Investigations of Heat Transfer Enhancement for Laminar Nanofluids Flow in a Circular Tube: Recent Literature Review

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Citation

Abstract
The heat transfer rate is considered as an important parameter for the design of any mechanical, electrical or electronic component. The convective heat transfer can be enhanced passively by changing the flow geometry, boundary conditions, or by enhancing the thermal conductivity of the fluid. The thermal conductivity of the fluid can be increased by the nanofluids. Nanofluids are studied because of their heat transfer properties, they enhance the thermal conductivity and convective properties over the properties of the base fluid. In addition, the article summarizes the recent research in experimental and numerical studies on forced convective heat transfer in nanofluids, their thermo-physical properties and their applications, and identifies the challenges and opportunities for future research.

1. Introduction

The purpose of this literature review is to go through the main topics of interest. The enhancement of heat transfer by use nanofluids are the subject of growing importance in myriad many applications, and nanofluids are a new class of heat fluids consisting of nanometer – sized particles (less than 100 nm) dispersed in convectional fluids. To date, there has been little research involving convection, especially forced convection. Most research has been focused on determining the thermal conductivity of nanofluids and not much attention has been given to finding the heat transfer coefficient from convection, hence the tube has been the subject of several studies. There are a number of published papers on this subject. This literature review will address a number of experimental and numerical studies which focused on the nanofluids performance of tube and carried out to cover the enhancement in heat transfer by the use of nanofluids in all applications and the effect of concentration, Reynolds number, Rayleigh number, type of nanofluid, angle of the tube and diameter of nanoparticle.

2. Literature Review

In recent years, the nanofluid has emerged as an alternative heat transfer fluid for heat transfer applications showing a significant potential for heat transfer improvement. The convective heat transfer of nanofluids has comparatively been less acclaimed in literature therefore the number of the publications dealing with the convective heat transfer of
nano fluids is limited. The most productive research has been continuously carried out by the following studies:

*S. Zeinali Heris et al.* [1] performed experimental investigation of convective heat transfer of alumina/water nanofluid in circular tubes. The test section consists of 6 mm diameter tube of 1 m length with 0.5 mm thickness. Nanofluids flows inside the tubes while saturated steam entered the annulus section in order to maintain the constant wall temperature. The Nusselt number were obtained for the different particle concentration as well as various Peclet and Reynolds number. The experimental results were compared to the theoretical values by the use of Seider - Tate equation. The increase in the heat transfer rate is due to the higher thermal conductivity of the nanoparticles. Some other factors are dispersion and chaotic movements of nanoparticles. The Brownian motion and migration of the particles plays an important role in the heat transfer enhancement.

*Choi and Zhang* [2] performed simulation of laminar forced convection heat transfer of Al$_2$O$_3$/water in pipe with return bend. A straight pipe of dimensionless diameter 1 and dimensionless length of 10 is considered. The grids on pipe consists of nodal points 5226 and elements of 4875 for the Finite Element Method (FEM), and nodal points of 292800 and elements 301701 for CFX with fine mesh to obtained more accurate solution. In total 25 cases have been simulated in the concentration of 0.0 %, 2.5 %, 5.0 %, 7.5 % and 10 % and Reynolds number of 10, 25, 50, 75, 100. The result shows that the average Nusselt number increases with the rise of the Reynolds number and the particle concentration. The heat transfer enhancement in the return section is more than the inlet and the outlet section of the pipe, due to the secondary flow.

*Tahir and Mital* [3] performed numerical investigation of laminar alumina /water nanofluid laminar forced convection heat transfer in circular channel. The effect of particle diameter, Reynolds number, and concentration are investigated. The fluid is treated as continuous media and the floe field is solved by Navier - Stokes Equations. The validated numerical model is used for formulating a three factorial design matrix with each of the three independent variables at three levels. The matrix considers the particle size (50nm, 75nm, and 100nm), Reynolds number (250, 750 and 1250), and particle volume fraction (1, 2.5, and 4 %). The effect of these variables were studied by developing three level, three factorial design with average heat transfer coefficient along the tube axis. It is seen that almost all the variation in the heat transfer coefficient is due to the change in these parameters. The Reynolds number is the most significant parameter in the heat transfer coefficient, while the particle volume fraction is the least significant.

