A REVIEW ON BEHAVIOR OF NANO FLUIDS ON HEAT TRANSFER

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Abstract

As a new research and technology frontier, nanofluids are used to enhance heat transfer including single-phase heat transfer, nucleate boiling heat transfer, flow boiling heat transfer and critical heat flux. This paper presents an overall review of a number of patents on nanofluid heat transfer technologies and their applications for the energy efficiency improvement in various thermal systems in recent years. Although a number of patents on nanofluids heat transfer technologies (more than 20 patents) have been invented, the fundament mechanisms of nanofluid heat transfer have not yet well understood so far. Thus, the applications of these technologies are greatly limited. According to this review, the future developments of these technologies are discussed. In order to be able to put the nanofluid heat transfer technologies into practice, fundamental studies are greatly needed to understand the physical mechanisms. Research in convective heat transfer using suspensions of nanometer-sized solid particles in base liquids started only over the past decade. Recent investigations on nanofluids, as such suspensions are often called, indicate that the suspended nanoparticles markedly change the transport properties and heat transfer characteristics of the suspension.

Keywords: *Nanofluid, Nanoparticles, heat transfer, Dispersion of particles*

1.0 INTRODUCTION:

Nanofluid a term coined is a new class of heat transfer fluids which is developed by suspending nanoparticles such as small amounts of metal, nonmetal or nanotubes in the fluids. The goal of nanofluids is to achieve the highest possible thermal properties at the smallest possible concentrations (preferably<1% by volume) by uniform dispersion and stable suspension of nanoparticles (preferably<10 nm) in host fluids. Nanofluids are engineered colloids made of a base fluid and nanoparticles (1-100 nm). Common base fluids include water, organic liquids (e.g. ethylene, tri-ethyleneglycols, refrigerants, etc.), oils and lubricants, bio-fluids, polymeric solutions and other common liquids. Materials commonly used as nanoparticles include chemically stable metals gold, copper), metal oxides (e.g., alumina, silica, zirconia, titania), oxide ceramics (e.g. Al2O3, CuO), metal carbides (e.g. SiC), metal nitrides (e.g. AIN, SiN), carbon in various forms (e.g., diamond, graphite, carbon nanotubes, fullerene) and functionalized nanoparticles. Solids have thermal conductivities which are orders of magnitude larger than those of conventional heat transfer fluids as shown in Table 1. By suspending nanoparticles in conventional heat transfern fluids, the heat transfer performance of the fluids can be significantly improved. As a fluid class, nanofluids have a unique feature which is quite different from those of conventional solidliquid mixtures in which millimeter and/or micrometersized particles are added. Such particles settle rapidly, clog flow channels, erode pipelines and cause severe pressure drops. All these shortcomings prohibit the application of conventional solid-liquid mixtures to microchannels while nanofluids instead can be used in micro-scale heat transfer. Furthermore, compared to nucleate pool boiling enhancement by addition of surfactants, nanofluids can enhance the critical heat flux (CHF) while surfactants normally do not. Thus, nanofluids appear promising as coolants for dissipating very high heat fluxes in various applications. Thermal properties of liquids play a decisive role in heating as well as cooling applications in industrial processes. Thermal conductivity of a liquid is an important physical property that decides its heat transfer performance. Conventional heat transfer fluids have inherently poor thermal conductivity which makes them inadequate for ultra high cooling applications. Scientists have tried to enhance the inherently poor thermal conductivity of these conventional heat transfer fluids using solid additives following the classical effective medium theory for effective properties of mixtures.

Synthesis of Nanofluids:

The thermal conductivity of heating or cooling fluids is a very important property in the development of energy efficient heat transfer systems. At the same time, in all processes involving heat transfer, the thermal conductivity of the fluids is one of the basic properties taken account in designing and controlling the process. Conventional heat transfer fluids have inherently poor heat transfer properties compared to most solids which is due to the higher thermal conductivities of solids (in orders of magnitude) compared to traditional heat transfer fluids. To overcome the rising demands of modern technology and also to reduce the limitations there is a need to develop new types of fluids that will be more effective in terms of heat exchange performance. Also nanoparticles can be classified by the technique that has been used for their synthesis which are:

1- Physical methods
1-1 Mechanical grinding
1-2 Inert gas condensation
2- Chemical methods
2-1 Chemical precipitation
2-2 Chemical vapor deposition
2-3 Micro-emulsions
2-4 Spray pyrolysis
2-5 Thermal spraying

2.0 LITERATURE REVIEW:

Koh Kai Liang Peter, (2014) The remarkable thermo physical properties that nanofluids possess give it rising potential as a working fluid in many industries. This paper aims to investigate whether the use of nanofluids as a working fluid, as opposed to using water/oil, will reduce the pipe dimensions in an industrial set up. An understanding of the thermal conductivity in nanofluids is discussed before a suitable heat analysis method is developed to give relationships for the Nusselt number. After which, an analysis on the thin-walled pipe with constant wall temperature is applied to evaluate whether the required pipe dimensions are smaller if nanofluids are employed as the working fluid.

