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# STUDY ESTIMATION OF THERMAL CONDUCTIVITY IN OXIDE NANOPARTICLES

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**ABSTRACT**

*Oxide nanofluids were generated and their thermal conductivities were estimated by a transient hotwired process. The experimental outcomes reveal that these nanofluids contain some number of nanoparticles that have considerably greater thermal conductivities than similar liquids without nanoparticles. Contrast between Crosser and Hamilton model and experiments reveals that the model can find the nanofluids thermal conductivity consisting big agglomerated aluminum oxide particles. However the model seems to be insufficient for nanofluids consisting of copper oxide particles. This recommends that not only particle form but size is regarded to be superior in developing the nanofluids thermal conductivity.*

Keywords: Oxide nanofluids, thermal conductivity, nanoparticles

## Introduction:

The fluids of traditional heat transfer such as water, oil and ethylene glycol combination are poor fluids of heat transfer inherently. There is a powerful requirement to enhance advanced fluids of heat transfer with essentially greater thermal conductivities and developed features of heat transfer than are presently feasible. Despite substantial former R&D concentrating on needs of industrial heat transfer, major developments in capabilities of heat transfer have been directed because of a major restriction in conventional fluids thermal conductivity. It is known well that solid form metals have thermal conductivities that are greater than those of fluids by magnitude orders. Oxides namely alumina are better thermal insulators contrast to metals such as copper have thermal conductivities greater than magnitude order greater than water. Therefore fluids consisting of suspended particles of solid are anticipated to show developed thermal conductivities significantly similar to those of fluids of conventional heat transfer. In fact several experimental and theoretical studies of efficient suspensions thermal conductivity consists of solid particles have been organized since theoretical work of Maxwell published greater than 100 years ago (Maxwell, 1881). Lack of suspensions stability that include particles consisting of coarse grain is a major reason why fluids with dispersed coarse grained particles have not been commercialized previously. Nanotechnology is anticipated to have applications in several areas involving nano electronic devices, biotechnology, transportation and scientific instruments (Ashley, 1994; Rohrer, 1996).

Modern nanotechnology offers huge chances to produce and process materials with average sizes of crystallite below 50 nanometer. Identifying a chance to use this developing nanotechnology to established thermal energy engineering Argonne has evolve the new heat transfer fluids class concept known as nano-fluids which transfer heat much effectively than conventional fluids (Choi, 1995). Argonne has already generated nanofluids and organized proof of concepts tests (Eastman et al, 1997). Specifically it was described that oxide nanoparticle such as copper oxide and aluminum oxide have outstanding properties of dispersion in oil, water and ethylene glycol and comprise stable suspensions. Nanofluids are anticipated to reveal leading properties common to those of conventional fluids of heat transfer and fluids consisting of micrometer sized particles. Because heat transfer exists at particles surface it is desirable to utilize particles with a big area of surface. Nano-particles provide big total areas of surface and therefore have huge importance for heat transfer application. Though Nano particles seems to be suited ideally for applications in which fluids flow through little spaces because Nano particles are small enough and stable not to clog the passages of flow. Successful employment of nanofluids will assists the present trend towards miniaturization of component by enhancing the design of lighter and smaller exchanger systems of heat. One such application is in cooling systems next generation for monochromators and mirror in greater intensity sources of X-ray such as Advanced Photon Source of Argonne. An advanced process of cooling that engages micro-channels with Nano-fluids could offer much effective cooling than any occurring approach (Lee and Choi, 1996). Over conventional suspensions another benefit of Nano-fluids of coarse grained particles in fluid systems is in their anticipated developed properties related to abrasion. Because large coarse grained particles have essential mass and they can scrape surfaces which the contact. This outcomes in reduced times of life of such tools as bearings and water pumps. Presently Hu and Dong (1998) reveals that in oil titanium nanoparticle increase resistance and reduce the coefficient of friction to wear. Therefore it is feasible that nanoparticle would develop the heat transfer fluids lubricating properties. The main aim of this study is to examine the oxide nano fluids thermal conductivity behavior with reduced particle concentrations experimentally.

