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Review Article

Heat transfer augmentation in a tube using inserts with nanofluids as working fluid: A Review

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Abstract

Over the past decade different research groups have worked on heat transfer characteristic in a tube type heat exchanger with nanofluids as working fluids. The heat transfer augments with the use of nanofluids due to improved thermophysical properties with addition of nanoparticles in the base fluid. Further the enhancement can be attained by using inserts inside the tube. This review article presents the works done by different researchers using inserts and nanofluids. The heat transfer is greatly improved with combination of nanofluids and inserts.

Keywords: *Heat Transfer enhancement, helical coil, twisted tape, inserts*

Introduction

With the miniaturization of electronic equipments and increase in the heat flux the heat dissipation has become a challenge. The technology improvement is required in the area of design of higher heat dissipating equipments. The higher heat transfer can be obtained either by increasing the area of heat exchanger or by using active and passive devices to produce secondary flow. The use of passive devices like twisted tapes, wire inserts, vortex generators (Dewan, *et al*,2004),(Joardar and Jacobi,2008),(Kumar and Murugesan,2012) etc. are effective in improving heat transfer. Nanoparticles were produced by (Choi,1995) and found increased thermal conductivity due to addition of small nanosized nanoparticles in base fluid. Recently nanofluids have find applications instead of traditional fluids as working fluids. The nanoparticles of different metals (e.g. Copper, Nickel, Aluminium), oxides (e.g. Al_2O_3, TiO_2, CuO, SiO_2, Fe_2O_3, Fe_3O_4 etc.) and compounds (e.g. CNT, SiC, $CaCO_3$, graphene etc.) size of 1 to100 nm are suspended in base fluids. Due to improved thermal conductivity the heat transfer is also improved. Heat transfer enhancement leads to higher heat dissipation or reduction in size of heat exchangers. Miniaturization of equipments is important in reducing the cost as well as reducing spaces. The reduction in size can be further possible if we combine enhancement methods. Like we can use working fluid as a nanofluids and use some passive technique also. Due to combination the results of heat transfer will be further improved.

The present review focuses on the combined use of nanofluids and inserts for heat transfer augmentation. The work done by different researchers using inserts with different twist ratios , its thickness and different nanofluids in different Reynolds range has been discussed.

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Heat transfer augmentation with inserts and nanofluids

Many studies have been performed using nanofluids (Xuan and Li,2000),(Kakac and Pramuanjaroenkij, 2009),(Wang and Mujumdar,2007),(Maiga, *et al*,2005) and inserts (Wang and Sunden,2002),(Garcia, *et al*,2005) separately in a tube type of heat exchanger. This section presents the overview of numerical and experimental studies with combined use of nanofluids and inserts for heat transfer enhancement in a tube.

(Pathipakka, *et al*,2010) performed CFD simulation in a circular tube with helical twist inserts using Al2O3 nanoparticles in water in laminar flow to find heat transfer of heat transfer characteristics. The nanoparticles loading of 0.5%, 1.0% and 1.5% and inserts with twist ratios 2.93, 3.91 and 4.89 were used in computations. It was observed that heat transfer augmentation increases with Reynolds number and decreases with twist ratio with greatest for 2.93.

(Sunder, *et al*,2010) experimentally studies the convective heat transfer of Al_2O_3 nanofluid in a circular tube. The longitudinal strip inserts with different aspect ratios were used in the Reynolds range of 3000 < Re < 22,000. The particle volume concentration was 0 - 0.5% and longitudinal strip aspect ratios of 0 < aspect ratio < 18.It was observed that heat transfer coefficients showed increase with nanofluid volume concentration and decrease with aspect ratio.

(Chandrasekar, *et al*,2010) experimentally studied the heat transfer of Al_2O_3/water (0.1% Vol. conc.) nanofluid in a horizontal tube with and without wire coil inserts in laminar regime. Better heat transfer was observed with nanofluid combined with wire coil insert. This was interpreted due to dispersion or back-mixing which flattens the temperature distribution and make the temperature gradient between the fluid and wall steeper.

(Mohammed, *et al*,2013)numerically studied the effect of louvered strip in a circular double pipe heat exchanger with Al_2O_3, CuO, SiO_2, and ZnO nanofluids. The louvered strip insert with two arrangements (forward and backward) are used. The turbulent flow with Reynolds range of 10,000 to 50,000 was taken. The particle loading of 1% to 4% was taken in water. The results show that the forward louvered strip has heat transfer about 367% to 411% at the highest slant angle of 30° and lowest pitch of 30 mm. The performance evaluation criterion (PEC) was found in range of 1.28–1.56. The highest Nusselt number value was observed in the order i.e., SiO2 Al_2O_3, ZnO, and CuO.

(Reddy, *et al*,2014) experimentally observed heat transfer of TiO2 nanofluids (0.0004% to 0.02%) in a double pipe with and without inserts (helical coil) in the range of Reynolds number from4000 to 15,000. The base fluid was 40% EG /60% DI. The heat transfer coefficient improved by 10.73% at 0.02% particle loading of nanofluid compared to base fluid. While the heat transfer coefficient further showed improvement by 13.85% compared to base fluid with helical coil insert having P/d = 2.5.

(Sadeghi, *et al*.,2016) using finite volume method studied convective heat transfer in a circular tube fitted with helical tape insert (twist ratios of 1.95–4.89). The nanofluids used were Al_2O_3 and SiO_2 with having spherical, cylindrical and platelets shapes (0.5–2.0% volume conc.). It was observed that the highest Nusselt number was obtained with Al_2O_3/water nanofluids. Further the number increased with increasing Reynolds number and decreasing twist ratio.