Harish Nagar, (2017) A Nanofluid is a fluid containing nanometer sized particles. The Nanofluids are obtained by dispersing nanometer sized particles in a conventional base fluids like water, oil, ethylene glycol etc. Nanoparticles of materials such as metallic oxides (Al_2O_3, CuO), nitride ceramics(AlN, SiN), carbide ceramics (SiC, TiC), metals (Cu, Ag, Au), semiconductors (TiO_2, SiC), single, double or multi walled carbon nanotubes, alloyed nanoparticles (Al_{70}, Cu_{30}) etc. have been used for the preparation of nanofluids. This paper presents a procedure for preparation of Nanofluids, Properties of Nanofluids and their applications in various fields including energy, mechanical and biomedical fields.

Mustafa Kilic, (2018) Present study is focused on numerical investigation of heat transfer and fluid flow from a heated surface by using nanofluids and impinging jets. Effects of Reynolds number, different particle diameter and different types of nanofluids (TiO2-water, CuO-water, NiO-water) on heat transfer and fluid flow were studied numerically. TiO2-water nanofluid was used as a base coolant. Three impinging jets were used to cool the surface. It is obtained that increasing jet velocities from Ren/Re1=1-1.33-1.67 to Ren/Re1=1-1.20-1.40 causes an increase of 49.9% on average Nusselt number (ANN) but increasing jet velocities from Ren/Re1=1-1.20-1.40 to Ren/Re1=1-1.17-1.33 causes a decrease of 4.6% on ANN.

3.0 METHODOLOGY:

3.1 Fabrication Fluids:

Methods for producing nanofluids: The delicate preparation of a nanofluid is important because nanofluids need special requirements such as an even suspension, durable suspension, stable suspension, low agglomeration of articles and no chemical change of the fluid. There are two fundamental methods to obtain nanofluids .

Two step process: This technique is also known as Kool-Aid method which is usually used for oxide nanoparticles. In this technique nanoparticles are obtained by different methods (in form of powders) and then are dispersed into the base fluid. The main problem in this technique is the nanoparticle agglomeration due to attractive Van der Waals forces.

One step process: In this process the dispersion of nanoparticles is obtained by direct evaporation of the nanoparticle metal and condensation of the nanoparticles in the base liquid and is the best technique for metallic nanofluids such as Cu nanofluids. The main problems in this

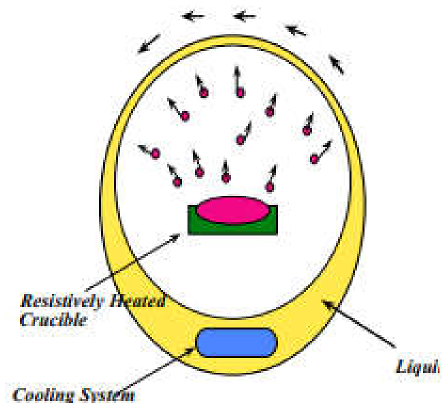


Fig: 1 Schematic diagram of nanofluid production on one step process

Techniques are low production capacity, low concentration of nanoparticles and high costs. While the advantage of this technique is that nanoparticle agglomeration is minimized. The suspensions obtained by either case should be well mixed, uniformly dispersed and stable in time.

3.2 Methods for dispersing particles:

Due to the high surface energy of nanoparticles they tend to agglomerate to decrease their surface energy. The agglomeration of nanoparticles causes rapid settling which deteriorates the properties of nanofluids. To keep the nanoparticles from agglomeration they are coated with a surfactant (steric dispersion) or charged to repulse each other in a liquid. Although the addition of the dispersant could influence the thermal conductivity of the base fluid itself, and thus, the real enhancement by using nanoparticles could be over shadowed. There are other dispersion methods

Fig: 2 Schematic diagrams of dispersion nanofluid particles.

such as using a high-speed disperser or an ultrasonic probe/bath and also changing the pH value of the suspension. The selection of suitable dispersants depends mainly upon the properties of the solutions and particles and the use of these techniques depends on the required application of the nanofluid. However metallic nanofluids due to their low thermal conductivity have limited interest but metallic nanofluids especially Cu nanofluids and Ag nanofluids due to their high thermal conductivity are the common nanofluids. More specifically we can say that all the metallic nanofluids compared to oxide nanofluids show much more enhancements so that metallic nanofluids and their volume percent is reduced by one order of magnitude at comparable K enhancements.

4.0 ANALYSIS:

Pioneering nanofluids research in ANL has inspired physicists, chemists, and engineers around the world.Promising discoveries and potentials in the emerging field of nanofluids have been reported.

