Characterization of Nanofluid of Copper

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ABSTRACT

Nanofluids are stable suspensions of nano-particles in a liquid. In order to avoid coagulation of the particles, the particles must be coated with a second distance holder phase which in most cases, consist of surfactants that are stable in the liquid. An important application of Nanofluids containing nano-particles is as a coolant, since the addition of only a few volume percent of nano-particles to a liquid coolant and significantly improves its thermal conductivity. The term nanotechnology has also been used more broadly to refer to techniques that produce or measure features less than 100 nanometers in size; this meaning embraces advanced micro fabrication and metrology. Nanotechnology based on molecular manufacturing requires a combination of familiar chemical and mechanical principles in unfamiliar applications. Metal nano-particles can be used in various application fields, such as optical filters or nanolithography. Metal nano-particles are also widely applied in catalysis because of the high surface to volume ratio. Copper nano-particles have been synthesized by the flow-levitation method and coated with carbon-and-hydrogen films through the hollow-cathode glow discharge. The uncoated and coated Cu nano-particles have been analyzed by transmission electron microscopy, X-ray diffraction, and infrared absorption. Their size, dispersion, and coating thickness have been examined. The addition of copper nanoparticle did not change the dependence of heat transfer on acoustic cavitations and fluid sub cooling. Ultrasonic velocity is the speed in which sound propagates in a certain material. It depends on material density and elasticity. It is related in a simple way to the various coefficients of compressibility, isentropic, isenthalpic and isothermal, hence the importance of its measurement and modeling in temperature and pressure ranges are widely used. In this work we have measured the ultrasonic velocity at different temperature and frequencies of 15 nm copper fluid using Interferometer technique.

INTRODUCTION

Nanotechnology is a most important and growing area in science. Nano-science, the science under pinning nanotechnology, is a multidisciplinary subject covering atomic, molecular and solid state physics, as well as much of chemistry. Nanostructures are known to exhibit novel and improved material properties. Nanotechnology is design, fabrication and application of nanostructures or nanomaterials, and fundamental understanding of the relationships between physical properties and material dimensions. Nanotechnology also promises the possibility of creating nanostructures of metastable phases with nano-conventional properties including super conductivity of magnetism. Fundamentally, these arise because the physical as well as chemical properties are very different when dimensions are reduced to nanometer range. Nanotechnology enthusiasts say that it will eventually be possible to build computers on the molecular scale, produce ultra strong materials, and allow the molecular correction of most diseases, even the repair of ageing cells. A very important aspect of nanotechnology is the miniaturization of current and new instruments, sensors and machines that will greatly impact world. Few possible miniaturizations are computers with infinitely great power that compute Algorithms to mimic human brains, biosensors that warn us at the early stage of the onset of disease and preferably at the molecular level and target specific drugs that automatically attack the diseased cells on site, nanorobots that can repair internal damage and remove chemical toxins in human bodies and nano- scaled electronics that constantly monitor our local environment. Nanotechnology has an extremely broad range of potential applications from nanoscale optics and electronics to nanobiological systems and nanomedicine to new substances and therefore it requires formation and contribution from multidisciplinary teams of chemists, physicists, engineers, materials scientists and molecular biologists, pharmaologists and other to work together on design and fabrication of nano-devices or devices with nanomaterials as building blocks and design and construction of novel tools for characterization of nanostructures and nanomaterials.

Application of nanostructures and nano-materials are based on the peculiar physical properties of nanosized materials, the huge surface are the small size that offers extra possibilities for manipulation and room for accommodating multiple functionalities. In future, amazing nanotech-based products are expected, including extraordinarily tiny computers that are very powerful, building materials that withstand earthquakes, advanced systems for drug delivery and custom-tailored pharmaceuticals as well as the elimination of invasive surgery, because repairs can be made from within the body. Future developments and implemention of nanotechnology could certainly change the nature of almost every human made object and activity. Its ultimate societal impact is expected to be as dramatic as first industrial revolution and greater than the combined influences that aerospace, nuclear energy, transistors, computers and polymers have in this century. Nanotechnology development is the need to understand the techniques for atomic and molecular based study of matter in nanoscale [1-3].

Nanofluids are dilute liquid suspensions of nanoparticles with at least one of their principal dimensions smaller than 100nm. There is a growth in the use of colloids which are nanofluids in the biomedical industry for sensing and imaging purposes. This is directly related to the ability to design novel materials at the nanoscale level alongside recent innovations in analytical and imaging technologies for measuring and manipulating nanomaterials. This has led to the fast development of commercial applications which use a wide variety of manufactured nanoparticles. The production, use and disposal of manufactured nanoparticles will lead to discharges to air, soils and water systems. Negative effects are likely and quantification and minimization of these effects on environmental health is necessary. True knowledge of concentration and physicochemical properties of manufactured nanoparticles under realistic conditions is important in predicting their fate, behavior and toxicity in the natural aquatic environment. Nanofluids have higher thermal conductivity and single-phase heat transfer coefficients than their base fluids [4].