(Azari, *et al*,2015) experimentally studied heat transfer enhancement with butterfly tube inserts (BTI) with an inclined angle of 90° in a tube at CHF boundary conditions. Al_2O_3/water nanofluid is used with 2.5% nanoparticles volume concentration. The Reynolds number was between 750–8500. The results showed that at 0.027% volume conc. and $Re = 1500$ enhancement of about 345% in the Nusselt was found.

(Suresh, *et al*.,2012) studied and compared thermal characteristics of nanofluids(Al_2O_3/water and CuO/water nanofluids with 0.1% volume conc.) in a straight circular duct having helical screw tape inserts. The inserts twist ratios was taken 1.78, 2.44 and 3. The thermal performance of helical screw tape inserts is better for CuO/water nanofluid than with Al_2O_3/water nanofluids.

(Aliabadi, *et al*,2015) investigated heat transfer and overall performance in a plane tube with twisted-tape inserts (variable twist lengths) in the presence of Cu–water nanofluids. The weight concentration of nanofluids was 0, 0.1, and 0.3 wt.%. The tests were performed in turbulent regime (7500 - 15,000). It was observed that all inserts having non-uniform twist lengths, performed better than the uniform one. Using short twist lengths at the beginning of inserts lead to increase in the heat transfer. By using Cu–water nanofluid (0.3 wt.% concentration) and twisted-tape insert (Low to High twist lengths) showed the overall enhancement ratio improvement of nearly 87%.

(Azmi, *et al*.,2014) experimentally showed enhancement in heat transfer coefficients with of tape inserts in tube using TiO_2/water nanofluid. The particle loading upto 3.0% at 30 C was taken in Reynolds range of 8000-30000. Results revealed a considerable heat transfer augmentation of 23.2% at 1.0% concentration. Further as in earlier cases the HTC increased with decrease in twist ratio. Observation showed increase in HTC by 81.1% at Reynolds number 23,558 at 1.0% concentration and twist ratio 5, in comparison to flow of water in a tube. Further with greater particle loading of 3% the decrease in An increase in decreased heat transfer was observed.

(Esmaeilzadeh, *et al*,2014) experimentally studied the effect of Al_2O_3/water nanofluids and twisted tape inserts with various thicknesses at constant heat flux in a circular tube on heat transfer. The nanofluids with 0.5% and 1% volume fraction was taken. The insert had twist ratio of 3.21 with thickness 0.5 mm, 1 mm and 2 mm. The laminar regime with Reynolds numbers150 to 1600 was considered. The results showed that better enhancement with more thickness of tape and nanofluids with higher concentration.

(Eiamsa-ard, *et al*,2014) investigated heat transfer in a tube with combination of multiple twisted tapes in different arrangements and TiO_2 nanoparticles/water. It was concluded that multiple twisted tapes with nanofluids showed better results compared with plain tube or the tube inserted a single twisted tape. This was due to increased surface area, swirl intensity and fluid mixing with multi-longitudinal vortices flow. So more studies should be performed by using combination of nanofluids and different types of inserts with minimum friction factor and maximum heat transfer. Further correlations which could be used for wider range and predicting accurate results should be developed.

Table 1: Research by different researchers using nanofluids and inserts

Author	Nanoparticles used	Type of insert	Flow regime	Type of study	Remarks
Pathipakka, *et al*,2010	Al_2O_3	helical twist inserts	Laminar	CFD simulation	Heat transfer enhances
Sunder, *et al*,2010	Al_2O_3	longitudinal strip inserts	Turbulent	Experimental	Heat transfer enhances
Chandrasekar, *et al*,2010	Al_2O_3	Wire coil inserts	Laminar	Experimental	Heat transfer enhances
Mohammed, *et al*,2013	Al_2O_3, CuO, SiO_2, and ZnO	louvered strip	Turbulent	Numerically	Heat transfer enhances
Reddy, *et al*,2014	TiO2	helical coil	Turbulent	Experimental	Heat transfer enhances
Sadeghi, *et al*.,2016	Al_2O_3 and SiO2	helical tape insert	Turbulent	Numerically	Heat transfer enhances
Azari, *et al*,2015	Al_2O_3	Butter fly tube insert	Turbulent	Experimental	Heat transfer enhances
Suresh, *et al*.,2012	Al_2O_3/water and CuO/water	helical screw tape inserts	Turbulent	Experimental	Heat transfer enhances
Aliabadi, *et al*,2015	Cu–water s	twisted-tape inserts (variable twist lengths)	Turbulent	Experimental	Heat transfer enhances
Azmi, *et al*.,2014	TiO_2/water	tape inserts	Turbulent	Experimental	Heat transfer enhances
Esmaeilzadeh, *et al*,2014	Al_2O_3/water	twisted tape inserts	Laminar	Experimental	Heat transfer enhances
Eiamsa-ard, *et al*,2014	TiO_2 nanoparticles/water	multiple twisted tapes	-	Experimental	Heat transfer enhances

Conclusion

This review article presents the review of researcher using combined nanofluids and inserts in a tube type heat exchanger. It can be concluded that the heat transfer enhances with the increase in Reynolds number and particle loading of nanofluids. It increases with the decrease in the twist ratio of inserts. The thickness adds to the heat transfer enhancement. Further multiple inserts showed much better enhancement.

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