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A Review on Nano Fluid: Synthesis Characterization and Application

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Abstract: **Recent investigations on nano fluids, as such suspensions are often called, indicate that the suspended nanoparticles markedly change the transport properties and heat transfer characteristics of the suspension. Downscaling or miniaturization has been a recent major trend in modern science and technology. Engineers now fabricate micro scale devices such as micro channel heat exchangers, and micro pumps that are the size of dust specks. Further major advances would be obtained if the coolant flowing in the micro channels were to contain nano scale particles to enhance heat transfer. Nano fluid technology will thus be an emerging and exciting technology of the 21st century. Nano fluids are quasi single phase medium containing stable colloidal dispersion of ultrafine or nano metric metallic or ceramic particles in a given fluid. Despite almost an eligible concentration (< 1 vol%) of the solid dispersoid, nano fluids register an extra ordinarily high level of thermal conductivity, which largely depends on identity(composition), amount (volume percent), size and shape of the dispersoid and viscosity, density and related thermo-physical parameters of the base fluid. Nano fluids possess immense potential of application to improve heat transfer and energy efficiency in several areas including vehicular cooling in transportation, power generation, defense, nuclear, space, microelectronics and biomedical devices. The biggest motivation for exploration and exploitation of nano fluid should come from the fact that the degree of consistently attained enhancement of thermal conductivity far exceeds the level predicted by the existing theory on the subject.**

Keywords: **Nanofluid Nano suspension, Nanoparticles; Heat transfer; Thermal conductivity.**

1. INTRODUCTION

Efficient transfer of energy in the form of heat, from one body to another is often required in almost all industries like Thermal and nuclear power plant, refrigeration and air conditioning system, chemical and processing plants, electronic devices, space shuttles and rocket-launching vehicles. Often a fluid is chosen as a medium for transferring heat and accordingly the mode of heat transfer is convection. The rate of heat transfer in convection is given by; popularly known as Newton's law of cooling. It is well known that metals in solid form have much higher thermal conductivity than that of fluids. Heat transfer by conduction through solid is orders of magnitu larger than that by convection/conduction through a fluid. For example, the thermal conductivity of copper at room temperature is about 700 times greater than that of water and about 3000 times greater than that of engine oil . Modern nanotechnology provides great opportunities to process and produce materials with average crystallite size below 50 nm. As already stated, the concept of nanofluid evolved in 1995 as an offshoot of synthesis of nanoparticles by chemical vapor deposition These fluids with nanometer sized particle suspension in traditional heat transfer fluid offered significantly better thermal properties relative to those of conventional heat transfer fluids and liquids with no or micrometer-sized particles. The ratio of surface area to volume is 1000 times greater for particles with a 10 nm diameter than that for particles with 10 μm diameter. The much larger surface areas of nanoparticles relative to those of micro/macro-sized particles should not only improve heat transfer capabilities, but also increase the stability of the suspensions. These nanofluids have an unprecedented combination of the two features most highly desired for thermal engineering applications: extreme stability and high thermal conductivity. Thus, 'nanofluid' is a new class of heat transfer fluid that utilizes dispersion of fine scale metallic particles in a heat transport liquid in appropriate size and volume fraction to derive a significant enhancement in the effective heat transfer coefficient of the mixture. In comparison to dispersing micron-size ceramic particles, nanofluids consist of suspension of ultra-fine or nano metric metallic particles with much smaller size and volume fraction, and yet offer a remarkably higher efficiency of heat transport.

