Australian Journal of Basic and Applied Sciences, 7(9): 97-102, 2013
ISSN 1991-8178

Enhancements Of Heat Transfer Nanofluid Flow In Circular Pipe With Twisted Tape Inserts: Review

[1]Tuqa Abdulrazzaq, [2,3]Hussein Togun, [1]M.K.A Ariffin, [2]S.N. Kazi, [2]A. Badarudin, [1]N.M. Adam, [1]S. Masuri, [2]E. Sadeghinezhad

[1]Faculty of Engineering Universiti Putra Malaysia (UPM), Malaysia 43400
[2]Faculty of Engineering University of Malaya (UM), Malaysia 50603
[3]Faculty of Engineering University of Thi-qar, Iraq 64001

Abstract: Heat transfer improvement in circular pipe by using nanofluid and twisted tape is presented in this review paper. Experimental and numerical studies are incorporated involving both the range of turbulent and laminar flow. Effect of type and volume fraction of nanofluid on performance of heat transfer was referred along with the length and twist ratio of the tape through the pipe on heat transfer rate and pressure drop. Increase of volume fraction of nanofluid and Reynolds number leads to enhancement of heat transfer rate. The obtained results indicate a good agreement between the experimental and numerical studies. The Maximum of Nusselt number obtained by using twist tape through the pipe which created recirculation flow. The augmentations of heat transfer become significant by using both nanofluid flow instead of normal fluid and insert of the tape through the passage of pipe.

Key words: Enhancement heat transfer, Twist tape, Recirculation flow, Nanofluid

INTRODUCTION

Enhancement of heat transfer in thermal system can be obtained by many techniques such as reconfiguration of geometry, change of cooling fluid, insert swirl generator etc.. There are many efforts done by researchers by experimental and numerical investigations to improve the heat transfer. In the past decades there were attempts to reduce the size of heat exchangers by increasing heat transfer rate. Heat transfer enhancement by using many pattern of twist tape through the pipe was studied by many researchers as shown in Fig. 1. A comprehensive survey on heat transfer augmentation with different techniques has been done by Begles (1985, 1988). Enhancement of heat transfer through the circular pipe with a full length twisted tape inserted by using water has been founded very significant. They have also presented a literature on experiments and modeling of heat transfer with swirl flow. Lia and Xin (2000) conducted a study on augmentation of convective heat transfer and friction loss to flowing flows inside tubes by using three-dimensional internal extended surfaces and twisted tape through four pipes. Laminar-transition- turbulent heat transfer to fluid flow through the pipe by using wire coil inserted was reported by Grace *et al*. (2005,2007, 2007). There are many experimental and numerical studies presented a good result about using of twisted tape inside pipe. In the last decade, the researchers have noticed that the nanofluid has thermal conductivity higher than the normal fluid due to the metalic nanoparticle as suspension in the fluid which contributes increase of thermal conductivity.

Recently, there are a few investigations related to use of both twisted tape and nanofluid have provided more positive results.

The objective of the present paper is to review the enhancement of heat transfer by using both nanofluid flow and twisted tape inside the pipe. Laminar and turbulent flow ranges are considered in this review also a numerical and experimental result are compared as well.

Fig. 1: Shape of twist tape

Corresponding Author: Hussein Togun, Faculty of Engineering University of Malaya (UM), Malaysia 50603
E-mail: htokan_2004@yahoo.com; Tel: (006)0172530157

The Twisted Tap In Pipe With Laminar Flow:

Experimental and numerical studies of heat transfer to laminar flow in pipe by using twisted tape are covered in this section. Laminar flow is obtained through the pipes with low velocity and Reynolds number below 2300.

Chandrasekar *et al*. (2010) performed experimental study of heat transfer and friction factor by using AL_2O_3 nanoparticles of 0.1% concentration and wire coil tape insert in the pipe. The results found are comparison between the Nusselt numbers before and after using the tape. Initially, the increment of Nusselt number from using nanofluid flow through the plane pipe was 12.24% at Re= 2275 while after the tape insert the improvement of Nusselt number was 15.9 % to 21.53% at the same Reynolds number. Helical screw tape insert through a straight pipe with nanofluid was investigated by Suresh *et al*. (2011). Al_2O_3/water and CuO/water of 1% concentration nanofluids were used in this experiment. The obtained results showed increase in Nusselt number about 10.38% for Al_2O_3 and 19.57% for CuO in comparison to water flow. When the helical screw tape was inserted in the pipe, the averageenhancements in Nusselt number obtained for Al2O3 were 215.5%, 173.78% and 129.98% and 234.39%, 195.99, and 141.82 for CuO and those improvements corresponding to twist angles.