**Characterization and Production of Nano Fluids:**

Nano fluids are generated by disseminating solid particles of nanometer scale into liquids such as ethylene, oils, water or glycol. Modern fabrication technique offers huge chances to process materials at nanometer and micrometer scales. Nanocrystalline or nanostructured materials are composed of individual crystallites that are less than 50 meter nanometer in size. Huge number of materials comprise by the integration of big number of Nano-crystallites always indicate changed properties greatly compared to those of conventional coarser grained materials (Gleiter, 1989). Nonconsolidated nanocrystalline powers reveal changed properties due to their free areas of surface. Much advancement has been made presently in the nano-crystalline materials processing. Gas condensation processing (Granqvist and Buhrman, 1976; Kimoto et al, 1963) was utilized in present experiments is the most similar method used presently in Nano-structured materials laboratory production. Gas condensation processing includes the nonmetallic or metallic vaporization species of precursor in the existence of controlled gas pressure. Collisions between the inert gas and vapor outcome in nanometer sized particles condensation of precursor material which are then gathered and utilized in either bulk consolidated or powder form. The gas condensation benefits over other processing technologies involve the capability to generate particles under cleaner circumstances. If powders are generated by condensation of gas certain agglomeration of individual particles exists. It is known well that these agglomerates needs small energy to break into little constituents and it is feasible that even agglomerated powders of Nano-crystalline particles can be dispersed into fluids successfully and outcome in better properties. Oxide nanofluids were generated by two step process in which the first oxide nanoparticle are prepared, followed by $2^{nd}$ step in which powders were distributed into base fluids in a mixing chamber in this study. Copper oxide and aluminum oxide nanoparticle generated by gas condensation were utilized as oxide nanoparticle and were scattered in ethylene glycol or water. Nano particles were described after and before scattering in liquids. Particle size characterization before liquids dispersion was undertaken using techniques of transmission electron microscopy. Both aluminum oxide and copper oxide particles revealed a log normal size distribution as anticipated for particles generated by the process of gas condensation. The distributions of particles were fit to a log normal function and both area and number weighted values were decided for average diameters of particle. The distribution of weighted size weights complete particles commonly and the distribution of weighted size weighs the particles according to their area of surface. Since the heat transfer is a surface phenomenon the area weighted average is anticipated to generate the much common values.

Transmission electron microscopy of Nano particles refined from solutions of nano-fluid was utilized to describe the solutions effects on behavior of agglomeration. Certain agglomerates are as big as 100 nanometer and copper oxide indicates a little size of grain than aluminum oxide and the agglomerate sizes of copper oxide are little than those of aluminum oxide. No trial was made to separate the Nano-particles which are agglomerated because they were scattered successfully into formed stable and liquid suspensions. To verify the impact of conductivities and volume fraction of solid phase and liquid on nanofluids thermal conductivity 4 oxide nanofluids with varied fractions of volume were generated. These 4 systems comprises of copper oxide in water, aluminum oxide in water, copper oxide in ethylene glycol and aluminum oxide in ethylene glycol with loadings of particle up to maximum of five volume percentage.

**Experiments:**

To estimate the nanofluids thermal conductivity the author utilized a transient method of hot wire because their nanofluids are conductive electrically this affected difficulty in using ordinary transient technique of hot wire. A new electrical and hot wire cell system has been configured for their experiment according to the method suggested by Nagasaka and Nagashima (1981).

**Transient Hot wire method:**

A transient hot wire method has been acquired in this study because present developments in electronic technologies have helped to set up this process as one of the most exact ways to decide thermal conductivity of fluid. The benefit of this process depends first in its almost whole removal of natural convection effects whose undesirable existence presents measurement issues made with constant state equipment. Additionally the process is rapid similar to constant state technologies. The major description of transient hot wire method application and theory were prepared by Kestin and Wakeham (1978), Johns et al (1988) and Roder (1981). A hot wire system includes a symmetrically suspended wire in a liquid in a vertical container of cylinder. The wire provides both as thermometer and as heating component and without exception platinum is the wire of option.