The use of nanofluids as a coolant could also be used in emergency cooling systems, where they could cool down overheat surfaces more quickly leading to an improvement in power plant safety. Some issues regarding the use of nanofluids in a power plant system include the unpredictability of the amount of nanoparticles that are carried away by the boiling vapour. One other concern is what extra safety measures that have to be taken in the disposal of the nanofluid. The application of nanofluid coolant to boiling water reactors is predicted to be minimal because nanoparticle carryover to the turbine and condenser would raise erosion and fouling concerns. The vast new world of nanotechnology provides fertile grounds for scientific advances and the development of novel devices and materials which will affect the well-being of all. Among the various novelties scientists and engineers have introduced over the recent years are nanofluids, or stable suspensions of nanoparticles into host fluids, which show great promises. Nanofluids are extensively studied for the heat transfer properties, and could potentially enhance the efficiency of large-scale heat exchangers used in chemical processing plants systems as well as smaller scale heat exchangers used in the automotive and computer cooling sectors. Other novel applications are being developed for mass transfer operations, for the harvesting of sunlight, and for imaging, sensing, transport and interactions in biological systems. Nanofluids bring together researchers from the fundamental sciences of physics, chemistry and biology and from engineering disciplines such as advanced materials, chemical, mechanical, biomedical and nuclear engineering, engineering physics and micro- and nano systems. The use of nanofluids in nuclear power plants seems like a potential future application. Another possible application of nanofluids in nuclear systems is the alleviation of postulated severe accidents during which the core melts and relocates to the bottom of the reactor vessel. If such accidents were to occur, it is desirable to retain the molten fuel within the vessel by removing the decay heat through the vessel wall.

The use of nanofluids 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. Through preliminary investigation, it was determined that copper nanofluid produces a higher wear rate than the base fluid and this is possibly due to oxidation of copper nanoparticles. Future engines that are designed using nanofluids' cooling properties would be able to run at more optimal temperatures allowing for increased power output. With a nanofluids engine, components would be smaller and weigh less allowing for better gas mileage, saving consumers money and resulting in fewer emissions for a cleaner environment. In electronic applications, nanofluids are used for cooling of microchips in computers and elsewhere. They are also used in other electronic applications which use micro-fluidic applications. A principal limitation on developing smaller microchips is the rapid heat dissipation. However, nanofluids can be used for liquid cooling of computer processors due to their high thermal conductivity. Further research of nanofluids in electronic cooling applications will lead to the development of the next generation of cooling devices that incorporate nanofluids for ultrahigh-heat-flux electronic systems. There is a new initiative which takes advantage of several properties of certain nanofluids 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 nanofluids are to be used to guide the particles up the bloodstream to a tumour 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. There are numerous biomedical applications that involve nanofluids 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 nanofluids that allow for the careful tailoring of their properties for different requirements in applications. Surface coating of nanoparticles and the colloidal stability of biocompatible water-based magnetic fluids are the two particularly important factors that affect successful application. Nanofluids could be applied to almost any disease treatment technique by reengineering the nanoparticles properties. Several significant gaps in knowledge are evident at this time, including, demonstration of the nanofluid thermal-hydraulic performance at prototypical reactor conditions and the compatibility of the nanofluid chemistry with the reactor materials [5].

Ultrasonic velocity has become a valuable tool for the study of various physical and chemical properties of the matter. Ultrasonic velocity measurement offers a rapid and destructive tool for the characteristics of materials. Various elastic parameters and estimation of grain size has been going on far the past several years. Elastic constants of isotropic solid can be determined ultrasonically when both longitudinal and transverse wave velocities are known [6, 7]. The aim of present work was to study the characterization of copper nanofluid using ultrasonic techniques.

EXPERIMENTAL DETAILS

Ultrasonic testing, although widely used in the steel casting, forging and fabrication industries, has not been applied to iron castings until recent years. The advent of nodular graphite irons, which increased the scope of the iron foundry to such a great extent, particularly in much increased service requirements, resulted in the demand for improved non-destructive testing techniques. Interferometry is the technique of diagnosing the properties of two or more waves by studying the pattern of interference created by their superposition. It is an important investigative technique in the fields of astronomy, fiber optics, engineering meterology, optical metrology, oceanography, seismology, quantum mechanics, plasma physics and remote sensing. An ultrasonic interferometric sensor has been introduced for the measurement of suitable changes in the physical properties of fluids such as density, viscosity and bulk modulus [8].