- Nanofluids have an unprecedented combination of the four characteristic features desired in energy systems.
- Increased thermal conductivity (TC) at low nanoparticle concentrations Strong temperature dependent TC Non-linear increase in TC with nanoparticle concentration
- Increase in boiling critical heat flux (CHF)
- These characteristic features of nanofluids make them suitable for the next generation of flow and heat-transfer fluids

Nanofluids Properties: Nanofluids were found to exhibit higher thermo physical properties such as thermal conductivity, thermal diffusivity and viscosity than those of base fluids. Heat transfer is enhancement in a solid. Fluid two-phase flow has been investigated for many years. Research on gas particle flow showed that by adding particles, especially small particles in gas, the convection heat transfer coefficient can be greatly increased. The enhancement of heat transfer, in addition to the possible increase in the effective thermal conductivity, was mainly due to the reduced thickness of the thermal boundary layer. In the processes involving liquid. vapor phase change, particles may also reduce the thickness of the gas layer near the wall. The particles used in the previous studies wereon the scale of a micrometer or larger. It is very likely that the motion of nanoparticles in the fluid will also enhance heat transfer. Therefore, more studies are needed on heat transfer enhancement in nanoparticle, fluid mixtures.

when the nanoparticle diameter is smaller than 20 nm, the viscosity is closely related to the pH of the nanofluid, and fluctuates with pH values from 5 and Although viscosity influences interfacial phenomena and flow characteristics,

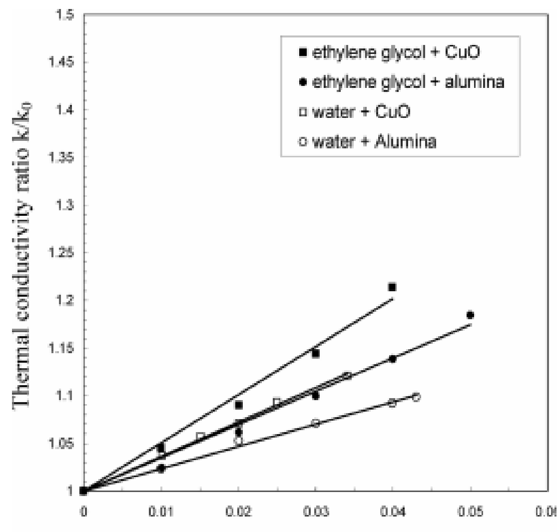
Table 1: Thermal Conductivities of various solids and Liquids at Room Temperature

Material	Form	Thermal Conductivity (W/mK)
Carbon	Nanotubes Diamond Graphite Fullerenes film	1800-6600 2300 110-190 0.4
Metallic Solids(pure)	Silver Copper Nickel	429 401 237
Non-Metallic solids	Silicon	148
Metallic liquids	Aluminum Sodium at 644 K	40 72.3
Others	Water Ethylene Glycol Engine Oil R 134a	0.613 0.253 0.145 0.0811

very few studies have been performed on the effective viscosity of nanofluids as a function of volumetric loading of nanoparticles. The primary results from these studies indicate that the viscosity of a nanofluid increases with increasing nanoparticle volume fraction. In addition to the very few experimental studies, no theoretical model is available for the prediction of the effective viscosity of nanofluids as a function of temperature and particle volume fraction. It is worthwhile to study temperature-dependent viscosity of nanofluids for their potential applications especially in microfluidic systems.

Thermal conductivity of nanofluids of solids and fluids:

Heat transfer nanofluids were first reported of the Argonne National Laboratory, USA in 1995. Since then, a number of studies have been conducted on the thermal properties (mainly thermal conductivity) and singlephase and boiling heat transfer performance (mainly singlephase heat transfer). It has been demonstrated that nanofluids can have significantly better heat transfer characteristics than the base fluids. Several good comprehensive reviews have summarized the available studies on heat transfer of nanofluids.



Graph 1: Volume Fraction

Graph Enhanced thermal conductivity of oxide nanofluids systems as measured. k/ko denotes the ratio of thermal conductivity of nanofluid to that of the base fluid.

5.0 CONCLUSION:

Research work on the concept, its thermo-physical properties, heat transfer enhancement mechanism, and application of the nanofluids is still in its primary stage. This study provides a review of research in this field with focus on thermal properties of nanofluids as well as in heat transfer applications to increase the efficiency. Various techniques have been proposed to enhance the heat transfer performance of fluids. Researchers have also tried to increase the thermal conductivity of base fluids by suspending micro- or larger-sized solid particles in fluids, since the thermal conductivity of solid is typically higher than that of liquids, These models take the particle dynamics into consideration, whose effect is additive to the thermal conductivity of a static dilute suspension. Thus, the particle size, volume fraction, thermal conductivities of both the nanoparticle and the base fluid, and the temperature itself are taken into account in such models for the thermal conductivity of nanofluids.

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