**Experimental procedure and apparatus:**

A transient hot wire cell was built and designed specifically for thermal conductivities measurement of Nano-fluids. Platinum is utilized for hot wire because its temperature/resistance rapport is known well over a vast range of temperature. The wire was bonded to supporters of rigid copper with one supporter side linked to a string of rubber so the tension of wire could be adjusted to own the wire straightly. The welded spots and wire were covered with an epoxy adhesive which was extraordinary insulation of electric and conduction of heat. The hot wire sensor system is resided at the mid of cylinder and the arrangement to gravity direction is adjusted by the system of string.

## Results and Discussion:

### Base fluids calibration:

In this study the base fluids is utilized as the liquids suspension are ethylene glycol and deionized water. To set up the measurements of thermal conductivity accuracy the experiments of calibration were carried out for ethylene glycol and water in 290K to 310K ranges of temperature and at atmospheric pressure. Though the electric power used to the wire for ethylene glycol and water is similar the temperature slopes increase are varied which means that the ethylene glycol and water thermal conductivities are varied as anticipated. Because the water's thermal conductivity is larger than that of ethylene glycol the water slope is decreased than that for ethylene glycol.

### Copper oxide and aluminum oxide Nano-fluids thermal conductivity measurement:

At room temperature the measurements of thermal conductivity were made and no trial was made to manage the nanofluids temperature at a steady temperature because the room temperature fluctuations in lab were little. The outcomes reveal that nanofluids consisting a little number of nanoparticles have considerably greater thermal conductivities than similar liquids without nanoparticle. The outcomes of experiment clearly reveal that the ratios of thermal conductivity develop linearly with fraction of volume but with varied increase rates for every system. The processing of copper oxide nanoparticle could have outcome in incomplete oxidation which would be apparent by existence of little number of unreacted greater thermal conductivity copper being existing in addition to copper oxide.

**Comparison with Crosser and Hamilton Model:**

Because of the theory absence for nanofluids thermal conductivity an existing model for liquid/solid system has been utilized to contrast the founded values with estimated nanofluids thermal conductivity. The model of Maxwell reveals that the efficient suspensions thermal conductivity consists of spherical particles develops with solid particles volume fraction. It is known that suspensions thermal conductivity relies not only on particles volume fraction but also on dispersed particles shape for non-spherical particles. Hamilton and Crosser (1962) evolved a detailed model for efficient to component mixtures thermal conductivity as a pure materials conductivity function the mixture composition and the dispersed materials shape. The thermal conductivity ratios estimated for copper oxide nanofluids are considerably greater than the predictions of Hamilton crossover model. It is feasible that a little number of metallic copper in copper oxide material utilized in these experiments developed the copper oxide nanofluids thermal conductivity.