Govarthan and Sivashanmugam (2010) have numerically studied the heat transfer behavior by using AL_2O_3 nanofluid and insert helical screw. In this investigation the simulations were conducted at volume fraction of nanofluid 0.5 %, 1%, and 5% and ratio of twists of helical screw were 2.93, 3.91 and 4.89. They showed increase in Nusselt number 5%-31% at different ratio twist of helical crew and different volume fractions. The higher value of Nusselt number was 31.29 at 1.5% AL_2O_3 volume fractions, 2.93 twist ratios of helical screw and Reynolds number was 2093. In contrast Khwanchit and Smith (2011) carried out experimental investigation to evaluate the heat transfer enhancement in circular tube equipped with modified twisted tape with alternate axis. CuO nanoparticle and base fluid water was used in experimental with volume fraction from0.3% to 0.7%.and the range of Reynolds number varied from 830 to 1990. The experimental results found enhance in Nusselt number reached to 12.8% as compared with plain tube.

Sharma *et al*. (2009) carried out experimental study to estimate heat transfer coefficient and friction factor in tube with inserted twisted tape. The results showed considerable enhancement of convective heat transfer with AL_2O_3 nanofluids compared to water flow and the heat transfer coefficient at 0.1% volume concentration AL_2O_3 was 23.7% higher compared to water. They noticed the maximum friction factor with twisted tape for 0.1% nanofluid volume concentration as 1.21 times as a compared with water flow in plain tube.

A heat transfer and friction factor characteristic of two different tubes one is a plain tube and the other is a dimpled tube are presented by Suresh *et al*. (2012). The experimental investigation was carried out with distilled water and CuO/water nanofluids where average size of nanoparticles is15.3 nm and the volume concentrations were 0.1, 0.2 and 0.3%. The maximum value of Nusselt numbers obtained were about 6, 9.9, and 12.6%, for the increased volume fraction of nanofluids compared to distilled water in plain tube. However, the experimental Nusselt numbers for 0.1,

0.2 and 0.3% volume concentration of CuO nanoparticles were about 3.4, 6.8 and 12%, respectively higher than those obtained for distilled water in dimpled tube.

Suresh *et al*. (2012) carried out a comparison study of thermal characteristics of Al2O3/water and CuO/water nanofluids flowing in straight circular duct with helical screw tape inserted. Different twisting ratio (y=1.78, 2.44 and 3 respectively) were used and the volume concentration of Al2O3/water and CuO/water nanofluid were 0.1% for both. The obtained results showed enhancements in Nusselt number for water with twist ratios of 1.78, 2.44 and 3 were 156.24%, 122.16% and 89.22% respectively as compared to plain tube. In contrast 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 Al2O3/water and in the case of CuO/ water the enhancements in Nusselt number were 179.82%, 144.29% and 105.63% for twist ratios 1.78, 2.44 and 3 respectively. Thermal performance analysis based on the constant pumping power criteria shows that helical screw tape inserts give better thermal performance when used CuO/water nanofluid than Al2O3/water nanofluid.

The Twisted Tap In Pipe With Turbulent Flow:

In this section augmentation of heat transfer to nanofluid flow through pipe with different type of twist tape is presented. Turbulent nanofluid flow is considered with different types of nanoparticle and volume fraction. Suresh *et al*. (2011) conducted experimental studies by using CuO/water nanofluid in a plain tube and a helically dimpled tube to evaluate heat transfer and friction factor characteristics and enhancement of heat transfer in both cases. The height of the dimple/protrusion was 0.6 mm, Reynolds number was between 2500 and 6000 and the concentrations of CuO nanoparticles were 0.1%, 0.2% and 0.3% by volume friction. The experimental results showed that the Nusselt number with dimpled tube and nanofluids under turbulent flow are about 19%, 27% and 39% (for 0.1%,

0.2% and 0.3% volume concentrations respectively) higher than the Nusselt numbers obtained for the classic liquid water, on the other hand dimpled tube friction factors were about 2–10% higher than the plain

tube. Masoud *et al*. (2009) performed investigation on experimental and computational fluid dynamics (CFD) on the friction factor, Nusselt number and thermal–hydraulic performance of a tube with the classic and three modified twisted tape inserts. The results showed that the Nusselt number and performance of the jagged insert were higher than the other ones. Maximum increase of 31% and 22% were observed in case of Nusselt number as the performance of the jagged inserts plain tube.