*K. B. Anoop et al.* [4] studied experimentally the effect of particle size on the convective heat transfer in nanofluid in the developing region. The nanofluid used was Al$_2$O$_3$/water. The particle size selected was 45 nm and 150 nm. It is found that both the fluid shows higher heat transfer characteristics than that of the base fluid, while the 45 nm shows higher heat transfer rate and heat transfer coefficient than of other fluid. It is observed that at x/D= 147, for 45 nm particle based nanofluid (4 wt %) with Re = 1550, the enhancement in heat transfer coefficient was around 25 % whereas for the 150 nm particle based nanofluids it was found to be around 11%. It is also observed that in 4 wt% nanofluid with average particle size 45 nm, at Re=1550, the enhancement in heat transfer coefficient was 31 % at x/D = 63, whereas it was 25 % and 10 % at x/D = 147 and 244, respectively.

*Wen and Ding* [5] focused on the entry region under laminar flow condition in a copper tube under a constant heat flux using nanofluids containing γ - Al$_2$O$_3$ nanoparticles of various concentrations. They presented that the local heat transfer coefficient at axial positions in the entry region was about 41 % and 47 % higher at Re = 1050 and 1600 in comparison with water, respectively, and the enhancement just decreased along the axial direction. It was shown that the enhancement increased with the Reynolds number as well as the volume concentration of nanoparticle.

*Yang et al.* [6] studied experimentally the convection heat transfer performance of the graphite nanofluids in laminar flow through a circular tube and showed that the nanoparticles increased the heat transfer coefficient of the fluid system in laminar flow, but the increase was much less than that predicted by the correlation based on static thermal conductivity measurements. Hence, they concluded that Reynolds number, temperature, nanoparticle loading, nanoparticle source, and the choice of the base fluid can all affect the heat transfer coefficients of nanofluids.

*Ding et al.* [7] reported a maximum enhancement of convective heat transfer of CNT (carbon nanotubes) nanofluids over 350 % at a Reynolds number of 800, and the maximum enhancement occured at an axial distance of approximately 110 times the tube diameter. The observed large enhancement of the convective heat transfer was attributed to the enhancement of thermal conductivity, particle re - arrangement, shear induced thermal conduction enhancement, reduction of thermal boundary layer thickness due to the presence of nanoparticles and the very high aspect ratio ofCNTs.

*Mohammad and Bagheri* [8] studied forced convection heat transfer behavior of three different types of nanofluids flowing through a uniformly heated horizontal tube under laminar regime has been investigated experimentally. Nanofluids were made by dispersion of γ - Al$_2$O$_3$, CuO and TiO$_2$ nanoparticles in an aqueous solution of carboxymethyl cellulose (CMC). All nanofluids as well as the base fluid exhibit shear - thinning behavior. Results of heat transfer experiments indicate that both average and the local heat transfer coefficients of nanofluids are larger than that of the base fluid. The enhancement of heat transfer coefficient increases by increasing nanoparticle loading. At a given Peclet number and nanoparticle concentration the local heat transfer coefficient decreases by axial distance from the test section inlet. It seems that the thermal entry length of nanofluids is greater than the base fluid and becomes longer.
as nanoparticle concentration increases.

Esfahany et al. [9] investigated the laminar flow of CuO / water and Al2O3 / water nanofluids through a 1m annular copper tube with 6 mm inner diameter and with 0.5 mm thickness and 32 mm outer diameter stainless steel tube, where saturated steam was circulated to create a constant wall temperature boundary condition rather than the constant heat flux condition employed by other researchers. The comparison of experimental results showed that the heat transfer coefficient enhanced with increasing volume fraction of nanoparticles as well as Peclet number (Pe = 5000), while Al2O3 – water showed more enhancement. The experiments were performed for a wide range of (650 – 2050) Reynolds number and for various concentrations of Al2O3 and CuO nanoparticles (0.2 – 3.0% vol. %).

M. Rahgoshay et al. [10] investigated numerically two-dimensional pulsating flow of nanofluid (Al2O3/water) through a pipe with isothermal walls. In order to solve Navier-Stokes and energy equations, the finite volume approach with collocated grid is employed. The momentum interpolation technique of Rhie and Chow is applied in SIMPLE algorithm. The simulation performed at different pulse parameters (Amplitude, Strouhal and Reynolds numbers) and volume fractions of nanoparticles for unsteady flow. Results of heat transfer experiments indicate that the effect of Strouhal number (frequency) is not more appreciable for the heat transfer enhancement, however a slight improvement of total Nusselt number was observed. Also increasing the amplitude of inlet flow, revealed that amplitude of Nusselt number increased but total Nusselt number did not change any more. Furthermore it was found that by increasing the Reynolds number and nanofluid’s volume fraction, the Nusselt number raise which consequently increases the total Nusselt number.