2. LITRETURE REVIEW

Since Nobel prize wimer Richard Feynrnan presented the concept of micro machines in 1959, miniaturization has been a major trend in modern science and technology. Almost 40 years later, another Nobel prize winner, H. Rohrer, presented the chances and challenges of the "nano-age" (Rohrer, 1996). The steady miniaturization trend has dropped from the millimeter scale of the early 1950s to the present-day atomic scale (Sohn, 1998). The concept and development of nano fluids is directly related to trends in miniaturization and nanotechnology. The pioneering efforts at Argonne National Laboratory (ANL) are keyed to potential commercial applications of nano fluids in many diverse industries. Supplementary efforts to increase heat transfer coefficient by agitation, increasing area, or adding solid dispersoids can achieve limited improvement if the thermal conductivity of the fluid itself is low. Thus, it is logical that efforts are made to increase the thermal conduction behavior of the cooling fluid itself. Earlier efforts have been made to increase the thermal conductivity of base fluids by suspending micro/macro-sized solid particles in fluids since the thermal conductivity of solid is typically 2–3 orders of magnitude higher than that of liquids (Table 1). However, adding micrometer size particles cause several problems arising out of sedimentation, clogging, pressure drop and erosion of channels/pipes/conduits.

3. CONCEPT OF NANO FLUID

Nano fluids are this new class of heat transfer fluids and are engineered by suspending nanometer-sized particles in conventional heat transfer fluids. The average size of particles used in nano fluids is below 50 nm. Maxwell's concept of enhancing the thermal conductivity of fluids by dispersing solid particles is old. The Supplementary efforts to increase heat transfer coefficient by agitation, increasing area, or adding solid dispersoids can achieve limited improvement if the thermal conductivity of the fluid itself is low. Thus, it is logical that efforts are made to increase the thermal conduction behavior of the cooling fluid itself. However, adding micrometer size particles cause several problems arising out of sedimentation, clogging, pressure drop and erosion of channels/pipes/conduits. Modern materials technology provided the opportunity to produce nanometer-sized particles which are quite different from the parent material (coarse grained) in mechanical, thermal, electrical, and optical properties. Though every fluid possesses nano metric molecular chains and hence can be called nanofluid, the real justification of the name nano fluid comes from the fact that nanofluid is characterized by stable colloidal dispersion of ultrafine or nano metric solids in extremely small quantity (< 1 vol%) that is present together with the base fluid to form a pseudo-single phase medium with phenomenally greater thermal conductivity than that of the base fluid. It must be kept in mind that biologists have been using the term nanofluid for different types of particles, such as DNA, RNA, proteins, or fluids contained in nano pores Nano fluids possess a unique combination of the two most essential features desired in thermal engineering applications, namely, chemical and physical stability and high thermal conductivity. The attractive features which made nanoparticles probable candidates for suspension in fluids are the large specific surface area, less particle momentum and high mobility..When the particles are properly dispersed, these features of nano fluids are expected to yield several benefits like: higher heat conduction due to large specific surface area and greater mobility (micro-convection) of tiny particles. It is already found that: (a) the thermal conductivity of nano fluids increases significantly with a rise in temperature, which may be attributed to the above reasons; (b) greater stability against sedimentation due to smaller size and weight; (c) more efficient heat transfer in micro channels; (d) negligible friction and erosion of conduit surfaces. The main excitement of using nanofluid arises due to the following features (a) Enhancement of thermal conductivity far beyond the level any theory could predict, (b) Dependence of thermal conductivity on particle size apart from concentration, (c) Greater stability of suspension using a stabilizing agent and (d) Retention of Newtonian behavior at small concentration without much pressure drop.

