A REVIEW PAPER ON EXPERIMENTAL HEAT TRANSFER IMPROVEMENT USING NANO-PARTICALS

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ABSTRACT: There is increasing interest in Nano fluid and its use in heat transfer improvement. Nanofluids are suspensions of nanoparticles in fluids that show significant enhancement of their properties at its proper nanoparticle concentrations. Nanofluids consist of a base fluid enriched with Nano size particles (less than 100 nm). Nanofluids are characterized by an enrichment of a base fluid like Water, Ethylene glycol or oil with nanoparticles in variety of types like Metals, Oxides, Carbides, Carbon. Mostly commonly recalled Nanofluids could be typified as TiO2 in water, CuO in water, Al2O3 in water, ZnO in Ethylene glycol. Today Nanofluids have got wide range of applications in transportation, power generation, nuclear, space, microelectronics, biomedical and many areas where heat removal is involved.

Keywords: Nanofluids, Nano- particles, Heat transfer enhancement, Applications of Nanofluid.

I. INTRODUCTION

Heat Energy Definition

Heat energy (or thermal energy or simply heat) is defined as a form of energy which transfers among particles in a substance (or system) by means of kinetic energy of those particles. In other words, under kinetic theory, the heat is transferred by particles bouncing into each other.

In physical equations, the amount of heat transferred is usually denoted by the symbol Q.

Heat always refers to the transfer of energy between systems (or bodies), not to energy contained within the systems (or bodies). This can be very confusing because we're used to in day-to-day conversation talking about heat as if it's contained in something. This distinction between heat and temperature is subtle but very important. Heat refers to the total energy of the molecular motion or kinetic energy of a material. Temperature, on the other hand, is a measure of the average or apparent energy of molecular motion.

Units of Heat Energy

As a form of energy, the SI unit for heat is the joule (J), though heat is frequently also measured in the calorie (cal), which is defined as "the amount of heat required to raise the temperature of one gram of water from 14.5 degrees Celsius to 15.5 degrees Celsius." Heat is also sometimes measured in "British thermal units" or Btu.

Heat Exchanger

(a device for transferring heat from one medium to another)

A **heat exchanger** is a device used to transfer heat between a solid object and a fluid, or between two or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact.[1] They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Another example is the heat sink, which is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant.

Types of Heat Exchangers

- Shell and tube heat exchanger
- Plate heat exchangers
- Plate and shell heat exchanger
- Adiabatic wheel heat exchanger
- Plate fin heat exchanger
- Pillow plate heat exchanger
- Fluid heat exchangers
- Waste heat recovery units
- Dynamic scraped surface heat exchanger
- Phase-change heat exchangers
- Direct contact heat exchangers
- Microchannel heat exchangers

Nano Fluid

I. Definition

A **nanofluid** is a fluid containing nanometer-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in **nanofluids** are typically made of metals, oxides, carbides, or carbon nanotube.

Nanofluids are potential heat transfer fluids with enhanced thermophysical properties and heat transfer performance can be applied in many devices for better performances (i.e. energy, heat transfer and other performances). In this paper, a comprehensive literature on the applications and challenges of nanofluids have been compiled and reviewed. Latest up to date literatures on the applications and challenges in terms of PhD and Master thesis, journal articles, conference proceedings, reports and web materials have been reviewed and reported. Recent researches have indicated that substitution of conventional coolants by nanofluids appears promising. Specific application of nanofluids in engine cooling, solar water heating, cooling of electronics, cooling of transformer oil, improving diesel generator efficiency, cooling of heat exchanging devices, improving heat transfer efficiency of chillers, domestic refrigerator-freezers, cooling in machining, in nuclear reactor and defense and space have been reviewed and presented. Authors also critically analyzed some of the applications and identified research gaps for further research. Moreover, challenges and future directions of applications of nanofluids have been reviewed and presented in this paper. Based on results available in the literatures, it has been found nanofluids have a much higher and strongly temperature-dependent thermal conductivity at very low particle concentrations than conventional fluids. This can be considered as one of the key parameters for enhanced performances for many of the applications of nanofluids. Because of its superior thermal performances, latest up to date literatures on this property have been summarized and presented in this paper as well. However, few barriers and challenges that have been identified in this review must be addressed carefully before it can be fully implemented in the industrial applications.