Syam and Sharma (2010) have conducted the experimental study of convective heat transfer and friction factor of AL_2O_3 nanofluid in a circular tube with different aspect ratios of longitudinal strip inserts. The regression equation of Gnielinski (1976) is valid for single phase fluids in the turbulent range, has underestimated the value of Nusselt number of 0.02% and 0.5% AL_2O_3 nanofluid at maximum Reynolds number by 7% volume concentration by 13.57%. The enhancement in heat transfer in a plain tube with 0.5% volume concentration 2 nanofluid when compared to water is 17.36% and 30.30% for Reynolds number of 3000 and 22,000, respectively.

Turbulent heat transfer and friction factor of Al2O3 Nanofluid in circular tube with twisted tape inserts experimentally studied by Syam and Sharma (2010). Thermophysical properties of AL_2O_3 nanofluid with different concentrations have been used once in a plain tube and other time with twisted tapes inserts at different ratio. They found that the heat transfer coefficients was 22.76% and 30.30% at Reynolds numbers of 10,000 and 22,000 and the nanofluids of 0.5% volume concentration for tube flow compared to water. In contrast the heat transfer coefficients at same Reynolds number and same volume concentration but at twist ratio of 5 is higher when compared to water in a plain tube by 33.51% and 42.17% respectively. While there is no significant increase in pressure drop or friction factor compared to water at the same twist ratio.

Khwanchit and Smith (2012) have investigated heat transfer enhancement by using CuO/water nanofluid at three different concentrations 0.3, 0.5 and 0.7%. In their studies the pipe equipped with twisted tape inserts at three different twist ratios: y/w=2.7, 3.6 and 5.3 (3) two different arrangements of twisted tape flow in a turbulent region.

The obtained results reveal that at similar operating conditions, heat transfer rate, friction factor as well as thermal performance factor associated with the simultaneous application of CuO/water nanofluid and twisted tape are higher than those associated with the individual techniques. Evidently, heat transfer rate increases with increasing CuO/water nanofluid concentration and decreasing twist ratio. Suresh *et al*. (2012) studied the spiraled rod inserts though the pipe under turbulent flow to evaluate the heat transfer and friction factor characteristics of nanofluids having volume concentrations of 0.3, 0.4 and 0.5% of nanoparticles. They observed that the heat transfer enhancement caused by suspending nanoparticles has become more pronounced with the increase of the particle volume concentration and also further improved with the spiraled rod inserts about 10–48% compared with plain tube. The results also showed isothermal pressure drop for turbulent flow with spiraled rod inserts were found to be between 2 and 8% higher than the plain tube which is similar to that for distilled water.

Syam *et al*. (2012) presented experimental estimation on Turbulent flow region to evaluate heat transfer and friction factor characteristics of magnetic Fe3O4 nanofluid flowing through a uniformly heated horizontal circular tube with and without twisted tape inserts. As a result founded that the heat transfer and friction factor enhancement of 0.6% volume concentration of Fe3O4 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. One the other hand the Nusselt number for single phase fluid predicts values which are lower by 13.4% for 0.6% of Fe3O4 nanofluid under similar operating conditions.

Hashemi and Akhavan (2012) presented experimental investigation on the heat transfer and pressure drop characteristics of nanofluid flow inside horizontal helical tube under constant heat flux. The nanofluid is prepared by dispersion through sonication of CuO nanoparticle in base oil and stabilized by means of an ultrasonic device and different particle weight concentrations of 0.5%, 1% and 2% are used. The effect of different parameters such as Reynolds number, fluid temperature and nanofluid particle concentration on heat transfer coefficient and pressure drop of the flow are studied. They showed that by using the helically coiled tube instead of the straight one, the heat transfer performance was improved but, the curvature of the tube result in the pressure drop thus, the heat transfer coefficient as well as pressure drop is increased by using nanofluid instead of base fluid. The evaluation of the two enhanced heat for heat transfer enhancement techniques studied in this investigation shows that applying helical tube instead of the straight tube is a more effective way to enhance the convective heat transfer coefficient compared to the second method where nanofluid is used instead of the base liquid.

