International Engineering Research Journal

Heat transfer enhancement of nanofluids CNT and GO in a double-pipe counter flow heat exchanger with and without twisted tape inserts

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Abstract

Nanofluid is a novel heat transfer fluid act as a coolant has potential for use in the heat transfer filed because of its augmentation in thermal properties that offers advantages in heat Transfer performance. The Paper Concentrate on the convective heat transfer, effectiveness of flow CNT (Carbon Nanotubes)and GO (Graphene Oxide) nanofluids in a double pipe heat exchanger with and without twisted tape inserts. Water is considered as a base fluid. The results of heat transfer enhancements CNT/water and GO/water Nanofluids are compared with and without twisted tape inserts.The simulation results will be compared with experimental results.

Keywords*:Nanofluids, Double pipe heat exchanger, Nanoparticles, Carbon nanotube*

1. Introduction

Heat Exchangers are widely used in many engineering applications such as automobile radiators and refrigeration, air conditioning, chemical industry, thermal power plants, food industry. In order to manage the growing demand from different industries, heat exchanger devices have to be small in size, light in weight and of high performance. Several techniques have been developed to improve the thermal performance of heat exchangers. These techniques can be classified either as active techniques which require external power such as electrical and surface vibrations or as passive techniques which employ, for the enhancement of heat transfer,, surfaces of the special geometries (fins, grooves, helical shapes) of additives for fluids. Conventional Heat Transfer fluids such as water, oil, and ethylene glycol are employed as a working fluid for the heating and cooling systems, having low thermal conductivity is a serious limitation in improving the performance and compactness of engineering equipment. To overcome this disadvantage, there is a strong motivation to develop advanced heat transfer fluids. Hence the idea of dispersing solid particles in the working fluid was introduced in order to improve the thermal conductivity of working/base fluid. The feasibility and application of solid particles ranging from 10^{-9} to 10^{-7} meters was previously examined by many researchers.
Recent advances in nanotechnology have allowed development of a new category of liquids termed *nanofluids.* Nanofluid Choi [1] is a liquid suspension, which is a solid-liquid composite materials containing nanometer sized solid particles, including chemically stable metallic particles (Cu, Al, Fe, Au and Ag), metal oxides (Al_2O_3, CuO, TiO_2, SiC, Fe_3O_4), several allotropes of carbon and carbon nanotubes, with thermal conductivities and with sizes significantly smaller than 100nm. Nanofluids possess the superior thermophysical and hydrodynamic properties when compared with conventional heat transfer fluids or working fluids and fluids that contain micrometer-sized metallic particles. Heat transfer takes place at the surface of the particle, it is desirable to use a particle with a large surface area. Nanoparticles, when dispersed in heat transfer fluids have extremely large surface areasand therefore they have a great potential for application in heat transfer.
Heat transfer within horizontal annuli/ Double Pipe has many engineering applications such as heat exchanger, solar collectors, thermal storage systems and cooling of electronic components. Many of the industrial applications use natural convection as the main heat transfer mechanism. Hence, it is important to understand the thermal behavior of heat transfer systems when there is anonly natural convention effect. Over the past decades, extensive work is done on connective heat transfer using nanofluids. Experimental studies on Enhancement in heat transfer characteristics using forced convection applications were conducted to the heat transfer enhancement using natural convection by many researchers. On the other side, little attention has received to the heat transfer enhancement using natural convection. The work conducted on natural convection heat transfer include the work of Abu-Nada et al. [2] who studied Aluminum oxide-water nanofluids in a horizontal concentric annuli based on the Rayleigh Number and L/D ratio.. For Ra = 10^3 and Ra = 10^5 the addition of Al_2O_3 nanoparticles improves the heat transfer. They found that for high values of Rayleigh number and high L/D ratio, nanoparticles with high thermal conductivity result in significant enhancement in heat transfer. Chun et al [3] experimentally analyzed convective heat