Durabi et al. [11] investigated the convective heat transfer effect on the nanofluid flow in the developing region of a tube with constant heat flux using computational fluid dynamics (CFD). For this purpose, nanofluid containing Al2O3 and water as a liquid single phase with two average particle sizes of 45 and 150 nm and four particle concentrations of 1, 2, 4 and 6 wt. % were used. Effect of particle size on convective heat transfer coefficient was investigated in different Reynolds numbers (500<Re<500) for various axial locations of tube. According to the modeling results, an equation was obtained for Nusselt number prediction using the dimensionless numbers. The results showed that the heat transfer coefficient enhanced with increasing the nanoparticle concentration and Reynolds number. Further, the heat transfer coefficient decreased with increasing the axial location and particle diameter. There was a good agreement between the results obtained from the simulation and the experimental data in higher Re numbers for nanofluids with low particle size. By applying the simulation results, an equation for Nu number based on the dimensionless numbers was investigated. The maximum error was around 10%.

Gabriela [12] studied a three-dimensional analysis is used to study the heat transfer characteristics of a double tube helical heat exchangers using nanofluid under laminar flow condition. CuO and TiO2 nanoparticle with diameter of 24 nm dispersed in water with volume concentration of 0.5 - 3 vol. % was used as working fluid. The mass flow rate of the nanofluid from the inner tube was kept and the mass flow rate of the water from the annulus was set at either half, full or double the value. Effect of nanoparticle concentration level and of the Dean number on heat transfer coefficient is presented. The results show that for 2% CuO nanoparticles in water and same mass flow rate in inner tube and annuls, the heat transfer rate of the nanofluid was approximately 14% greater than of pure water and the heat transfer rate of water from annulus than through the inner tube flowing nanofluid was approximately 19% greater than for the case which through the inner and outer tube flow rate. The results also show that the convective heat transfer coefficient of nanofluids and water increased with increasing of the mass flow rate and with Dean Number.

Khalid Faisal Sultan [13] conducted a study to investigate the theoretical and experimental heat transfer and flow of nanofluids through a horizontal and an inclined circular tube heated by an axial uniform heat flux. This study was done in thermally and hydrodynamically fully developed region with laminar flow. Three types of nanofluids were used through this work, Al2O3 (25nm) – distilled water, Al2O3 (30nm) – distilled water and CuO (50nm) – distilled water. The range of Reynolds number was chosen to be (100 – 900), range of Rayleigh number was between (1×105 – 4×106) and concentrations were from (0.25 – 2.5 vol %). The results showed that the values of Nusselt number ratio (NuR) were evaluated to be (45 %, 31 %, 25 %) for the three nanofluids (Al, Al2O3, CuO) – distilled water, respectively.

Suresh and Venkitara [14] studied experimental work, a fully developed laminar convective heat transfer and pressure drop characteristics through a uniform heated circular tube Al2O3 - Cu/water hybrid nanofluid is presented for this synthesis Al2O3 - Cu Nano composite powder in thermo chemical route that involves hydrogen reduction technique and then dispersed hybrid Nanopowder in deionized water to form stable hybrid nanofluid of 0.1% volume concentration. The prepared powder was characterized by x-ray diffraction and scanning microscope to confirm the chemical composition to determine the particle size and to study the surface methodology. The convective heat transfer experimental results showed a maximum enhancement of 13.56 % in Nusselt number at Reynolds number of 1730 when compared to the Nusselt number of water. The experimental results also show that 0.1% Al2O3 - Cu/water hybrid nanofluid have slightly higher friction factor when compared to Al2O3 0.1% water nanofluid.

