A REVIEW ON HEAT TRANSFER ENHANCEMENT WITH NANOFLUID

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ABSTRACT

A new engineering medium, called nanofluid attracted a wide range of researches on many cooling processes in engineering applications, which are prepared by dispersing nanoparticles or nanotubes in a host fluid. In this paper, the stability of nanofluids is discussed as it has a major role in heat transfer enhancement for further possible applications. It also represents general stabilization methods as well as various types of instruments for stability inspection. Characterization, analytical models and measurement techniques of nanofluids after preparation by a single step or two-step method are studied.

Keywords: Heat Exchanger, Heat Transfer Enhancement, Nanofluid, Stability, Thermal Conductivity.

I INTRODUCTION

Heat transfer enhancement of thermal systems has many industrial applications owing to the lack of energy resources. A possible effective way of improving the heat-transfer performance of common fluids is to suspend various types of small solid particles, such as metallic and non-metallic particles, in conventional fluids, such as water, mineral oils and ethylene glycol, to form colloidal. Recent developments in nanotechnology and related manufacturing techniques have made possible the production of nano-sized particles. Fluids with nanoparticles suspended in them are called nanofluids.

The poor thermal properties of convective heat transfer fluid acts as a main barrier to the growth of energy efficient heat exchangers. In recent years nanofluids have been introduced as ideal candidate for enhancing heat transfer. Owing to the small .size of the nanoparticles, little pressure drop is observed in the fluid where it behaves like a pure fluid or single phase liquid.

The conventional method for increasing heat dissipation is to increase the area available for exchanging heat to use a better heat conductive fluid. However, this approach involves an undesirable increase in the size of a thermal management system; therefore, there is an urgent need for new and novel coolants with improved performance. The innovative concept of ‘nanofluids’ – heat transfer fluids consisting of suspended of nanoparticles – has been proposed as a prospect for these challenges.

II NANOFLUID

2.1 History

The term nanotechnology is new, but its existence of the functional devices and structure of nanosized devices are not new in this world. In 1905, experimental data on the diffusion theory showed that the molecule has nanometer diameter, which is considered as the notable landmark in the scientific history of nanotechnology.

In 29 December 1959: Visionary statement by Prof.R.P.Feynman, "There is enough space at the bottom"

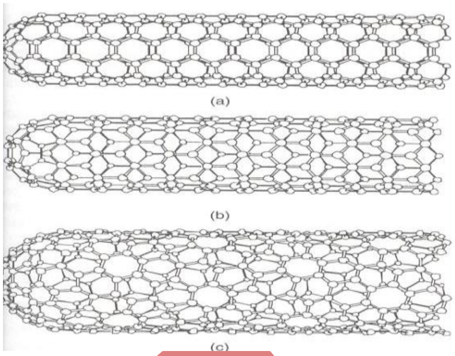

Fig 1: Some Common Structure Of Carbon Nanotubes(Cnt)

A carbon nanotube is a tube shaped material,made of carbon,having a diameter measuring on the nanometer scale. Carbon nanotubes are Allotropes of carbon with a cylindrical nanostructure. Nanotubes have been constructed with length to diameter ratio of up to 132,000,000:1 significantly larger than for any other material. The cylindrical carbon molecules have unusual properties which are valuable for nanotechnology. In particular owing to their extraordinary thermal conductivity and mechanical and electrical properties carbon nanotubes find application as additives to various structural materials.

2.2 Need of Nanofluids

- Due to nano size particles, pressure drop is minimum.
- Higher thermal conductivity of nano particles will increase the heat transfer rate.
- Successful employment of nanofluid will lead to lighter and smaller heat exchanger.
- Drastic change in the properties of the base fluid, by suspending nanofluids.
- Heat transfer rate increases due to large surface area of the nano particles in the base fluid.
- Nanofluids are most suitable for rapid heating and cooling systems.
- Due to nano size particles, fluid is considered as integral fluid.