RESULTS AND DISCUSSION

Both laminar and turbulent nanofluid flow through the pipe with inserting twist tape was presented in this paper. During the literature survey about heat transfer augmentation in pipe the numerical and experimental results revealed many facts, firstly the improvement of heat transfer obtained by using nanofluid is due to nanoparticles have higher thermal conductivity than normal fluid. The types of nanoparticle influence the heat transfer are based on metallic or non-metallic and also increase of volume fraction leads to enhance Nusselt

number. The length and angle of twist tape inserted through the pipe have effect on the Nusselt number. Generally, the results showed increase in Nusselt number by using twist tape as compared to the plain pipe. The summary of experimental and numerical results with using nanofluid flow and twisted tape are reported in .

Table1: Summary of experimental and numerical results with using nanofluid flow and twisted tape.

Enhancement	Shape of obstacles	Type of flow	Concentration	Material	Type of study	Reference
Before using the obstacle Nusselt number was =12.24% and Re=2275 after using obstacle Nusselt number=15.9%,21.53% at Re=2275	Wire coil	Laminar	0.1%	AL_2O_3	Experimental	Chandrasekar *et al*. (2010)
AL_2O_3 size =3nm ,CuO=30nm Nusselt before insert =10.83%for AL_2O_3 ,and 19.57% for CuO After insert Nusselt is215.5%,173.7%,129.98 % for AL_2O_3 , 234.39%,195.99%and14 1.82%CuO	Helical screw tap	Laminar	0.1%for AL_2O_3 , 0.1% for CuO	AL_2O_3 ,CuO	Experimental	Suresh *et al*. (2011)
According to the experimental result found that the enhancement of Nusselt number enhancement was 0.19% , 0.27%,0.39% for(0.1%,0.2%,0.3%) concentrations	Helically dimpled tube	Turbulent	0.1% 0.2% 0.3%	CuO	Experimental	Suresh *et al*. (2011)
Increase in 31% and22% of Nessult number as compere with the plain tube	Three modified twisted tape	Turbulent			Experimental and computational	Masoud et al. (2009)
The enhancement of Nusselt number is 23.7% after using the twisted tape	twisted tape	Transition	0.1%	AL_2O_3	Experimental	Sharma *et al.* (2009)
The increase in Nusselt number is 5%-31% for different helical insert and different concentrations	Helical	laminar	0.5%,0.1%, 1.5%	AL_2O_3	CFD	Govarthan and Sivashanmugam (2010)
	Longitudinal strip inserted	Turbulent	$0<\phi<0.5\%$	AL_2O_3	Experimental	Syam and Sharma (2010
Heat transfer enhancement by 33.51% and 42.17%	Twisted tape	turbulent	0.5%	AL_2O_3	Experimental	Syam and Sharma (2010)
Increment of Nusselt number is up to12.8and 7.	Twisted tape with alternate axis	Laminar	0.7%	CuO	Experimental	Khwanchit and Smith (2011)
The Nusselt is 3.4%, 6.8%, 12% higher than the plain water	Helically dimpled	Laminar	0.1%, 0.2%, 0.3%	CuO	Experimental	Suresh and Chandrasekar (2012)
Thermal performance factor was 1.57 for CuO/water	Twisted tape	Turbulent	0.7%	CuO	Experimental	Khwanchit and Smith (2012)
Performance index is greater than 1 for concentrations 1% and 2%.	Horizontal helically coiled tube	Laminar	0.5%,1%,2%	CuO	Experimental	Hashemi and Akhavan (2012)
Increase of Nusselt number about 10–48% compared to plain tube	Spiraled rod	Turbulent	0.3%,0.4%,0.5%	Al_2O_3	Experimental	Suresh *et al*. (2012)
	Plain	Turbulent	6.3%	Fe_3O_4	Experimental	Syam *et al*. (2012)

Enhancement of Nusselt number for CuO was 156.24% ,122.1% , 89.22% and enhancement of Nusselt number for Al_2O_3 is 179.8%,144.29%, 105.63%	Helical screw	Transition	0.1% for Al_2O_3 0.1% for CuO	Al_2O_3 ,CuO	Comparison	Suresh *et al*. (2012)

ACKNOWLEDGMENT

The authors gratefully acknowledge high-impact research Grant UM.C/HIR/ MOHE/ENG/46, UMRG RG084/10AET, and the University of Malaya, Malaysia for support in conducting this research.

REFERENCES

Bergles A.E., 1988. Some perspectives on enhanced heat transfer, second- generation heat transfer technology, ASME J. Heat Transfer, 110: 082-1096.

Bergles, A.E., 1985. Techniques to augment heat transfer in: W.M. Rohsenow, J.P. Hartnett, E. Ganie (Eds), Handbook of Heat Transfer Application , McGraw-Hill, New York.

