, 2%, 5.1%, and 10.1%. Relative enhancement in the heat transfer coefficient is increased by increasing in the nanoparticle concentration for both nanofluids. This may be due to thermal conductivity of the nanofluid, the presence of the Brownian motion, nanoparticle migration in nanofliuid, possible slip at the wall, and thinner boundary layer thickness. Comparision shows similar properties for both nanofluids with the particle concentration are same. This can be related to the higher thermal conductivity and lower particle size of Al_2O_3 nanoparticles in Al_2O_3-water nanofluid.

The various authors have performed the experimentation related to heat transfer enhancement with nanofluid and inserts of different form. Various forms of inserts are available such as twisted tape, helical wire coiled, helical screw tape, etc., with various oxide forms of nanofluids are Al_2O_3, TiO_2, SiO_2, CuO, ZnO, Fe_3O_4, etc. Amongst all Al_2O_3 and CuO were frequently used this all due its easy suspension quality in base fluid. Higher the concentration of nanofluid results into considerably high thermal performance. Proper handling of nanofluid is very much essential to reduce its oxidation.

CONCLUSION

This review paper has considered heat transfer, pressure drop and thermal performance investigation for laminar and turbulent flow of various twisted tape with different twist ratio and nanofluid with different concentration. Use of fine grade of nanoparticles results in increase in the surface area which results in increase rate of heat transfer. With modified geometry of twisted tape more turbulent the flow during the swirl of fluid gives higher heat transfer rate compare to plane twisted tape.

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