Considering the heat transfer point of view, one of the most important challenge faced by the experts is the necessity to increase the heat flux and to reduce the size of the heat exchanger for the efficient use of the energy. Nanotechnology is being considered for use in many applications to provide cleaner, more efficient energy utilization.

Maximizing the heat transfer area is a common statergy to improve the heat transfer and many heat exchangers such as radiators and plate and frame heat exchanger designed to maximize the heat transfer area. This statergy cannot be applied to the micro electro mechanical systems (MEMS).

Nanofluids can be used for the wide variety of industries, ranging from transportation to energy production and in electronics systems like microprocessor. The novel and advanced concept of coolant offer intriguing heat transfer characteristics compared to conventional fluid. Application of the nanofluids in the industries may be hindered by the several factors such as long term stability, increase pumping power and pressure drop, nanofluids thermal performance in turbulent and fully developed region, lower specific heat of nanofluids and higher production cost of nanofluids.

2.3 Application

Nanofluids can be used to cool automobile engines and welding equipments and to cool high heat flux device such as high power microwave tubes, and high power laser diode array. Nanofluid could flow through the tiny passage in MEMS to improve the efficiency. In the transportation industry, nanocars,General Motors (GM),Ford among others are focusing on nanofluid research projects.

Some common applications are:-

- Engine cooling
- Engine transmission oil
- Boiler exhaust flue gas recovery
- Cooling of electronics circuits
- Nuclear system cooling
- Solar water heating
- Refrigeration (domestic and chillers)
- Defence and Space applications
- Thermal storage
- Bio-medical applications
- Drilling and lubrications

The measurement of nanofluid critical heat flux (CHF) in a forced convection loop is useful for the nuclear applications. If nanofluid improves the chiller efficiency by 1%, a saving of 320 billion KWh of electricity or equivalent 5.5 million barrel of oil per year would be release in US alone. The nanofluids find the potential for deep drilling operations. A nanofluid can also be used for increasing the dielectric strength and life of transformer oil by dispersing nanodiamonds particles.

III NANOFLUID PREPARATION METHOD

Preparing a stable and durable nanofluid is a prerequisite optimizing its thermal properties. Therefore, many combinations of material might be used for particular applications, namely: nanoparticles of metals, oxides, nitrides, metal carbides, and other non-metals with or without surfactant molecules which can be dispersed into fluids such as water, ethylene glycol, or oils. Two different techniques apply to produce nanofluids namely: single-step and two-step method.

3.1 Two-Step Technique

In this method, dry nanoparticles/nanotubes are first produced,and then they are dispersed in a suitable liquid host, but as nanoparticles have a high surface energy, aggregation and clustering are unavoidable and will appear easily. Afterward, the particles will clog and sediment at the bottom of the container. Thus, making a homogeneous dispersion by two step method remains a challenge. However, there exist some techniques to minify this problem like high shear and ultrasound. Therefore, we will discuss different methods of making a stable nanofluid in the next section. Nanofluids containing oxide particles and carbon nanotubes are produced by this method. This method works well for oxide nanoparticles and is especially attractive for the industry due to its simple preparing method. But its disadvantage due to quickly agglomerated particles brings about many challenges nowadays.

As nanoparticles disperse partially, dispersion is poor and sedimentation happens so a high volume concentration is needed increasing the heat transfer (10 times of single step) and accordingly the cost would be as much as loading. The two-step method is useful for application with particle concentrations greater than 20 vol.%but it is less successful with metal nanoparticles. However, some surface treated nanoparticles showed excellent dispersion.The first materials tried for nanofluids preparation were oxide particles, mainly because they are easy to make and chemically stable in solution.