A **nanofluid** is a fluid containing nanometer-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil.

Nanofluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchanger, in grinding, machining and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid. Knowledge of the rheological behavior of nanofluids is found to be very critical in deciding their suitability for convective heat transfer applications. Nanofluids also have special acoustical properties and in ultrasonic fields display additional shear-wave reconversion of an incident compressional wave; the effect becomes more pronounced as concentration increases.

In analysis such as computational fluid dynamics (CFD), nanofluids can be assumed to be single phase fluids. However, almost all of new academic paper use two-phase assumption. Classical theory of single phase fluids can be applied, where physical properties of nanofluid is taken as a function of properties of both constituents and their concentrations. An alternative approach simulates nanofluids using a two-component model.

The spreading of a nanofluid droplet is enhanced by the solid-like ordering structure of nanoparticles assembled near the contact line by diffusion, which gives rise to a structural disjoining pressure in the vicinity of the contact line. However, such enhancement is not observed for small droplets with diameter of nanometer scale, because the wetting time scale is much smaller than the diffusion time scale.

II. PREPARATION OF NANOFLUID

There are two primary methods to prepare nanofluids: A two-step process in which nanoparticles or nanotubes are first produced as a dry powder. The resulting nanoparticles are then dispersed into a fluid in a second step. Single-step nanofluid processing methods have also been developed.

Two-Step Methods

Several studies, including the earliest investigations of nanofluids, used a two-step process in which nanoparticles are first produced as a dry powder. This method is more extensively used to produce nanofluids because Nano powders are commercially available nowadays. A variety of physical, chemical, and laser-based methods are available for the production of the nanoparticles to be used for nanofluids.

One-Step Methods

The nanoparticles may agglomerate during the drying, storage, and transportation process, leading to difficulties in the following dispersion stage of two-step method. Consequently, the stability and thermal conductivity of nanofluid are not ideal. In addition, the production cost is high.

Applications

Great capability of Nanofluids in heat transfer enhancement has encouraged researcher in recent decades to develop concepts and technologies advocated by manufacturers of ultra-compact, miniaturized and intrinsic electronic chips.

The uplifting demand for higher speed, multiple functioning, more powerful and smaller sized boards has almost doubled number of transistors on electronic chips with production of localized heat flux over 10 MW/m2 and the total power exceeding 300 W. Promising to fulfill this critical need, technologies like “Nanofluid in Oscillating Heat Pipe” and “Nanofluid with Tunable Thermal Properties” emerged by Ma et al. 2006 and Philip et al 2008 respectively. According to Ma et al. “there is no exiting low cost cooling mechanism that can effectively manage this amount of heat effectively”. According to Philip et al., the observed reversible tunable thermal property of Nanofluid with advantage of % 300 increase in thermal conductivity of the based fluid may find many technological applications for this fluid in nanoelectromechanical system (NEMS) and microelectromechanical system (MEMS) based devices.

For example, depending upon the cooling requirement, the current or magnetic field can be precisely programmed to.

Advantages

Spectacular capability of Nanofluids in heat transfer/removal enhancement can properly address the energy demand and emission issues of the present world. In United State only, utilization of Nanofluids for industrial cooling could result in great energy savings and resulting emissions reductions. For U.S. industry, the replacement of cooling and heating water with Nanofluids has the potential to conserve 1 trillion Btu of energy. For the U.S. electric power industry, using Nanofluids in closed-loop cooling cycles could save about 10– 30 trillion Btu per year (equivalent to the annual energy consumption of about 50,000–150,000 households). The associated emissions reductions would be approximately 5.6 million metric tons of carbon dioxide; 8,600 metric tons of nitrogen oxides; and 21,000 metric tons of sulfur dioxide.