transfer coefficient of nanofluids made of alumina nanoparticles and transformer oil which flow through a double pipe heat exchanger system in the laminar flow regime. The experimental study show that addition of nanoparticles in the fluid increases the average heat transfer coefficient of the nanoparticles, particle loading, and particle shape are key factors for enhancing the heat transfer properties of nanofluid. Duangthongsuk and Wongwises [4] performed the experimental study on the forced convective heat transfer and analyzed the flow characteristics of a nanofluid consisting of 0.2 vol. % TiO_2 nanoparticles of about 21nm diameter and water as a working fluid,, flowing in a horizontal double-pipe counter flow heat exchanger under turbulent flow conditions. The experimental study results showed that the convective heat transfer coefficient of nanofluid is higher than that of base fluid by about 6-11% at 0.2 vol. % of TiO_2 nanoparticles. They found the heat transfer coefficient of nanofluid increases with an increasing Reynolds number and an increasing mass flow rate of the hot water and nanofluid and increases with decrease in the nanofluid temperature. Also the temperature of the heating fluid has no significant effect on the heat transfer coefficient of nanofluid. They have suggested that additional work is required to investigate the effects of different particle concentration on the convective heat transfer coefficients.

Reza et al [5] investigated the enhancement of heat transfer coefficient and Nusselt number of a nanofluid containing nanoparticles Al_2O_3 with a particle size of 20nm and volume fraction of 0.1%-0.3%, with water as a working fluid, in a double-pipe counter flow heat exchanger under turbulent conditions. They both noted that, a considerable increase in heat transfer coefficient and Nusselt number up to 19%-24% respectively compared to the base fluid. The increase in the heat transfer may be due to the high density of nanoparticles on the wall pipe and the migration of the particles. It has been observed that the heat transfer coefficient increase with the operating temperature and concentration of nanoparticles.

Pantzaliet al [6] conducted an experimental study with the use of Al_2O_3, TiO_2, CNT and CuO nanoparticles with different particle sizes and concentration. They found that among the listed nanoparticles, CuO nanofluid is the most stable and with higher particle concentration would lead to a significant thermal conductivity enhancement. They have used 4% CuO suspension and checked the performance in commercial herringbone-type plate heat exchanger. They have concluded that the turbulent flow is employed in industrial heat exchangers, where large volumes of nanofluids are necessary. They had also summarized the relevant experimental studies in Table1

Table 1 Available experimental studies on heat transfer using nanofluids

Reference	Nanofluid-Ø %	Nanofluid conduit	Type of Flow	Result
Wen & Ding (2004)	Al_2O_3 - 0.6,1, 1.6	4.6mm i.d. horizontal tube	Lamin.	+47% in h
Ding et al. (2006)	CNT- 0.5	4.6mm i.d. horizontal tube	Lamin.	+350% in h
Yang et al. (2005)	Graphite-oil	4.6mm i.d. horizontal tube	Lamin.	+22% in h
Jung et al. (2009)	Al_2O_3 -<0.3	1.8mm i.d. horizontal tube	Lamin.	+8% in h
Zeinali Heris et al. (2006)	Al_2O_3 - 0.2, 1, 2, 3 6mm	6mm i.d. horizontal tube	Lamin.	+30% in Nu
Lee and Mudawar (2007)	Al_2O_3 - 1, 2 mm	MCHSa Single-phase	Lamin.	h enhamnt.
Chein and Chuang (2007)	CuO - 0.204, 0.256, 0.294, 0.4	MCHS	Lamin.	The enhancement reduces as V increases
Rea et al. (2009)	Al_2O_3 - 0.9, 1.8, 3.6	4.5mm i.d. vertical tube	Lamin.	No abnormal enhancement
Nguyen et al. (2007b)	Al_2O_3 - 1,3.1, 6.8	Miniature PHE	Mildly turbul.	+42% in h
Pantzali et al. (2009)	CuO - 0.04	Miniature PHE	Mildly turbul.	<+20% increase in heat transfer rate
He et al. (2007)	TiO_2 -0.24, 0.6, 1.1	4mm i.d. vertical tube	Lamin. & Turb.	+12% in h (laminar) > +40% in h (turbulent)
Pak and Cho (1998)	Al_2O_3 - 1.34, 2.78	10.7mm i.d. horizontal tube	Turbul.	+75% for a given Re
Xuan and Li (2003)	Cu -0.3, 0.5, 0.8, 1, 1.2	10mm i.d. horizontal tube	Turbul.	>+39% in Nu

Kiyuel andChongyoup[7] investigated the rheological properties of nanofluids using CuO particles of 10-30 nm in length and ethylene glycol and studied the thermal conductivity enhancement. From the rheological property it has been found that the volume fraction at the dilute limit is 0.002, which is much smaller than the value based on the shape and size of the individual particles due to aggregation of particles. The thermal conductivity of nanofluid increases as concentration of particles increases, it was found that even at very low concentration of 0.001, about 2.6% increase is observed y high compared to the volume fraction of particles. They found that effectiveness of adding particles is large enough when the volume fraction is less than 0.001 is used. Their study also showed that the metal oxides can be promising candidates as dispersed particles in nanofluid if aggregation can be minimized.