3.2 Single Step Technique

In this method nanoparticle manufacturing and nanofluid preparation are done concurrently. The single-step method is a process combining the preparation of nanoparticles with the synthesis of nanofluids, for which the nanoparticles are directly prepared by physical vapour deposition (PVD) technique or a liquid chemical method (condensing nanophase powders from the vapor phase directly into a flowing low-vapor–pressure fluid is called VEROS). In this method drying ,storage, transportation, and dispersion of nanoparticles are avoided, so the agglomeration of nanoparticles is minimized and the stability of the nanofluids is increased. A disadvantage of this method is that it is impossible to scale it up for great industrial functions and is applicable only for low vapor pressure host fluid. This limits the application of the method.

IV LITERATURE SURVEY

M.H.kayhani et al. [1] Experimental analysis of turbulent convective heat transfer and pressure drop of Al_2O_3/water nanofluid in horizontal tube ; Turbulent flow convective heat transfer and friction factor characteristics of Al_2O_3/water nanofluid flowing inside a uniformly heated horizontal circular tube are conducted in this Letter. To do this, Al_2O_3 nanoparticles of 40 nm size were characterised and dispersed in distilled water to form stable suspension containing 0.1, 0.5, 1.0, 1.5 and 2.0% volume concentrations of nanofluids. Results indicate that heat transfer coefficients

increase with nanofluid volume concentration and do not change with Reynolds number. The enhancement of the Nusselt number is about 22% at Re ¼ 13 500 using 2% alumina nanoparticles compared to distilled water.

Experimental results are also compared with the existing correlations of convective heat transfer coefficient and pressure drop in turbulent regime. The measured pressure loss when using nanofluids is almost equal to that of the base fluid.

P.E. Phelan et al. [2] Convective Heat transfer for water based alumina nanofluids in a single 1.02mm tube Nanofluids are colloidal solutions which contain asmall volume fraction of suspended submicron particles or fibers in heat transfer liquids, such as water or glycol mixtures. Compared with the base fluid, numerous experiments have generally indicated an increase in effective thermal conductivity and a strong temperature dependence of the static effective thermal conductivity. However, in practical applications, a heat conduction mechanism may not be sufficient for cooling high-heat-dissipation devices such as microelectronics or powerful optical equipment. Thus, thet hermal performance under convective heat transfer conditions becomes our main task. We report here the heat transfer coefficient in both developing and fully-developed regions by using water-based alumina nanofluids. Our experimental test section consists of a single 1.02-mm-diameter stainless steel tube, which is electrically heated to provide a constant wall heat flux. Both pressure drop and temperature differences are measured. The characterization of nanofluids such as pH, electrical conductivity, particle sizing and zeta potential area lso documented. Based on these results, the analysis and applicability of convective heat sinks containing nanofluids are evaluated for contemporary uses.

Ahamad R. Sajadi et al. [3] Investigation of Turbulent Convective Heat Transfer of $Ti0_2$/water Nanofluid in Circular Tube; turbulent heat transfer behavior of titanium dioxide water nanofluid in a circular pipe is investigated experimentally. In this article, a new correlation of the Nusselt number is presented using the results of experiments on titanium dioxide nanoparticles dispersed in water where the volume fraction of nanoparticles in base fluid is less than0.25%. The experimental measurements were carried out inthe fully developed turbulent regime for various particle volumetric concentrations. Results indicated that addition of small amounts of nanoparticles to the base fluid augmented heat transfer remarkably. Increasing the volume fraction of nanoparticles in the range studied in this work did not show much effect on heat transfer enhancement. Experimental results are then compared with existing correlations for nanofluid convective heat transfer coefficient in turbulent regime.