4. STEP PROCESS REVIEW FOR MAKING NANOFLUID

4.1 Two Step Process

The preparation of nano fluids begins by direct mixing of the base fluid with the nano materials. In the first step, nano materials are synthesized and obtained as powders, which are then introduced to the base fluid in a second step. Nanoparticles can be produced from several processes which can be categorized into one of five general synthetic methods. These five methods are: (i) transition metal salt reduction (ii) thermal decomposition and photochemical methods (iii) ligand reduction and displacement from organometallics (iv) metal vapor synthesis, and (v) electrochemical synthesis. Transition-metal nano clusters are only kinetically stable because the formation of the bulk metal is its thermodynamic minimum. Therefore, nano clusters that are free dissolved in solution must be stabilized in a way that prevents the nano clusters from coalescing, because such agglomeration would eventually lead to the formation of the thermodynamically favored bulk metal. Bonnemann et al developed a method for the production of very small (< 2 nm) and stable nanoparticles via chemical reduction pathways, which might be suitable for application in nanofluid synthesis. Kim et al. prepared nano fluids consisting of commercially obtained CuO nanoparticles in ethylene glycol by sonication without stabilizers. The two-step process is commonly used for the synthesis of carbon nanotube based nano fluids. Single-wall carbon nanotubes (SWCNTs) and Multi-walled carbon nanotubes (MWCNTs) are cylindrical allotropes of carbon. SWCNTs consist of a single cylinder of graphene, while MWCNTs contain multiple graphene cylinders nesting within each other . The carbon nanotubes are usually produced by a pyrolysis method and then suspended in a base fluid with or without the use of a surfactant. Some authors suggested that the two-step process works well only for nano fluids containing oxide nanoparticles dispersed in de-ionized water as opposed to those containing heavier metallic nanoparticles Since can be obtained commercially in large quantities.

4.2 One step process

Few methods exist for the preparation of nanofluids through a one step process. These methods include the thermal decomposition of an organometallic precursor in the presence of a stabilizer, chemical reduction and polyol synthesis. The polyol method is one of the most well known pathways to noble metal nanoparticles . In the polyol process, a metal precursor is dissolved in a liquid polyol (usually ethylene glycol), after which the experimental conditions are adjusted to achieve the reduction of the metallic precursor by the polyol, followed by atomic metal nucleation and metal particle growth The „direct-evaporation‟ technique was developed by Choi et al It consists of a cylinder containing a fluid which is rotated. In the middle of the cylinder, a source material is vaporized. The vapour condenses once it comes into contact with the cooled liquid (Figure 2.1). The drawbacks of this technique however, are that the use of low vapour pressure liquids are essential and only limited quantities can be produced. . Excellent control of size and very narrow size distributions can be obtained by using such methods. A submerged arc nanoparticle synthesis system (SANSS) was developed to prepare CuO nanoparticles dispersed uniformly in a dielectric liquid (deionized water). The method successfully produced a stable nanofluid. In principle, a pure copper rod is submerged in a dielectric liquid in a vacuum chamber. A suitable electric power source is used to produce an arc between 6000 - 12000 °C which melts and vaporizes the metal rod in the region where the arc is generated. At the same time, the deionized water is also vaporized by the arc. The vaporized metal undergoes nucleation, growth and condensation resulting in nanoparticles dispersed in deionized water. Nano fluids containing CuO particles of size 49.1 ± 38.9 nm were obtained.

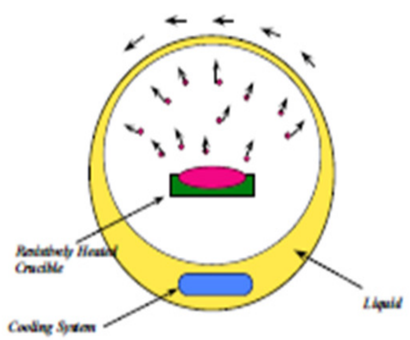

Figure 2.1 One-step nanofluid production system (Choi et.al. [28])