Chandrasekar, M., S. Suresh, A. Chandra Bose, 2010. 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, 34: 122-130.

Garc, A., P.G. Vicente, A. Viedma, 2005. Experimental study of heat transfer enhancement with wire coil inserts in laminar-transition- turbulent-regimes at different Prandtl number, Int. J. Heat and Mass Transfer, 48: 4640-4651.

Govarthan Pathipakka, P. Sivashanmugam, 2010. Heat transfer behavior of nanofluids in a uniformly heated circular tube fitted with helical inserts in laminar flow Superlattices and Microstructures., 47: 349-360.

Grac, A., J.P. Solano, P.G. Vicente, A. Viedma, 2007. Enhancement of laminar and transition flow heat transfer in tubes by mean of wire coil inserts, Int. J. Heat and Mass Transfer, 50: 3176-3189.

Grac, A., J.P. Solano, P.G. Vicente, A. Viedma, 2007. Flow Pattern assessment in tubes with wire coil inserts in laminar and transtion regimes, Int. J. Heat and Mass Transfer, 28: 516-525.

Hashem, S.M., M.A. Akhavan-Behabadi, 2012. An empirical study on heat transfer and pressure drop characteristics of CuO–base oil nanofluid flow in a horizontal helically coiled tube under constant heat flux, International Communications in Heat and Mass Transfer, 39: 144-151.

Khwanchit Wongcharee, Smith Eiamsa-ard, 2011. Enhancement of heat transfer using CuO/water nanofluid and twisted tape with alternate axis, International Communications in Heat and Mass Transfer., 38: 742–748.

Khwanchit Wongcharee, Smith Eiamsa-ard, 2012. Heat transfer enhancement by using CuO/water nanofluid in corrugated tube equipped with twisted tape, International Communications in Heat and Mass Transfer, 39: 251-257.

Lia, Q., M.D. Xin, 2000. Augmentation of convective heat transfer inside tube with three dimensional internal extended surfaces and twisted-tape inserts, chemical Engineering Journal., 78: 95-105.

Masoud Rahimia, Sayed Reza Shabanian, Ammar Abdulaziz Alsairafi, 2009. Experimental and CFD studies on heat transfer and friction factor characteristics of a tube equipped with modified twisted tape inserts, Chemical Engineering and Processing, 48: 762-770.

Sharma, K.V., L. Syam Sundar, P.K. Sarma, 2009. 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 International Communications in Heat and Mass Transfer, 36: 503-507.

Suresh, S., K.P. Venkitaraj, P. Selvakumar, 2011. Comparative study on thermal performance of helical screw tape inserts in laminar flow using Al_2O_3/water and CuO/water nanofluids., 49: 608-622.

Suresh, S., K.P. Venkitaraj, P.r. Selvakuma, M. Chandrasekar, 2012. 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, Experimental Thermal and Fluid Science., 39: 37–44.

Suresh, S., M. Chandrasekar, P. Selvakumar, 2012. Experimental studies on heat transfer and friction factor characteristics of CuO/water nanofluid under laminar flow in a helically dimpled tube, Heat Mass Transfer, 48: 683-694.

Suresh, S., M. Chandrasekar, S. Chandra Sekhar, 2011. Experimental studies on heat transfer and friction factor characteristics of CuO/water nanofluid under turbulent flow in a helically dimpled tube Experimental Thermal and Fluid Science, 35: 542-549.

Suresh, S., P. Selvakumar, M. Chandrasekar, V. Srinivasa Raman, 2012. Experimental studies on heat transfer and friction factor characteristics of Al2O3/water nanofluid under turbulent flow with spiraled rod inserts, Chemical Engineering and Processing, 53: 24-30.

Syam Sundar, L., K.V. Sharma, 2010. Heat transfer enhancements of low volume concentration Al_2O_3 nanofluid and with longitudinal strip inserts in a circular tube International Journal of Heat and Mass Transfer 53:4280–4286. [17] Gnielinski,V., 1976. New equations for heat and mass transfer in turbulent pipe and channel flow, Int. Chem. Eng., 16 :359-368.

Syam Sundar, L., K.V. Sharma, 2010. Turbulent heat transfer and friction factor of Al_2O_3. Nanofluid in circular tube with twisted tape inserts International Journal of Heat and Mass Transfer, 53: 1409-1416.

Syam Sundar, L., N.T. Ravi Kumar, M.T. Naik, K.V. Sharma, 2012. 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, International Journal of Heat and Mass Transfer, 55: 2761-2768.