Jean-Antoine Gruss et al. [4] Influence of nanoparticle shape factor on convective heat transfer and energetic performance of water-based SiO and ZnO nanofluids. To appreciate the merits, in terms of energy, of two nanofluids and of two shapes of nanoparticles, an experimental study has been carried out on water-based SiO_2 and ZnO nanofluids flowing inside a horizontal tube whose wall temperature is imposed. Pressure drop and heat transfer coefficients have been measured at two different inlet temperatures (20 ^{0}C, 50 ^{0}C) in heating and/or cooling conditions at various flow rates (200 < Re< 15,000). The Reynolds and Nusselt numbers have been determined by using thermal conductivity and viscosity measured in the same conditions as those in tests. The results obtained show a small improvement of Nusselt numbers of studied nanofluids compared to those of the base fluid. An energy Performance Evaluation Criterion (PEC) has been defined to compare heat transfer rate to pumping power. Only nanofluid with ZnO nanoparticles having a shape factor greater than 3appears to reach a PEC as high as that of water.

K.V.Sharma et al. [5] Heat transfer enhancements of low volume concentration Al_2O_3 nanofluid and with longitudinal strip inserts in a circular tube; The turbulent convective heat transfer and friction factor behavior of Al_2O_3 nanofluid in a circular tubewith different aspect ratios of longitudinal strip inserts are studied experimentally. Experiments are conducted with water and nanofluid in the range of 3000 < Re < 22,000, particle volume concentration0 < u < 0.5% and longitudinal strip aspect ratios of 0 < AR < 18. The agreement between the values of Nusselt number obtained with water is satisfactory when compared with the data of Heish and Huang. Results indicate that heat transfer coefficients increase with nanofluid volume concentration and decrease with aspect ratio.

Stephen U.S. Choi et al.[6] Flow and convective heat transfer characteristics of water-based Al_2O_3 nanofluids in fully developed laminar flow regime, In that paper measured the pressure drop and convective heat transfer coefficient ofwater-based Al_2O_3 nanofluids flowing through a uniformly heated circular tube in the fully developed laminar flow regime. The experimental results show that the data for nanofluid friction factor show a good agreement with analytical predictions from the Darcy's equation for single-phase flow. However, the convective heat transfer coefficient of the nanofluids increases by up to 8% at a concentration of 0.3 vol% compared with that of pure water and this enhancement cannot be predicted by the Shah equation. Furthermore, the experimental results show that the convective heat transfer coefficient enhancement exceeds, by a large margin, the thermal conductivity enhancement. Therefore, we have discussed the various effects of thermal conductivities under static and dynamic conditions, energy transfer by nanoparticle dispersion, nanoparticle emigration due to viscosity gradient, non-uniform shear rate, Brownian diffusion and thermo phoresison the remarkable enhancement of the convective heat transfer coefficient of nanofluids. Based on scale analysis and numerical solutions, we have shown, for the first time, the flattening of velocity profile ,induced from large gradients in bulk properties such as nanoparticle concentration, thermal conductivity and viscosity. We propose that this flattening of velocity profile is a possible mechanism for the convective heat transfer coefficient enhancement exceeding the thermal conductivity enhancement.

Tom McKrell et al. [7] Laminar convective heat transfer and viscous pressure loss of alumina–water and zirconia–water nanofluids,Laminar convective heat transfer and viscous pressure loss were investigated for alumina–water and zirconia–water nanofluids in a flow loop with a vertical heated tube. The heat transfer coefficients in theentrance 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, provided that the loading- and temperature-dependent thermo physical properties of the nanofluids are utilized in the evaluation of the dimensionless numbers. In other words, no abnormal heat transfer enhancement or pressure loss was observed within measurement errors.

Somchai Wongwises et al [8]; Heat transfer enhancement and pressure drop characteristics of TiO_2–water nanofluid in a double-tube counter flow heat exchanger,This article reports an experimental study on the forced convective heat transfer and flow characteristics of a nanofluid consisting of water and 0.2 vol.% TiO_2 nanoparticles. The heat transfer coefficient and friction factor of the TiO_2–water nanofluid flowing in a horizontal double-tube counter flow heat exchanger under turbulent flow conditions are investigated. The Degussa P25 TiO_2 nanoparticles of about 21 nm diameter are used in the present study. The results show that the convective heat transfer coefficient of nanofluid is slightly higher than that of the base liquid by about 6–11%. The heat transfer coefficient of the nanofluid increases with an increase in the mass flow rate of the hot water and nanofluid, and increases with a decrease in the nanofluid temperature, and the temperature of the heating fluid hasno significant effect on the heat transfer coefficient of the nanofluid. It is also seen that the Gnielinski equation failed to predict the heat transfer coefficient of the nanofluid. Finally, the use of the nanofluid has a little penalty in pressure drop.