Heyhat et al. [15] experimentally studied the heat transfer coefficient and friction factor of the nanofluids flowing in a horizontal tube under laminar flow conditions. The experiments have been done on fully developed region with Reynolds number range (400 - 2000) under the constant wall temperature condition. Al2O3 nanoparticles with diameters of
40 nm dispersed in distilled water with volume concentrations of 0.1–2 vol. % were used as the test fluid. All physical properties of the Al$_2$O$_3$/water nanofluids needed to calculate the pressure drop and the convective heat transfer coefficient have been measured. The results show that the heat transfer coefficient of nanofluid is higher than that of the base fluid and increased with increasing the Reynolds number and particle concentrations. The heat transfer coefficient increases by approximately 32% in the fully developed region at 2 vol. % nanofluid. The measured pressure loss for the nanofluids was in general much higher than for pure water.

Jianli Wang et al. [16] investigated experimentally the heat transfer and pressure drop of nanofluids containing carbon nanotubes in a horizontal circular tube with Reynolds number range (30 - 200). A considerable enhancement in the average convective heat transfer is observed compared with the distilled water. For the nanofluids with volumetric concentration of 0. 05% and 0. 24%, the heat transfer enhancement are 70% and 190% at Reynolds number of about 120 respectively, while the enhancement of thermal conductivity is less than 10%, therefore, the large heat transfer increase cannot be solely attributed to the enhanced thermal conductivity. By measuring the pump power supply and the thermal conductance of the test tube, results suggest that the nanofluids at low concentration enhance the heat transfer with little extra penalty in pump power, thus have great potential for applications in the heat transfer systems.

Mirmasoumi and Behzadmehr [17] studied numerically laminar mixed convection of a nanofluid consists of water and Al$_2$O$_3$ in a horizontal tube. Two - phase mixture model has been used to investigate hydrodynamic and thermal behaviors of the nanofluid over wide range of the Grashof number range (30 - 200). A considerable enhancement in the average convective heat transfer is observed compared with the distilled water. For the nanofluids with volumetric concentration of 0. 05% and 0. 24%, the heat transfer enhancement are 70% and 190% at Reynolds number of about 120 respectively, while the enhancement of thermal conductivity is less than 10%, therefore, the large heat transfer increase cannot be solely attributed to the enhanced thermal conductivity. By measuring the pump power supply and the thermal conductance of the test tube, results suggest that the nanofluids at low concentration enhance the heat transfer with little extra penalty in pump power, thus have great potential for applications in the heat transfer systems.

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Behzadmehr et al. [18] simulated laminar mixed convection Al$_2$O$_3$/Water nanofluid flow in elliptic ducts with constant heat flux boundary condition employing two phase mixture model. Three - dimensional Navier - Stokes, energy and volume fraction equations have been discretized using the finite volume method. The Brownian motions of nanoparticles have been considered to determine the thermal conductivity and dynamic viscosity of Al$_2$O$_3$/Water nanofluid, which depend on temperature. Simulation effects of solid volume fraction, aspect ratio and buoyancy forced on thermal and hydraulics behaviors of nanofluid flow in elliptic ducts have been presented and discussed. The calculated results show good agreement with the previous numerical data. Results show that in a given Reynolds number (Re) and Richardson number (Ri), increasing solid nanoparticles volume fraction increases the Nusselt number (Nu) while the skin friction factor decreases. Increasing aspect ratio (AR = b/a) in elliptic tubes reduces the local skin friction factor whereas it does not have any specified effect on the local Nusselt number.

Allahyari et al. [19] studied numerically laminar mixed convection of a nanofluid consisting of water and Al$_2$O$_3$ in a horizontal tube with heating at the top half surface of a copper tube. The bottom half of the tube wall is well insulated and can be assumed adiabatic. Heat conduction mechanism is considered through the tube wall. Three dimensional governing equations with using two - phase mixture model have been used to investigate hydrodynamic and thermal behaviour of the nanofluid over wide range of nanoparticle volume fraction. For a given nanoparticle mean diameter the effects of nanoparticle volume fraction on the hydrodynamics and thermal parameters are presented and discussed at different Richardson numbers. It is shown that increasing the nanoparticle concentration significantly augments the heat transfer coefficient while the skin friction coefficient does not considerably affect.

Xuan and Li [20] investigated experimentally the convective heat transfer and flow characteristics for Cu/water nanofluid flowing through a straight tube with a constant heat flux. The results of the experiment showed that the suspended nanoparticles remarkably enhanced the heat transfer performance of the conventional base fluid, and their friction factor data coincided well with that of the water. According to them, the convective heat transfer coefficient of Cu/water nanofluid increased about 60% at 2% volume concentration. They assumed that the convective heat transfer enhancement is mainly due to dispersion of the suspended nanoparticles.