The ultrasonic interferometer is simple in construction and operation and gives accurate and reproducible results. From these results, one can readily determine the velocity of sound in a liquid with high accuracy. Formerly, the absorption of sound in the liquid and the coefficient of reflection at the reflector surface have been obtained through a complicated analysis of the electrical and equivalent electrical circuits of the quartz crystal and the associated fluid column. In our experimental work we use multifrequency interferometer. This multifrequency generator can generate ultrasonic waves of several frequencies form 1 MHz to 12 MHz in the medium. The multifrequency ultrasonic interferometer consists of the two parts- the high frequency generator and the measuring cell. The high frequency generator is designed to excite the quartz plate fixed at the bottom of the measuring cell at its resonant frequency to generate ultrasonic waves in the experimental liquid in the measuring cell. A micro ammeter to observe the changes in current and two controls for the purpose of sensitivity regulation and initial adjustment of micro ammeter is provided on the high frequency generator. The measuring cell is a specially designed double walled cell for maintaining the temperature of liquid constant during the experiment. A fine micrometer screw has been provided at the top, which can lower or raise the reflector plate in the cell through a known distance. It has a quartz plate fixed at its bottom the ultrasonic interferometer may be used for determination of ultrasonic velocity. The measuring cell is connected to the output terminal of the high frequency generator through a shielded cable the cell is filled with the experimental liquid before switching on the generator the ultrasonic waves moves normal from the crystal till they are reflected back from the movable plate and the standing waves are formed in the liquid in between the reflector plate and the quartz crystal. The micrometer is slowly moved till the anode current meter on high frequency generator shows a maximum. A number of maximum readings of anode current are passed on and their n is counted the total distance x thus moved by the micrometer gives the value of wavelength λ with the help of the following relation;

$$x = n \times \lambda /2 \quad (1)$$

Once the wavelength is known the ultrasonic velocity V of copper nanofluid can be calculated with the help of following relation;

$$V = \lambda \times f \quad (2)$$

EVALUATION

Ultrasonic velocity measurements have been successfully employed to detect and assess weak and strong molecular interactions present in nanofluids. These studies can also be used to determine the extent of complexation and calculate the stability constants of such complexes [9]. Nanofluids are suspensions of nanoparticles in fluids that show significant enhancement of their properties at modest nanoparticle concentrations. Nanofluids are considered to offer important advantages over conventional heat transfer fluids. Nanofluids contain suspended metallic nanoparticles, which increases the thermal conductivity of the base fluid by a substantial amount [10, 11]. The term Nanoscience often refers to research that discovers and characterizes new behaviors and properties of materials at the nanoscale. Nanotechnology describes how discoveries at the nanoscale are put to work, especially by controlling the behavior of matter and building useful devices. Some of these devices have demonstrated applications in medicine, electronics, robotics and energy production. Measurement of ultrasonic velocity gives the valuable information about the physicochemical behaviour of the liquid and liquid mixtures. Several relations, semi-empirical formula and theories are available for the theoretical computation of ultrasonic velocity in liquid and liquid mixtures.

The ultrasonic velocity was measured at different temperature using multi frequency interferometer with a high degree of accuracy operating at different frequencies from 1 and 2 MHz. The ultrasonic velocity for 1 and 2 MHz frequencies for nanofluid of copper is 1132.7 m/sec and 1109.7 m/sec at room temperature. Interpretation of data shown in figures is presented in Table 3.

RESULTS AND DISCUSSIONS

Ultrasonic velocity measurements are helpful to study the ion-solvent interactions in aqueous and non-aqueous solutions in recent years. Ultrasound has been extensively used to determine the ion solvent interactions in aqueous containing electrolytes.

Nanofluids do not behave in the same manner as simple liquids with classical concepts of spreading and adhesion on solid surfaces. This fact opens up the possibility of nanofluids being excellent candidates in the processes of soil remediation, lubrication, oil recovery and detergency. Future engineering applications could abound in such processes. The ultrasonic velocity of copper nanofluid for frequencies 1 and 2 MHz are given in Tables 1 and 2. For 1 MHz frequency, we measure the velocity from room temperature to 44^0C. The measured data is presented in Table 1. The temperature variations of ultrasonic velocity are shown in Figure 1; it is clear from this Figure and Table, the ultrasonic velocity is changing at different temperatures.