Hamid Niazmand et al. [9] Numerical investigation of effective parameters in convective heat transfer of nanofluids flowing under a laminar flow regime, This article presents a numerical investigation on heat transfer performance and pressure drop of nanofluids flows through a straight circular pipe in a laminar flow regime and constant heat flux boundary condition. Al_2O_3, CuO, carbon nanotube (CNT) and titanate nanotube (TNT) nanoparticles dispersed in water and ethylene glycol/water with particle concentrations ranging between 0 and 6 vol.% were used as working fluids for simulating the heat transfer and flow behaviours of nanofluids. The proposed model has been validated with the available experimental data and correlations. The effects of particle concentrations, particle diameter, particles Brownian motions, Reynolds number, type of the nanoparticles and base fluid on the heat transfer coefficient and pressure drop of nanofluids were determined and discussedin details. The results indicated that the particle volume concentration, Brownian motion and aspect ratioof nanoparticles similar to flow Reynolds number increase the heat transfer coefficient, while the nanoparticle diameter has an opposite effect on the heat transfer coefficient. Finally, the present study provides some considerations for the appropriate choice of the nanofluids for practical applications.

Phillip T. Robbins et al. [10] Experimental and theoretical studies of thermal conductivity, viscosity and heat transfer coefficient of titania and alumina nanofluid.Thermal conductivity, viscosity and heat transfer coefficient of water-based alumina and titania nanofluids have been investigated. The thermal conductivity of alumina nanofluids follow the prediction of Maxwell model, whilst that of titania nanofluids is slightly lower than model prediction because of high concentration of stabilisers. None of investigated nanofluids show anomalously high thermal conductivity enhancement frequently reported in literature. The viscosity of alumina and titania nanofluids was higher than the prediction of Einstein–Batchelor model due to aggregation. Heat transfer coefficient measured in nanofluids flowing through the straight pipes are in a very good agreement with heat transfer coefficients predicted from classical correlation developed for simple fluids. Experimental heat transfer coefficients in both nanofluids as well as corresponding wall temperatures agree within ±10% with thevalues obtained from numerical simulations employing homogeneous flow model with effective thermo physical properties of nanofluids. These results clearly shows that titania and alumina nano-fluids do notshow unusual enhancement of thermal conductivity nor heat transfer coefficients in pipe flow frequently reported in literature.

V DISCUSSION

The various authors have performed the experimentation related to the heat transfer enhancement by using oxide form nanofluid such as CuO, Al_2O_3 ,TiO_2, ZnO. Amongst all Al_2O_3 and CuO are frequently used due to the ease of suspension in the basefluid. The use of proper ultrasonic mixer is essential for the uniform mixing of the nanoparticles. Proper care has to be taken while handling the nanoparticles in order to avoid the oxidation. The use of the nanofluid with higher concentration provides considerably higher thermal performance for all Reynolds number.

VI CONCLUSION

1. The higher the nanoparticles weight fraction, the more the rate of heat transfer enhancement.
2. The heat transfer rate is directly proportional to Nusselt and Peclet number of the fluid.
3. The fine grade of nanoparticles increases the surface area which results in increase in the heat transfer rate.
4. Nanofluid stability and its production cost are major factors that hinders the commercialization of the nanofluids. By solving these challenges, it is expected that nanofluid can make substantial impact as coolant in heat exchanging devices.
5. There has been considerable pressure drop by the use of nanofluid, but can overcome to some extend if extremely fine powder is used (less than 20 nm).

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