D. Ashitian et al. [21] investigated effect of MWCNT inside flattened tubes at uniform wall temperature condition. The test section consists of copper tube surrounded by a steam chamber to keep temperature of the wall constant. Weight fraction of 0. 0%, 0. 1%, 0. 2%, and 0. 4% were selected. Copper tube of 14. 5 mm ID and test section of oblong shape with inside height of 13. 4 mm, 11. 7 mm, 10. 6 mm, 8. 6 mm were used. The heat transfer without the nanofluid is carried out so as to compare it with nanofluids. The results shows that the Nusselt number rises suddenly by 132% at the Peclet number of 420000 for 0. 4wt. % whereas the corresponding value for the 0. 2 wt. % nanofluid is approximately 58% for the same range of Peclet number. It can be concluded that the Nusselt number and hence the heat transfer rate goes up by increasing the nanoparticle weight fraction.

Demir [22] studied force convection of nanofluid consisting of water with Al$_2$O$_3$ and TiO$_2$ nanoparticle in a horizontal tube with constant wall temperature are investigated numerical. The horizontal test section is modeled and solved using CFD program a single phase
model have two-dimensional equation is employed with either constant temperature dependent properties to study the hydrodynamic and thermal behavior of the nanofluid flow. The numerical investigation is performed for a constant particle size of Al$_2$O$_3$ as a case study after the validation of the model by mean the experimental data of Duangthongusuk and Wongwises with TiO$_2$ nanoparticle. The velocity and temperature vectors are presented in the entrance and fully develop region. The variation of the fluid temperature, local heat transfer coefficient and pressure drop along tube length are show in their study. Effect of nanoparticle concentration and Reynolds Number on the wall shear stress, Nusselt number, and heat transfer coefficient and pressure drop are presented. Numerical results shown the heat transfer enhancement due to presence of nanoparticle in the fluid in accordance with the results of the experimental study used for validation process of numerical model.

Bianco et al. [23] investigated numerically developing laminar forced convection flow of an Al$_2$O$_3$/ water nanofluid in a circular tube, submitted to a constant and uniform heat flux at the wall. A single - and two - phase model (discrete particle model) is employed with either constant or temperature - dependent properties. The investigation is accomplished for size particles equal to 100 nm. The maximum difference in the average heat transfer coefficient between single - and two - phase models results is about 11 %. Convective heat transfer coefficient for nanofluids is greater than that of the base liquid. Heat transfer enhancement increases with the particle volume concentration, but it is accompanied by increasing wall shear stress values. The heat transfer always improves, as Reynolds number increases, but it is accompanied by an increase of shear stress too. Moreover a comparison with data present in the literature is carried out.

Rea et al. [24] investigated laminar convective heat transfer and viscous pressure loss for alumina / water and zirconia / water nanofluids in a fixed loop with a vertical heated tube. The heat transfer coefficients in the entrance region and in the fully developed region are found to increase by 17 % and 27 %, respectively, for alumina / water nanofluid at 6 vol. % with respect to pure water. The zirconia / water nanofluid heat transfer coefficient increases by approximately 2 % in the entrance region and 3 % in the fully developed region at 1.32 vol. %. The measured pressure loss for the nanofluids is in general much higher than for pure water. However, both the measured nanofluid heat transfer coefficient and pressure loss are in good agreement with the traditional model predictions for laminar flow.

A summary is follow in Table (1).

<table>
<thead>
<tr>
<th>Researchers</th>
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The effect of Strouhal number (frequency) is not more appreciable for the heat transfer enhancement.
Increasing the amplitude of inlet flow, revealed that amplitude of Nu increased, but total Nu did not change any more.
The heat transfer coefficient enhanced with increasing the nanoparticle concentration and Re number and decreasing the axial location.

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Researchers | Type of search | Boundary condition | Nanofluids | Results |
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Gabriela [12] | Numerical study | Double tube helical heat exchanger | CuO / Water TiO2 / Water | The heat transfer rate of the nanofluid was approximately 14% greater than of pure water.
The heat transfer coefficient of nanofluids increased with increasing of Dean No.
The amount of the increase in Nu ratio for three types of nanofluid is Al, Al2O3, and CuO/water and these ratios are respective - by (45%, 32%, and 25%) with insulation.
The average of the heat transfer increasing significantly by increases of the Φ and Ra.