K. Hamid et al [8] focused on the effect of temperature on the heat transfer behavior using TiO_2 nanofluid, TiO_2 nanoparticles dispersed in ethylene glycol in a circular tube under constant heat flux boundary conditions with forced convection. A maximum enhancement of 28.5% compared with base fluid at 1.5% volume concentration and working temperature of 70ºC is observed. The nanofluid performance is significantly influenced by working temperature. The effect of temperature is significant in relation to heat transfer performance at high volume concentration and high working temperature because of the improvement of thermal properties.

H. Salma et al [9] performed the experiment on multi walled carbon tubes (water-based) nanofluids, with a volume concentration of 0.026%, in a coaxial heat exchanger. They studied the effect of aspect ratio of nanotubes, thermal conductivity and type of base fluid. He stated that, the convective heat transfer coefficient of nanofluids increased as the aspect ratio of nanotubes increases and decreased when the thermal conductivity of base fluid increases. Results shows that 12% increase in average connective heat transfer coefficient at low concentration of 0.026% vol. as compared to base fluid.

50-50 Ethylene glycol shows greater heat transfer enhancement as compared to water, with the same test conditions.

D. Cabaleiro et al [10], studied the thermophysical properties and stability of graphene nanoplatelets in an ethylene glycol (10:90).The graphene nanofluids are prepared, based on stability analysis using zeta potential and dynamic light scattering (DLS) measurements. The thermophysical properties of nanofluids such as thermal conductivity, density, anddynamic viscosity increases with nanoparticles mass concentration up to 5, 12.6 and 3% respectively. The temperature effect is on the dynamics viscosity and density of nanoparticles but not on the thermal conductivity enhancements.

T.T. Baby et al [11], investigated the thermal conductivity and heat transfer properties of hydrogen exfoliated graphene [HEG] and functionalized HEG (f-HEG), dispersed in ethylene glycol and deionized water. Functionalized HEG (f-HEG), shows an enchantment of about 16% at 25°C and 75% at 50°C in thermal conductivity at volume fraction of 0.05%. He also commented on, Nusselt number enhancement, increases with increase in volume fraction and Reynolds number for f-HEG. He concluded that the enhancement in Nusselt number is more than the enhancement in thermal conductivity of HEG and f-HEG nanofluids.

M. Salem et al [12], experimentally investigated the forced convective heat transfer and pressure drop characteristics of graphene oxide nanofluid using water as a base fluid flowing inside a circular tube, with a combination of four different volume concentration 0.05%, 0.1%, 0.15%, 0.20%. He concluded on the 1. The viscosity and thermal conductivity of graphene oxide increases with volume concentration 2. Nusselt number of nanofluid increases with increase in Reynolds number. 3. Addition of nanoparticle sin base fluid increases the pressure drop.

J. Wang et al [13] experimentally investigated the pressure drop and heat transfer of carbon nanotubes nanofluid dispersed in distilled water, following in a Horizontal circular tube. Experimental result reported that at Reynolds number of 120, the heat transfer enhancement are 70% and 190% for the volume concentration of 0.05% and 0.24% and enhancement in thermal conductivity is less than 10%. He concluded that the nanofluids shows the heat transfer enhancement at low concentration with little extra penalty in pump power, by measuring the pump power supply and the thermal conductance, which is contradictory to many preachers work.

M. Mirzaei et al [14] studied the heat teransfer and pressure drop characteristics of graphene oxide dispersed in water, with volume fraction of 0.02%, 0.07%, 0.12%, flowing in a circular tube with wire coil inserted in it. The results shows that, 77% enhancement in heat transfer coefficient with 0.12 vol. % of grapheneoxide. He also predicted that, with the increasing flow rate of nanofluid, convective heat transfer coefficient increases.