In more localized end points, faster and more robust data servers and computers, electronic devices, sensors and actuators can appreciably boost the businesses, reduce the instances of circuit burns and electricity cut-offs and hence save a significant amount of money to end users and service providers. Consequently a potential of 2-billion dollar-peryear Investment is estimated to flow into this great technology.

Applications

Below are some general examples for the vast array of applications of nano particulate dispersion and coatings.

i. Metalworking

Nanofluids could be used as metalworking coolant fluids for grinding and polishing components.

ii. Energy supply and production

Solar energy systems could take advantage of nanofluids to enhance heat transfer from solar collectors to storage tanks.

iii. Cosmetics

An area of a nano particles technology that has incredible potential in the cosmetics industry. There is a great-demonstrated demand, and the technology can be made simple, since properties of color and light fastness are achieved by components mixing in the cosmetics preparation. A survey indicates a worldwide gross volume of $ 14-18 billion for toiletries i.e. traditional hygiene products such as powder, spray, perfumes and deodorants. The large market for sunscreens and skin rejuvenation preparations promise additional revenue. The diet industry is said to gross $33 billion annually. One way that nanoparticles technology is addressing this market is through introducing nano particulate taste enhancer into low calorie substrate.

iv. Medicine / Pharmacology

In the area of medical applications, finely dispersed pharmaceuticals offers rapid drug delivery and reduce dosages for patients. Dispersions of strong and resilient biocompatible materials suggest opportunities for artificial joints. These generally are ceramic materials containing nanoparticles. Overall, much of the demand for nano particulate dispersions and coatings comes from the cosmetics and pharmaceutical industries, in particular, liquid dispersion preparation is widely used to apply topical coatings to the human epidemics because the can be absorbed faster and more completely than conventional coatings.

v. Printing

In the area of image capture / image output addressed by ink jet technology, nanoscience can help control the properties of the inks. The production and use of nano-particulate ink benefits as laser assist delivery of the ink droplets to maintain an accurate deposition of ink on its target. Another application in this field is to achieve ideal absorption and drying times for desired coloured properties and permanency.

vi. Semiconductors

One form of bottom up technology is receiving considerable attentions in thin films for the semiconductor industry. Here a single atoms or molecules are deposited by physical vapor deposition technology in order to produce enhanced electronics properties for information storage and processing speed.

vii. Sensors

Chemical or physical sensors often use nanoparticles because they provide high surface area for detecting the state of chemical reactions, because the quality of detection signal is improved. Because of more accurate determination of leakage is reducing waste. Some commercial sensors and actuators are already in use to maintain and monitor vapor in chemical reactor.

GENERAL CONCLUSION

The convective heat transfer performance and flow characteristics of Al2O3 nanofluid flowing in a horizontal shell and tube heat exchanger has been experimentally investigated. Experiments have been carried out under turbulent conditions.

The effect of particle concentration and the Reynolds number on the heat transfer performance and flow behavior of the nanofluid has been determined. Important conclusions have been obtained and are summarized as following:

1. Dispersion of the nanoparticles into the distilled water increases the thermal conductivity and viscosity of the nanofluid, this augmentation increases with the increase in particle concentrations.
2. At a particle volume concentration of 2% the use of Al2O3/water nanofluid gives significantly higher heat transfer characteristics.
   For example at the particle volume concentration of 2% the overall heat transfer coefficient is 700.242 W/m2 K and for the water it is 399.15 W/m2 K for a mass flow rate of 0.0125 L/s so the enhancement ratio of the overall heat transfer coefficient is 1.754,
   This means the amount of the overall heat transfer coefficient of the nanofluid is 57% greater than that of distilled water.
3. Friction factor increases with the increase in particle volume concentration. This is because of the increase in the Viscosity of the nanofluid and it means that the nanofluid incur little penalty in pressure drop.

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