Table 1. Temperature Variation of Ultrasonic velocity of copper nanofluid at 1 MHz

Temperature (^{0}C)	36	37	38	39	40	41	42	43	44
Velocity (m/sec)	1133	1167	1154	1171	1172	1150	1171	1165	1154

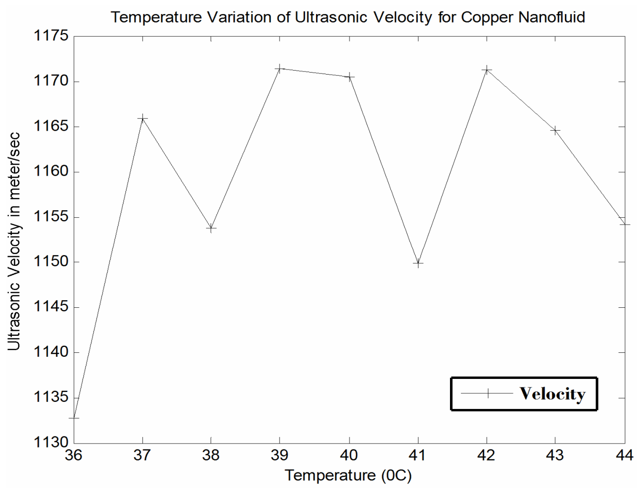

Figure 1. Temperature Variation of Ultrasonic Velocity for 1 MHz

Ultrasonic velocity measurements play a large role in several fields of industrial endeavor. Obviously, such measurements are used to characterize piezoelectric and magnetostrictive materials used as ultrasonic generators and sensors by the ultrasonic industry itself. The measuring data of ultrasonic velocity of copper nanofluid for 2 MHz frequency are shown in Table 2. Figure 2 presents temperature variation of ultrasonic velocity for copper nanofluid.

Table 2. Temperature Variation of Ultrasonic velocity of copper nanofluid at 2 MHz

Temperature (^{0}C)	35	36	37	38	39	40	41
Velocity (m/sec)	1109	1117	1213	1158	1117	1185	1032

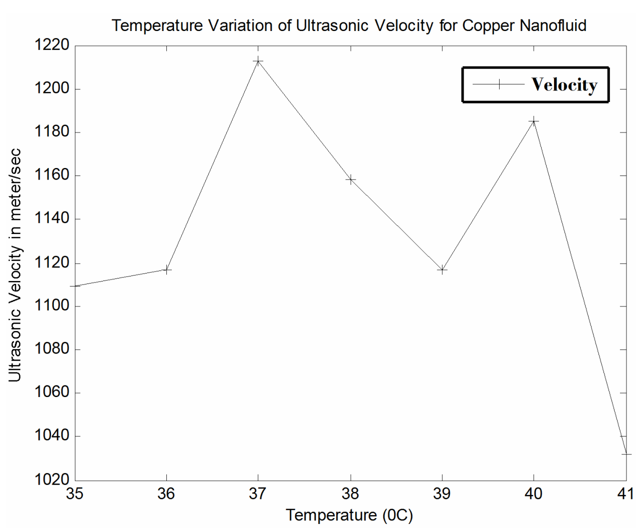

Figure 2. Temperature Variation of Ultrasonic Velocity for 2 MHz

Table 3. Best fit polynomial $Y = A_1 + A_2 * T + A_3 * T^2 + A_4 * T^3 + A_5 * T^4$ for Ultrasonic Velocity of Copper Nanofluid

Frequency	A_1	A_2 ($\times 10^2$)	A_3 ($\times 10^3$)	A_4 ($\times 10^4$)	A_5 ($\times 10^5$)
1MHz	-0.18	0.25	-1.53	4.12	-4.14
2MHz	-1.55	2.35	-1.33	33.46	-31.55

Nanofluids are important because they can be used in numerous applications involving heat transfer and other applications such as in detergency. Colloids which are also nanofluids have been used in the biomedical field for a long time, and their use will continue to grow. Nanofluids have also been demonstrated for use as smart fluids. Nanofluids employed in experimental research have to be well characterized with respect to particle size, size distribution, shape and clustering so as to render the results most widely applicable. Once the science and engineering of nanofluids are fully understood and their full potential researched, they can be reproduced on a large scale and used in many applications. Colloids which are also nanofluids will see an increase in use in biomedical engineering and the biosciences. Ultrasonic velocity measurements provide an important tool to study the liquid state. Such studies have been used to understand the intra and inter molecular interactions in liquids. Detailed information about the nature of molecular interactions can be obtained from various ultrasonic parameters computed on the basis of experimental investigations.

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