5. TECHNOLOGY FOR PRODUCTION OF NANOPARTICLES AND NANOFLUID

All physical mechanisms have a critical length scale, below which the physical properties of materials are changed. Therefore, particles <100 nm exhibit properties different from those of conventional solids. The noble properties of nano phase materials come from the relatively high surface-area to-volume ratio that is due to the high proportion of constituent atoms residing at the grain boundaries. The thermal, mechanical, optical, magnetic, and electrical properties of nano phase materials are superior to those of conventional materials with coarse grain structures. Consequently, the research and development of nano phase materials has drawn considerable attention from material scientists and engineers alike (Duncan and Rouvray, 1989).Much progress has been made recently in the production of nano phase materials, and The gas-phase `condensation process involves the evaporation of a source material and the rapid condensation of vapor into nanometer-sized crystallite or loosely agglomerated clusters in a cooi, inert, reduced pressure atmosphere (Kimoto et al., 1963; Gmnqvist and Buhrrnan, 1976). A chemistry-based solution-spray conversion process starts with water-soluble salts of source materials. The solution is then turned into an aerosol and dried by a spray-drying system. Rapid vaporization of the solvent and rapid precipitation of the solute keeps the composition identical to that of the starting solution. The precursor powder is then placed in a fluidized-bed reactor to evenly pyrolyze the mixture, drive off volatile constituents, and yield porous powders with a uniform homogeneous fine structure (Ashly, 1994). It is well known, however, that these agglomerates, which are typically 1 ym or so in size, require little energy to fracture into smaller constituents, and thus it is possible they will not present a problem in this application.

If, however. agglomeration is a problem, it would prevent realization of the fill potential of the high surface areas of nanoparticles in nano fluids. VEROS has been essentially ignored by the nano crystalline-materials community because of difficulties in subsequently separating the particles from the fluids to make dry powders or bulk materials. Two techniques are used to make nano fluids: the single-step direct evaporation method, which simultaneously makes and disperses the nanoparticles directly into the base fluids. and the two-step method which first makes nanoparticles and then disperses them into the base fluids. In either case, a well-mixed and uniformly dispersed nanofluid is needed for successful reproduction of properties and interpretation of experimental data. For nano fluids prepared by the two-step method, dispersion techniques such as high shear and ultrasound can be used to create various particle/fluid combinations. Nano powders produced in bulk at low prices can be used to make nano fluids by the two-step method. Although this technique works well for oxide nanoparticles, it is not as effective for metal nanoparticles such as copper, presumably due to greater sensitivity to the effects of agglomeration for dense particles such as metals than for lighter particles such as oxides. For nano fluids containing high conductivity metals, it is clear that the single-step direct etziporation technique is preferable to gas-condensation processing. We are currently working with an industrial partner to test the fusibility of scaling-up the direct-evaporation process to envisioned production level quantities ANL has already produced oxide nano fluids by the two-step technique and metal nano fluids by the single-step technique to conduct proof-of-concept tests (Eastman et al., In particular, it was demonstrated that stable suspensions can be achieved by maintaining particle size below a threshold level.

6. APPLICATIONS OF NANO FLUID

6.1 Heat Transfer Applications

7.1.1. Industrial Cooling Applications

Routbort et al. started a project in 2008 that employed nano fluids for industrial cooling that could result in great energy savings and resulting emissions reductions. For U.S. industry, the replacement of cooling and heating water with nano fluids has the potential to conserve 1 trillion Btu of energy. For the U.S. electric power industry using nano fluids 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. Han et al. [12] have used phase change materials as nanoparticles in nano fluids to simultaneously enhance the effective thermal conductivity and specific heat of the fluids. As an example, a suspension of indium nanoparticles (melting temperature,) in polyalphaolefin has been synthesized using a one-step, nano emulsification method.

6.2. Smart Fluids

Nano fluids can be used as a smart material working as a heat valve to control the flow of heat. The nanofluid can be readily configured either in a “low” state, where it conducts heat poorly, or in a “high” state, where the dissipation is more efficient. To leap the chasm to heating and cooling technologies, the researchers will have to show more evidence of a stable operating system that responds to a larger range of heat flux inputs.