L. Liao et al [15] developed a new kind of aqueous drag-reducing fluid with CNTs added in working fluid of aqueous cetyltrimethyl ammonium chloride, CTAC, whose thermophysical and rheological properties are measured. Results indicate that the flow drag of the aqueous CTAC solution is 45% of that of water at optimal CTAC concentration and by maintaining the frag reducing effects, addition of CNT in drag reducing fluid improves the heat transfer coefficient.

Several investigations were conducted to study the performance of convective heat transfer by using the passive augmentation techniques.

Pardhiet al[16] reviewed the passive augmentation techniques in heat exchanger. The surface or geometrical modifications to the flow channel by using metal inserts, extended surface or additional devices are listed under Passive heat transfer augmentation techniques.They have reviewed the technique of augmenting the performance of heat transfer in a heat exchanger for laminar and turbulent flow by insert of plain and modified twisted tapes.

S. Sundar et al [17] considered the transition flow convective heat transfer and friction factor characteristic of water propylene glycol-based CuO nanofluids flowing in a horizontal circular tube fitted with and without helical inserts. CuO nanoparticles of average diameter less than 30nm were suspended in the base fluid and nanofluids of three different concentrations were prepared and experiment were conducted by inserting helical inserts having twist ratio in the range of 0-9 and Reynolds number ranging from 2,500-10,000. They observed that, the enhancement in the heat transfer coefficient of the 0.5% CuO nanofluid is about 14.4% and it is increased to about 28% at Reynolds number 10,000 in plain tube. The heat transfer enhancement with the helical insert of twist ratio 3 is 4.9 times at Reynolds number 25000 and 5.4 times at Reynolds number 10,000 compared to the heat transfer coefficient of base fluid in a plain tube. The use of helical inserts in fluid flow aids in significant enhancement in heat transfer coefficient of fluids accompanied by a pressure drop. The friction factor penalty is very much less compared to the benefit of heat transfer enhancements.

Aghayari and Maddah [18] performed the experimental study to investigate the performance of iron oxide-water nanofluid with nanoparticles of size 15nm and the concentration ranging from 0.12% to 0.2% by volume, in a double pipe heat exchanger with perforated twistedtapes under turbulent flow regime. They reported, the simultaneous application of nanoparticles and perforated twisted tape insets enhances the heat transfer and it increases with the decrease in the twist ratio. The maximum increase in the Nusselt number is achieved for the 0.2% of Iron Oxide nanofluid with twist ratio of 2.5.

Bhramara et al [19] conducted the experimental study on the convective heat transfer, friction factor, effectiveness and number of units of Fe_3O_4/water nanofluids flow in a double-pipe U-bend heat exchanger with and without wire coil inserts under turbulent flow conditions at different Reynolds number 16,000-30,000, different particle concentrations 0.005%-0.06% and different wire coil inserts of coil pitch to tube inside diameter (P/D) ratios 1, 1.34 and 1.79. The experimental results indicate that, Nusselt number increases with increasing Reynolds number and particle concentrations and decreasing P/D ratio of wire coil inserts. Their study showed that, the Nusselt number enhancement for 0.06% volume concentration of nanofluid is 14.7% and it further increases to 32.03% for the same 0.06% nanofluid with wire coil inserts of P/D =1 at a Reynolds number 28,954 compared with water. The friction factor increase of 0.06% nanofluid is about 1.092 times and with wire coil inserts of P/D=1, the friction factor increase is approximately 1.162 times at a Reynolds number of 28,94 compared with water.

Targui and Kahalerras [20] presented the work in the numerical simulation of nanofluids flow in a double pipe heat exchanger provided with porous baffles in which copper oxide, aluminum oxide, Titanium oxide, Silver and copper nanoparticles are circulated. The Darcy-Brinkman-Forchheimer model is adopted to describe the flow in the porous regions and the governing equations with the boundary conditions are solved by the finite volume method. It is found that the gain in heat transfer is related to the solid volume fraction than to the nature of nanoparticles. The highest rate of improvement is obtained with Ag nanoparticles, and the lowest rates of heat transfer are obtained with TiO_2 nanoparticles.