Khalid Faisl Sultan [13] | Experimental study | Uniform heat flux | Al2O3 / Water CuO / Water Al / Water | A maximum enhancement of 13.56% in Nu at Re = 1730 when compared to the Nusselt number of water.
The heat transfer coefficient of nanofluid is higher than that of the base fluid and increased with increasing the Reynolds number and particle concentrations.
A considerable enhancement in the average heat transfer is observed compared with the distilled water.
The nanofluids at low concentration enhance the heat transfer with little extra penalty in pump power.

Suresh and Venkitara [14] | Experimental study | Constant heat flux | (Hybrid) Al2O3 - Cu/Water | 

Heyhat et al. [15] | Experimental study | Constant wall temperature | Al2O3 / Water | 

Jianli Wang et al. [16] | Experimental study | Uniform heat flux | CNT / Water | 

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Mirmasoumi and Behzadmehr [17] | Numerical study | Uniform heat flux | Al2O3 / Water | The increase in Nusselt number and friction coefficient in the entrance region were observed with the increase in particle volumetric fractions.
At constant Re increasing the nanoparticles concentration increases the heat transfer.
Increasing the nanoparticle concentration significantly augments the heat transfer coefficient while the skin friction coeffici - ent does not considerably affect.
Increasing the Richardson number signifies - antly augments the heat transfer coefficient because of its effects on the secondary flow.
The convective heat transfer coefficient of Cu/water nanofluid increased about 60% at 2% volume concentration.
The heat transfer enhancement is mainly due to dispersion of the nanoparticles.
The Nu rises suddenly by 132% at the Peclet number of 420000 for 0.4wt. %.
The Nusselt number and hence the heat transfer rate goes up by increasing the nanoparticle weight fraction.

Behzadmehr et al. [18] | Numerical study | Constant heat flux | Al2O3 / Water | 

Allahyari et al. [19] | Numerical study | Constant heat flux at the top surface of tube wall | Al2O3 / Water | 

Xuan and Li [20] | Experimental study | Constant heat flux | Cu / Water | 

D. Ashtiani et al. [21] | Experimental study | Constant wall temperature | MWCNT / Oil | 

Table (1). Continued.

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Demir [22] | Numerical study | Constant wall temperature | Al2O3 / Water TiO2 / Water | The heat transfer enhancement due to presence of nanoparticle in the fluid in accordance with the results of the expert - mental study used for validation process of numerical model.
Heat transfer enhancement increases with the particle volume concentration, but it is accompanied by increasing wall shear stress values.

Bianco et al. [23] | Numerical study | Uniform heat flux | Al2O3 / Water | 

Rea et al. [24] | Experimental study | Constant heat flux | Al2O3 / Water Zirconia / Water | The heat transfer coefficients in the fully developed region are found to be increased in 27% for Al2O3 / water nanofluid at 6 vol. % with respect to pure water.
3. Conclusions

Laminar nanofluid flow through a circular tube was presented in this paper. During the literature survey about heat transfer augmentation in a tube, 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 following conclusions have been drawn from the present review:

1. Increasing the nanoparticles concentration had not considerable effect on the heat transfer enhancement in the range of 0.25% concentration.
2. The rate of the heat transfer coefficient enhancement of nanofluid to that of pure water decreased with increasing the Reynolds number.
3. The pressure drop of nanofluid increased with increasing the volume fraction of nanoparticles.
4. The average heat transfer coefficient of nanofluids is larger than that of the base fluid. The enhancement of heat transfer coefficient increases with an increase in the Peclet number and the particle concentration.
5. The convective heat transfer enhancement of nanofluids is much more than the effect of the thermal conductivity enhancement.
6. At a certain Peclet number and axial position, the local heat transfer coefficient of nanofluids increases with increasing nanoparticle concentration.
7. Besides of many attempts made to determine the nanofluids’ thermal conductivity and viscosity, being important thermophysical properties no definitive agreements have emerged on these properties.
8. Heat transfer performance of the base fluid can significantly be increased by the suspended nanoparticles since heat transfer coefficient of the nanofluid was found to be larger than that of its base fluid for the same Reynolds number.

References