**Comparisons with Masuda et al experiments:**

No studies of experiment have been undertaken on copper oxide nanofluids thermal conductivity. Direct contrast between the current experimental information and those of other examiner is feasible only for aluminum oxide or water nanofluids. Presently Masuda et al (1993) revealed that aluminum oxide particles at a fraction volume of 4.3% can develop water thermal conductivity by 30% experimentally. The ratios of thermal conductivity in present experiments are reduced than those of Masuda et al by greater than 20 percent. This is not unexpected since the aluminum oxide particles mean diameter utilized in Masuda et al experiments is 13 nanometer which in the current experiments is 38 nanometer. Because ratio of surface area to volume is 3 times greater for 13 nanometer diameter particles than for 38 nanometer diameter particles a larger development in efficient thermal conductivity is anticipated. Another reason for essential variations is that Masuda et al utilized the technique of electrostatic repulsion and a greater speed shearing disperser. These techniques might alter in nanoparticle morphology which was described in model of Hamilton crosser as n (a shape factor). Primarily because the author did not utilize such technologies, nanoparticle in systems were agglomerated and thus became spherical and larger than those utilized by Masuda et al. However it is essential to mention that the profile of model for nonspherical particles initiate to diverge from Masuda et al experimental information at a much reduced volume fraction. This recommends strongly that not only particle form but also size is regarded to be dominant in developing nanofluids thermal conductivity. Therefore it is rational to anticipate that the model will fail to find the nanofluids thermal conductivity consisting of particles little than 13 nanometer. Because heat transfer between the fluid and particles exist at interface of particle fluid the expectation of author is that if the authors have much interfacial area then the author would anticipate heat transfer to be much rapid and efficient. Therefore it is desirable to utilize particles with a large surface area to ratio of volume. Hamilton and Crosser (1962) theoretical work concentrated on feasible impacts of developing specific area of surface by handling shapes of particles to be non-spherical. Therefore a much more dramatic growth in efficient thermal conductivity is anticipated as an outcome of reducing the size of particle than can be acquired by changing the shapes of larger particle. It is known well that in regime of micro scale the thin film material's thermal conductivity is much reduced than its bulk value due to distribution of major energy carriers (electron and/or phonon) at its boundary (Majumdar, 1998; Flik and Tien, 1990). The intrinsic oxide nanoparticle thermal conductivity may be decreased contrast to huge number of oxides due to the effect of size. Assisting this notion the Yttria Stabilized Zirconia thermal conductivity thin films with controlled grain sizes of crystalline was measured presently (Soyez et al, 1998). Approximately a two reduction factor in 10 nanometer grain sized yttria stabilized zirconia contrast to that of huge material is viewed at room temperature. The models found resistance of surface boundary when the size of particle reduces. Comparison of aluminum oxide in results of water with those of Masuda et al (1993) indicate clearly that the efficient conductivity for this system develops with reduced size of particle compared to predictions based on resistance of boundary. Also these models are enclosed to conventional suspensions consisting of micrometer or millimeter sized particles. A nanofluid seems to be varied from conventional suspensions. The much bigger nanophase powder surface areas common to those of conventional powders not only develop capabilities of conduction heat transfer markedly but also develop the suspensions stability. The author required to evolve a much comprehensive theory in future to describe the nanofluids behavior. It seems that the nanofluids thermal conductivity is structure dependent. Any new nanofluid thermal conductivity models must involve the structure dependent and surface area behavior as well as the boundary resistance and size effect.

## Conclusions and Future Research Plan:

To examine the dilute nanofluids thermal conductivity experimentally the author estimates the 4 nanofluids namely aluminum oxide in ethylene glycol, aluminum oxide in water, copper oxide in ethylene glycol and copper oxide in water by a transient method of hot wire experimentally. The current results of experiment reveals that nanofluids consisting only a little number of nanoparticle have considerably greater thermal conductivities than similar liquids without nanoparticle. The current experimental information reveals that the nanofluids thermal conductivity relies on particles and base fluids thermal conductivity. Using similar nanoparticle for nanofluids the ratio of conductivity develops the nanofluid systems ethylene glycol are often greater than those of water nanofluid systems. The ratio of conductivity of copper oxide system is often greater than that of aluminum oxide system for nanofluids using similar liquid.

Contrast between the estimated nanofluids thermal conductivity and the founded model values evolved by Hamilton and Crosser (1962) were made. The model of Hamilton-Crosser is capable of finding the nanofluids thermal conductivity of finding nanofluids thermal conductivity consisting big agglomerated aluminum oxide particles. However the model seems to be insufficient for nanofluids consisting of particles of copper oxide. Further work is needed to clarify the reasons for this discrepancy. To clearly perceive the thermal conductivity mechanisms development of nanofluids future research is required. One of the major variations between theoretical model and experimental data is that the increase rate of thermal conductivity relies on size of particle strongly. Therefore not only the particle shape effect which was regarded by Hamilton and Crosser (1978) but much essentially the particle size effect must be examined. In future the author required to evolve a much comprehensive theory to describe nanofluids complex behavior. In this study the stationary nanofluids thermal conductivity was regarded. Numerous examiners have outlined augmentation of efficient suspensions thermal conductivity with polystyrene sized millimeter particles under laminar flow (Ahuja, 1975; Sohn and Chen, 1981). Therefore the author anticipates that the efficient nanofluids thermal conductivity under conditions of flow might be greater than that viewed in current experimental outcomes. Hence the tests of heat transfer to assess the nanofluids thermal performance under controlled conditions of flow are presently being organized.

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