Akbarinia and Behzadmehr [21] fully developed laminar mixed convection of a nanofluid consisting of water and Al_2O_3 in a horizontal curved tubes has been studied numerically using three-dimensional elliptic governing equations. It showed that for a given Reynolds number, buoyancy force has a negative effect on the Nusselt number while the nanoparticles concentration has a positive effect on the heat transfer enhancement. For a given Reynolds number, at low Grashoff number, nanoparticles concentration does not have a significant effect on the skin friction reduction. Increasing nanoparticles concentration also has a positive effect on the heat transfer enhancement at different Re-Gr combinations.

K. Wongcharee et al [22], investigated the thermohydraulic characteristics of the circular tubes equipped with alternate clockwise and counterclockwise twisted-tapes (TA) for the Reynolds number ranging from 830 to 1990, the twisted tapes with different twist ratios (y/W= 3, 4 and 5) are inserted into the uniform wall heat flux tubes andwater is utilized as a base fluid. The plain tube and the tube inserted with twisted tape (TT) are compared. It is found that Nusselt number, friction factor and thermal performance factor associated by TA are higher than those associated by TT. The one with the smallest twist ratio of y/W= 3 is found to be the most efficient for heat transfer enhancement. The Twisted tape with alternate axis yield higher Nu than Twisted Tape by around 70.9 to 104.0%. Nu increases with decreasing twist ratio. The TA with y/ W= 3 gives higher transfer rate than the TA with y/W= 4 and 5 by around 15.6% and 30.7%, respectively. The friction factor increases with decreasing twist ratio. The friction factors of the tube with the TA at y/W= 3, 4 and 5 are respectively found to be around 50%, 49% and 33% higher than those of the tube with the TT at the same twist ratio.

A. Sawarkar et al [23] investigated the heat transfer enchantment using forced convection in which water is flow inside horizontal pipe. They both experimentally determined the influence of semi-circular cut twisted tape on pressure drop, Nusselt number (Nu) and friction factor (f). The test are conducting using the twisted tape with two different twist ratio for Reynolds number (Re) ranges between 4000 to 9000 under uniform heat flux conditions. Tubes fitted with semi-circular cut twisted tape inserts affect the heat transfer coefficient and friction factor. The geometry of the semi-circular cut twisted tape inserts makes it possible for water to flow easily through the pipe. This leads to a mixing of water with different temperatures and velocities. Mixing increases the temperature gradient of the thermal boundary layer and causes uniformity in fluid temperature. This enhances heat transfer. The semi-circular cut twisted tape offered a higher heat transfer rate and friction factor compared to the smooth tube and plain twisted tape. Nusselt number increases with decrease in twist ratio along with increase in cut radius. Friction factor decreases with increase of Reynolds number with increase in cut radius.

S. Sarada et al [24] experimentally investigated the augmentation of turbulent flow heat transfer in a horizontal tube by means of varying width twisted tape inserts with air as the working fluid. Twisted tapes of widths ranging from 10 mm to 22 mm, which are lower than the tube inside diameter of 27.5 mm are used. Experiments are carried out for plain tube with/without twisted tape insert at constant wall heat flux and different mass flow rates. The twisted tapes are of three different twist ratios (3, 4 and 5) each with five different widths (26-full width, 22, 18, 14 and 10 mm) respectively. The Reynolds number varied from 6000 to 13500. Both heat transfer coefficient and pressure drop are calculated and the results are compared with those of plain tube. It is found that the enhancement of heat transfer with twisted tape inserts as compared to plain tube varied from 36 to 48% for full width (26mm) and 33 to 39% for reduced width (22 mm) inserts. Reduction in tape width causes reduction in Nusselt numbers as well as friction factors. The maximum friction factor rise was about 18% for 26mm and only 17.3% for reduced width inserts compared to plain tube.

A. Yadav[25] studied the influences of the half-length twisted tape insertion on heat transfer and pressure drop characteristics in a U-bend double pipe heat exchanger. In the experiments, the swirling flow was introduced by using half-length twisted tape placed inside the inner test tube of the heat exchanger. The results obtained from the heat exchangers with twisted tape insert are compared with those without twisted tape i.e. Plain heat exchanger. The heat transfer coefficient is found to increase by 40% with half-length twisted tape inserts when compared with plain heat exchanger. On equal mass flow rate basis, the heat transfer performance of half-length twisted tape is maximum followed by smooth tube.

