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Nanofluids Technology Applications

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Abstract

Heat transfer fluids are critical in new technologies being developed in energy, manufacturing, transportation, and electronics industries among others. New and emerging technologies such as in highly integrated microelectronic devices, reduction in cutting fluids use and higher output engines have created a demand for advanced cooling capacities. The result of this has been a critical need to provide an innovative new mode of heat transfers and improvements in the present heat transfer fluids. This paper explores the characteristics, production , applications and developments in Nanofluids.

Keywords: *Nanofluids, Cooling, Micro lubrication*

1. INTRODUCTION

Nanofluids are a relatively new category of fluids that are created by the dispersal of nanometer-sized particles in the base fluids in order to increase tribological properties and heat transfer. Various studies conducted into Nanofluids have demonstrated that the convection heat transfer and the thermal conductivity can be greatly improved by the aforementioned suspended particles. In addition, recent research into tribology shows that the Nano-particle added to lubricating fluids have a higher load carrying capacity, friction reduction, and anti-wear capacities. With such features, it is obvious that the Nanofluids are very attractive in lubrication and cooling applications in various industries such as energy, manufacturing, transportation, and electronics among others. The base fluids can be even water.

1.1. Nano-fluids in Cooling Applications

The heat transfer fluids are critical the modern industries such as energy, manufacturing, transportation, and electronics among others. New and emerging developments such as highly integrated microelectronic devices, reduction in the applied cutting fluids and higher output engines have created a demand for advanced cooling capacities. The result of this has been a critical need to provide an innovative new mode of heat transfers and improvements of the present heat transfer fluids (Shen,Bin,2008).

Heat transfer fluids are limited in the rate of transfer of heat with solids demonstrating a higher rate of transfer of heat. Therefore, suspending pieces of solids in the liquids results in significant increases in the thermal conductivity of the Nanofluids as compared to the conventional heat transfer fluids. The suspension of particles in liquids has been the subject of numerous studies going back a century. However, the studies were limited by the technology to millimeter or even micrometer-sized particles that were not small enough to make a significant difference. Recent developments in Nano-particle synthesizing techniques including the ability to suspend Nano-particles uniformly and in a stable manner in the fluid, have made it possible to generate a new class of engineered fluids that have a high heat transfer rate ; (Shen,Bin,2008). The Nano particles are small enough to act as the molecules of the fluids, therefore, do not clog or block the fluid passages but increase the thermal capacities drastically.

1.2. Classifications of Nanofluids

Nanofluids are classified into two categories: Metallic and non-metallic fluids.
The metallic Nanofluids contain metallic nanoparticles such as Gold (Au), Iron (Fe), Silver (Ag), and Copper (Cu). The non-metallic Nanofluids contain non-metallic particles such as Silicon Carbide (SiC), Aluminum Oxide (AL2O3) and Copper Oxide (CuO);(Deutche, Gestzliche,Unfallversicherung,2010)

The heat conduction models for the solid-liquid mixtures were established more than a century ago with models such as Maxwell model in 1904. However, as mentioned earlier the size of these particles severely limited the effectiveness of the fluids as in heat conduction. As such when the models are applied to the Nanofluids, they tend to underestimate the fluid's thermal conductivity. Thermal conductivity of Nanofluids is best tested by the transient hot-wire method. Metallic nanofluids have been systematically studied, with their respective changes in conductivity being recorded. For example, the thermal conductivity of ethylene glycol improved by 40 percent on the addition of 0.3 percent of Copper nanoparticles of 10 nm in diameter. Also, the thermal conductivity of water has been demonstrated to increase by up to 78 percent by an addition of 7.5 percent Copper particles of 100 nm in diameter (Master Chemical Corp.,2014).

Non-metallic fluids such as CuO, TiO2, Al2O3, SiC and even carbon nanotubes have also correspondingly been studied. Various studies have had differing results; in 1993, it was reported that the thermal conductivity of water increased by 30 percent with an addition of 4.3 percent AL2O3 nanoparticles of the average diameter of 13 nm. However, another study by Lee obtained the results of only a 15 percent increase for the same nanoparticles used. In 2002, the thermal conductivity of water for the same nanoparticle loading had obtained a 22 percent increase. The differences in the results are attributed to the differences in average particle sizes in the samples used;(Tai,Stephenson,Furness,2014). Nanofluids of CuO particles, when added to ethylene glycerol, have a greater increase in the thermal conductivity of the glycerol than when the nanoparticles of AL2O3 are added.

Carbon nanotubes are regarded with special attention especially due to seemingly amazing properties that the nanotubes apparently possess. The properties include extraordinary strength, efficient conduction of heat, and the unique electric properties. Carbon nanotubes (CNTS) are comprised of fullene related structures that are made up of graphite cylinders or a number of concentric cylinders. The result of the CNT addition to synthetic oil was simply staggering with an increase of thermal conductivity by 150 percent with an addition of 1 percent particles of carbon nanotubes.