6.3 Cancer Theraupetics

There is a new initiative which takes advantage of several properties of certain nano fluids to use in cancer imaging and drug delivery. This initiative involves the use of iron-based nanoparticles as delivery vehicles for drugs or radiation in cancer patients. Magnetic nano fluids are to be used to guide the particles up the bloodstream to a tumor with magnets. It will allow doctors to deliver high local doses of drugs or radiation without damaging nearby healthy tissue, which is a significant side effect of traditional cancer treatment methods. In addition, magnetic nanoparticles are more adhesive to tumor cells than non-malignant cells and they absorb much more power than micro particles in alternating current magnetic fields tolerable in humans; they make excellent candidates for cancer therapy. Magnetic nanoparticles are used because as compared to other metal-type nanoparticles, these provide a characteristic for handling and manipulation of the nanofluid by magnetic force. . This combination of targeted delivery and controlled release will also decrease the likelihood of systemic toxicity since the drug is encapsulated and biologically unavailable during transit in systemic circulation. The nanofluid containing magnetic nanoparticles also acts as a super-paramagnetic fluid which in an alternating electromagnetic field absorbs energy producing a controllable hyperthermia. By enhancing the chemotherapeutic efficacy, the hyperthermia is able to produce a preferential radiation effect on malignant cells.

6.4 Biological Application

There are numerous biomedical applications that involve nano fluids such as magnetic cell separation, drug delivery, hyperthermia, and contrast enhancement in magnetic resonance imaging. Depending on the specific application, there are different chemical syntheses developed for various types of magnetic nano fluids that allow for the careful tailoring of their properties for different requirements in applications.

Nano fluids could be applied to almost any disease treatment techniques by reengineering the nanoparticles’ properties. In their study, the nanoparticles were laced with the drug docetaxel to be dissolved in the cells’ internal fluids, releasing the anticancer drug at a predetermined rate. The nanoparticles contain targeting molecules called aptamers which recognize the surface molecules on cancer cells preventing the nanoparticles from attacking other cells. In order to prevent the nanoparticles from being destroyed by macrophages—cells that guard against foreign substances entering our bodies—the nanoparticles also have polyethylene glycol molecules.

For most biomedical uses the magnetic nanoparticles should be below 15 nm in size and stably dispersed in water. A potential magnetic nanofluid that could be used for biomedical applications is one composed of Fe Pt nanoparticles. This Fe Pt nanofluid possesses an intrinsic chemical stability and a higher saturation magnetization making it ideal for biomedical applications. However, before magnetic nano fluids can be used as drug delivery systems, more research must be conducted on the nanoparticles containing the actual drugs and the release mechanism.

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6.5Nanofluid in Fuel

The aluminum nanoparticles, produced using a plasma arc system, are covered with thin layers of aluminum oxide, owing to the high oxidation activity of pure aluminum, thus creating a larger contact surface area with water and allowing for increased decomposition of hydrogen from water during the combustion process. During this combustion process, the alumina acts as a catalyst and the aluminum nanoparticles then serve to decompose the water to yield more hydrogen. It was shown that the combustion of diesel fuel mixed with aqueous aluminum nanofluid increased the total combustion heat while decreasing the concentration of smoke and nitrous oxide in the exhaust emission from the diesel engine .

6.6 Nanofluid Coolanant.

In looking for ways to improve the aerodynamic designs of vehicles, and subsequently the fuel economy, manufacturers must reduce the amount of energy needed to overcome wind resistance on the road. At high speeds, approximately 65% of the total energy output from a truck is expended in overcoming the aerodynamic drag. This fact is partly due to the large radiator in front of the engine positioned to maximize the cooling effect of oncoming air. The use of nano fluids as coolants would allow for smaller size and better positioning of the radiators. Owing to the fact that there would be less fluid due to the higher efficiency, coolant pumps could be shrunk and truck engines could be operated at higher temperatures allowing for more horsepower while still meeting stringent emission standards.

7. SCOPE FOR FUTURE WORK

1. Development of theoretical equations for thermo physical properties of CuO nano fluids is the grey area to be explored.
2. The effect of nanoparticle size on heat transfer and friction characteristics of nanofluids can be taken up for investigation.
3. Study on heat transfer investigation by changing the relative proportion in the base fluid constituents can be taken up as future work.

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