It is observed that less research work is found for convective heat transfer enhancement and its augmentation techniques.The use of passive augmentation techniques increases the performance of heat transfer of nanofluids.

2. Preparation of Nanofluids

The term Nanofluids is widely used after 1995, which is the fluids act as a working medium in heat transfer applications, with particles of average size less than 100nm dispersed in it. The presence of these particles alters the thermal and transport properties of the fluid. The Thermal conductivity of solid is typically higher than that of liquids seen from Table 2. [26]

Table 2 Thermal Conductivity of Additives and base fluid used in Nanofluids

Material	Scientific Formula	Thermal conductivity (W/Mk)
Metallic solids	Cu	401
	Al	237
	Ag	428
	Au	318
	Fe	83.5
Nonmetallic Solids	Al oxide	40
	CuO	76.5
	Si	148
	CNTs	~3000(MWCNTs)~ 6000(SWCNTs)
	BNNTs	260~600
	Graphite	100-190
Base Fluids	Water	0.613
	(EG)	0.253
	Engine Oil	0.145

The Preparation of nanofluids is the first key and important step in experimental studies with nanofluids because nanofluids needs special requirements such as an even suspension, stable suspension, low agglomeration of particles and no chemical change of the fluid [26].

Dhinesh and Valan [27], reviewed the preparation of metal and metal oxides nanofluids and hybrid nanofluids and the various techniques used to study the physical and chemical characteristics of nanofluid. Thermo-physical and heat transfer properties of nanofluids including the improved thermal conductivity, viscosity and specific heat models for nanofluids are presented.

Yanjiao and Zhou [26] summarizes the research in synthesis and characterizations of stationary nanofluids. They have also threw light on the stability of nanofluids. Nanofluids are not a simple mixture. Nanoparticles tend to aggregated as time elapsed, the agglomeration of nanoparticles results in settlement and clogging of microchannels and also decreases the thermal conductivity. The simple and reliable method is sedimentation method. In this method, an external force is utilized to initiate the sedimentation. The sediment weight or the sediment volume measured after the predetermined time period represents the stability. As per Yanjiao Nanofluids are said to be stable if the dispersed particle concentration remains constant with respect to time. Zeta Potential analysis is another method, zeta potential is defined as the potential difference between dispersion fluid and the layer of stationary attached to the surface of the dispersed particles. It represents the degree of repulsion among the similarly charged adjacent particles. The zeta potential can be either positive or negative. Therefore suspensions with a high value of zeta potential are considered to be electrically more stable as compared to suspensions with low zeta potentials. They have also listed the other methods such as UV spectrophotometer i.e. spectral absorbency analysis. Generally the relationship between the absorbance intensity and concentration of particles in the fluid is linear. If the nanoparticles, dispersed in the fluid have a characteristics absorption band in the region of 190-1100 nm wavelength, then it is a simple and reliable method to establish the stability of nanofluids. Amarinder and Sharma et al [28] also describes the method to evaluate the stability i.e. light scattering and electron microscopy technique. Imagery analysis of the nanofluids can be done by suing electron microscope namely Scanning Electron Microscope (SEM) or Transmission Electron Microscope (TEM). TEM is preferred and most of the researches utilizes for their characterization. A very simple method is used i.e. Dynamic Light Scattering (DLS) for the particle size analysis. Other important characterization techniques for the structure and morphology nanoparticles are Small Angle X-ray Scattering (SAXS) and Small Angle Neutron Scattering (SANS)

Amarinder and Sharma et al [28] also summarized the techniques used to increase the stability of nanofluid. The first techniques is the use of ultrasonic agitators to break the clustered particles back into individual particles and it depends on how long the nanofluid sample was kept in the agitator. The second techniques is of modification in surface involves the addition of functional particles into the base fluid which are capable of providing very stable nanofluids. The stability of nanofluid also increased by adding the surfactants in nanofluids. It is an easy and economical method to achieve stability of Nanofluid. Surfactants even if they are added in small quantities they have significant effect on surface characteristics of nanofluids. They are added to increase the surface contact of two materials which is termed as wet ability.

G.H.Ko et al [29] prepared the stable aqueous suspension of carbon nanotubes, using two different methods, first is dispersion of nanotubes using surfactant sodium dodecyl sulfate (SDS) and second is introduction of functional groups of oxygen on the CNT surfaces by acid treatment. Results shows that, nanofluids prepared by the acid treatment have smaller viscosity than the one made using surfactant.