1.3. Methods of Producing Nanofluids:

a) One-step Physical Process

The technique applied here synthesizes the nanoparticles, and disperses them into a fluid in one step . Initially, this method was used in the preparation of extremely fine particles of Silver through the vacuum evaporation of the nanoparticles into an oil substrate that was running. It involves the vaporization of the source material of the nanoparticles in vacuum conditions where the vapor condenses upon contact with the flowing fluid. A good dispersion is obtained from the minimization of agglomeration of the nanoparticles by the constantly flowing fluid . The one-step process of synthesizing nanofluids is very expensive; in addition, the volume of the fluid that can be synthesized by the physical one-step process is limited in comparison to the other production processes; (Shen,Bin,2008)

b) Two-step Physical Process

In this process, the nanoparticles are first made as dry powder through methods such as inert gas condensation. Inert gas condensation involves the vaporization of the nanoparticle source material in a vacuum chamber and the consequent condensation of vapor into nano particles, this is achieved through collisions with an inert gas under controlled pressure; (Shen,Bin,2008)

The second stage of this process involves the dispersal of the particles into the fluid. This process in hugely advantageous in that it has allowed the commercialization of the technique as it has been scaled to an economically viable process producing nanoparticles in tonnage quantities ;including AL2O3 and CNT nanofluids. Al3O2 dry powders are usually directly sprayed into water without a surfactant.

c) One-step Chemical Process

The one step chemical process was developed originally to produce stable Copper in ethylene glycol nanofluids through reducing the copper sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) with another compound; sodium hypophosphite ($NaH_2PO_2 \cdot H_2O$) under microwave irradiation in ethylene glycerol. The improvements to the thermal conductivity are comparable to the improvements of Copper nanofluids prepared in the one-step physical processes. Nevertheless, it is important to note that this method is still in the research stages, and the range nanofluids, that it is capable of synthesizing, are limited; (Shen,Bin,2008)

4. Nanofluids for Lubrication Applications

Solid lubricants are useful for situations in which the conventional liquid lubricants are inadequate such as extremes contact pressures and high pressures. The suitability is due to the layered structure of solids with the weak molecular bonds between layers, this allows the layers to slide over each other on minimal application of force. Molybdenum disulfide (MoS_2) and graphite are the main solid lubricants used. Nonetheless, othersubstances are also used as solid lubricants including, polytetrafluoroethylene (PTFE), boron nitride, and tungsten disulfide.

Tribological properties of the lubricating oils are increased by adding nanoparticles. An investigation into the tribological capacities of a phase two paraffin oil lubricant infused with diamond nanoparticles resulted in a lubricant that had excellent anti-wear, load carrying capacity and friction reduction properties. Molybdenum Sulfide possesses exceptional lubricating capacities in its nano particulate form, and that is capable of reducing the friction under exceptional circumstances;(Deutche, Gestzliche,Unfallversicherung,2010)

5. Nano fluids in Machining

During minimum lubrication machining, the CF is evaporated at the point of application and separate coolant recirculation system is not required. Lubrication is obtained via the CF and the cooling is achieved by pressurized air that reaches the cutting tool/workpiece interface; (Kurgin,Barber,Zou,2010). Sustainability is one of the major benefits offered by minimum lubrication. Sustainability in machining processes is mainly influenced by its associated CF technology. In conventional flood cooling, the flow rate is typically about 20 L/min. Flood cooling systems require infrastructure for delivery, recycling, filtration, and waste-fluid treatment. Furthermore, the systems demand constant monitoring and treatment to control CF concentrations and to avoid fungal and bacterial growth. Worldwide, manufacturers currently consume over two billion liters of water-based and straight-oil CFs each year, which creates a significant demand for sustainable lubricants and machining processes;(Tai,Stephenson,Furness,2014 Vegetable oil-based lubricants are sustainable and environmentally friendly because of their non-toxicity, renewability and biodegradability;(Handawi,Elmunafi,Noordin,Kurniawan,2015).Many positive results in terms of machinability and tool life have been reported by the use of vegetable oil during micro lubrication.

2. CONCLUSIONS

Nanofluids are a relatively new category of fluids that have shown to have superior tribological and heat transfer.properties They are very attractive in lubrication and cooling applications in various industries such as energy, manufacturing, transportation, and electronics among others. Advantages of using nanofluids in minimum quantity lubrication in machining are significant and compare favorably to flood cooling in terms of the resulting quality of parts. In addition this technology is sustainable, environmentally friendly and very cost effective compared to flood cooling. Nano lubricants have proven to be very effective in both cooling and lubricating and continue to be excellent candidates in machinability research.

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