Table 3 Synthesis of Nanofluids system reported in literature

System	Synthesis Process	Particle loading (vol %)	Increase in thermal conductivity (%)
Cu/EG	Single-step	0.3	40
Cu/H_2O	Single-step	0.1	23.8
Cu/H_2O	Two-step	7.5	78
Fe/EG	Single-step	0.55	18
Ag/toluene	Two-step	0.001	16.5 (60ºC)
Au/toluene	Two-step	0.00026	21 (60ºC)
Au/ethanol	Two-step	0.6	1.3±0.8
Fe_3O_4/H_2O	Single-step	4	38
TiO_2/H_2O	Two-step	5	30-33
Al_2O_3/H_2O	Two-step	5	20
Al_2O_3/EG	Two-step	0.05	29
CuO/H_2O	Two-step	5	11.5
SiC/H_2O	Two-step	4.2	15.9
NCTs/EO	Two-step	2	30
NCTs/Polyoil	Two-step	1	160
NCTs/EG	Two-step	1	19.6
NCTs/H_2O	Two-step	1	7.0
NCTs/Decene	Two-step	1	12.7
H_2O /FC-72	Two-step	12	52

The preparation of nanofluids from nanoparticles arebroadly classified as Single-step method and Two-step method. The single step method is a process of combining the preparation of nanoparticles with the synthesis of nanofluids, for which the nanoparticles are directly prepared by physical vapor deposition. The two step method for preparing nanofluid is a process by dispersing nanoparticles into base fluids. Nanoparticles, nanofibers or nanotubes used in this method are first produced as a dry powder by inert gas condensation, chemical vapor deposition, mechanical alloying and the nanosized powder is then dispersed into a fluid in a second processing step [26].

Yonijao et al [26] summarized the synthesis process of different nanofluids systems reported in literature, represented in Table 3

3. Experimental Setup

Experimental apparatus used in this study is as shown in Fig. 1. It consists of test section (heat exchanger), two tanks, four RTDs for temperature measurement and two pumps for transporting nanofluid as the hot fluid and the other for the cold water. The heat exchanger consists of counter flow double pipe heat exchanger with the length of 1650mm. Hot fluid flows into the pipe made up of copper having inner and outer diameter as 10.5mm and 12.5mm respectively, and cold water in the annular region of pipe having inner and outer diameter as 27.5mm and 33.5mm respectively. Insulation is provided at the outer surface of annular region made up of glass wool material. For the measurement of temperature at inlet and outlet section, RTDs are provided. A storage tank is provided for cold fluid of 400L capacity and for hot fluid of 15L capacity. Rotameter is provided for the measurement of flow rates of both the fluids. An electric heater is provided with a temperature controller to maintain constant temperature of hot water.

During the test run, the inlet and exit temperatures of the hot nanofluid and water, mass flow rates of the hot nanofluid and water will be measured. The experiment is carried out in the heat Transfer lab at RSCOE, Tathawade Pune.

Fig.1 Experimental setup of double-pipe counter flow heat exchanger

The nanofluids used in the present study are CNT and TiO_2 using water as a base fluid.

The Experimental Condition s are used in the study are as follows

- Temperature of Nanofluid is 40°C, 45°C and 50°C
- The Mass flow rate of Hot Nanofluid is ranging from 90-240LPH and that of water ranging from 180-480 LPH
- Volume concentrations of GO and CNTs are 3.5% and 3% by volume respectively are used.
- Twisted tape of stainless steel copper material
- Width of twisted tape is 10.5mm
- Twist ratio of twisted tape is 6 and 8

In the present study, Comparison of heat transfer enhancement between CNTs and GO/water nanofluid will be concluded.

4. Conclusion

Many important, complex and interesting phenomenon involving nanofluids have been reported in the literature. Attention has been focused in the improvement of heat exchanger efficiency by adding solid particles to heat transfer fluids. Many researchers have investigated the effect of nanoparticles on different process parameters like hydrodynamic and thermophysical properties like effect of temperature on heat transfer enhancement, Effect of Rayleigh number. Researchers has given more focused on Aluminum oxide, Copper oxide nanoparticles, having high thermal conductivity value.

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