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HEAT TRANSFER ENHANCEMENTS AND APPLICATION POTENTIONAL IN NANOLLUIDS RESEARCH

MR. PRASHANT J. PATIL [1], Dr. CHANDRAKANT R. PATIL[2]

1. **Principal, Abhinav Education Society's COET (P) Pune, India.**
2. **Prof. Mechanical Dept. Prof. Ram Meghe College of Engg. and Management, Amravati, India**

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Corresponding Author
Mr. Prashant J. Patil

Abstract

Researches in heat transfer have been carried out over the previous several decades, leading to the development of the currently used heat transfer enhancement techniques. The use of additives is a technique applied to enhance the heat transfer performance of base fluids. Recently, as an innovative material, nanometer-sized particles have been used in suspension in conventional heat transfer fluids. The fluids with these solid-particle suspended in them are called 'nanofluids'. The suspended metallic or nonmetallic nanoparticles change the transport properties and heat transfer characteristics of the base fluid. Research work on the concept, heat transfer enhancement mechanism, and application of the nanofluids is still in its primary stage. Most systems/processes whose performance is affected by heat generation could benefit from nanofluid coolants. Nanofluids have great potential for thermal management and control involved in a variety of applications such as electronic cooling, micro electro mechanical systems (MEMS) and spacecraft thermal management. This study provides a review of research in this field with focus on thermal conductivity studies of nanofluids and their applications.

1. INTRODUCTION

Conventional fluids, such as water, engine oil and ethylene glycol are normally used as heat transfer fluids. Although various techniques are applied to enhance the heat transfer, the low heat transfer performance of these conventional fluids obstructs the performance enhancement and the compactness of heat exchangers. The use of solid particles as an additive suspended into the base fluid is a technique for the heat transfer enhancement. Improving of the thermal conductivity is the key idea to improve the heat transfer characteristics of conventional fluids. Since a solid metal has a larger thermal conductivity than a base fluid, suspending metallic solid fine particles into the base fluid is expected to improve the thermal conductivity of that fluid. The enhancement of thermal conductivity of conventional fluids by the suspension of solid particles, such as millimeter- or micrometer-sized particles, has been well known for more than 100 years. However, they have not been of interest for practical applications due to problems such as sedimentation, erosion, fouling and increased pressure drop of the flow channel. The recent advance in materials technology has made it possible to produce nanometer-sizes particles that can overcome these problems. Innovative heat transfer fluids-suspended by nanometer-sized solid particles are called 'nanofluids'. These suspended nanoparticles can change the transport and thermal properties of the base fluid.

Three properties that make nanofluids promising coolants are:(i) increased thermal conductivity, (ii) increased single-phase heat transfer, and (iii) increased critical heat flux.

Research has shown that relatively small amounts of nanoparticles, of the order of 5 Vol. percent or less, can enhance thermal conductivity of the base fluid to a large extent. Therefore, exploiting the unique characteristics of nanoparticles, nanofluids are created with two features very important for heat transfer systems:(i) extreme stability, and (ii) ultra-high thermal conductivity. This new class of heat transfer fluids has shown several distinct properties with large enhancements in thermal conductivity as compared to the base liquid, temperature and particle size dependence reduced friction coefficient, and significant increase in critical heat flux. The aim of this paper is to present a review of the open literature describing recent developments in the enhancement of heat transfer by using nanofluids.

2. SYNTHESIS OF NANOFLUIDS-

The optimization of nanofluid thermal properties requires successful synthesis procedures for creating stable suspensions of nanoparticles in liquids. Depending on the requirements of a particular application, many combinations of particle materials and fluids are of potential interest.

However, there is not yet a standard preparation method for nanofluids. Different studies prepared nanofluids using different approaches. There are two fundamental methods to obtain nanofluids: (a) two-step process in which nanoparticles are first produced as a dry powder, typically by an inert gas. The resulting nanoparticles are then dispersed into a fluid. This method may result in a large degree of nanoparticle agglomeration.(b) chemical approach using wet technology, a single-step approach, is emerging as a powerful method for different metals, semiconductors, non-metals, and hybrid systems.

3. THERMAL CONDUCTIVITY OF NANOFLUIDS

3.1 Experimental Investigations-

Thermal conductivity is an important parameter in enhancing the heat transfer performance of a heat transfer fluid. Since the thermal conductivity of solid metals is higher than that of fluids, the suspended particles are expected to be able to increase the thermal conductivity and heat transfer performance. Many researchers have reported experimental studies on the thermal conductivity of nanofluids. The transient hot wire technique works by measuring the temperature/time response of the wire to an abrupt electrical pulse. The wire is used as both heater and thermometer. Al_2O_3 and CuO are the most well-known nanoparticles used by many researchers in their experimental works.

Lee et al. measured the thermal conductivity of nanofluids. The number-weighted particle diameter and the area weighted particle diameter used were 18.6 and 23.6nm for CuO, and 24.4 and 38.4nm for Al_2O_3, respectively. These particles were used with two different base fluids: water and ethylene glycol to get four combinations of nanofluids (CuO in water, CuO in ethylene glycol, . Al_2O_3 in water and . Al_2O_3 in ethylene glycol). The nanofluids showed substantially higher thermal conductivities than those of the same liquids without the nanoparticles.

Wang et al. used the steady-state parallel-plate technique to measure the thermal conductivity of nanofluids containing Al_2O_3 and CuO nanoparticles. The particles were dispersed in water, ethylene glycol. Experimental data showed that the thermal conductivity of all nanofluids were higher than those of their base fluids. The thermal conductivity of the nanofluids increased with increasing volume fraction of the nanoparticles.

Eastman et al. reported an experimental study on the thermal conductivity of ethylene glycol-based nanofluids containing copper nanoparticles. The nanofluid exhibited an anomalously increased effective thermal conductivity. The thermal conductivity increased up to 40% for nanofluids consisting of 0.3% (by volume) of Cu nanoparticles of a mean diameter less than 10nm dispersed in ethylene glycol.

Xie et al. measured the thermal conductivity of Al_2O_3 nanoparticle suspensions. The effects of the pH value of the suspension, the specific surface area (SSA) of the dispersed . Al_2O_3 particles, the crystalline phase of the solid phase, and the thermal conductivity of the base liquid on the enhanced thermal conductivity ratio were investigated. For the suspensions containing the same base liquid, the thermal conductivity enhancements were highly dependent on the specific surface area (SSA) of the nanoparticles

3.2. Analytical investigations-

As is evident from the work of many researchers, the thermal conductivity of nanofluids increased as a function of thermal conductivity of both the base fluid and the nanoparticle material, the volume fraction, the surface area, and the shape of the nanoparticles suspended in the liquid. There are no theoretical formulas currently available in open literature for predicting the thermal conductivity of nanofluids. The Maxwell model, an existing traditional model for thermal conductivity, was proposed for solid–liquid mixtures with relatively large particles. Many later proposed models have been based on the Maxwell model. The effective thermal conductivity is

keff ,Maxwell $= \frac{kp+2k1+2(kp-k1)\emptyset}{kp+2k1-(kp-k1)\emptyset}\, k1$

where kp is the thermal conductivity of the particle, k1 is the thermal conductivity of the liquid and f is the particle volume fraction of the suspension.

Hamilton and Crosser developed a model for the effective thermal conductivity of two-component mixtures. The model is a function of the conductivity of both the particle and base fluid, and the shape of the particles.

keff; Hamilton $=\frac{kp+(n-1)k1-(n-1)(k1-kp)\emptyset}{kp+(n-1)k1+(k1-kp)\emptyset}\, k1$

where n is the empirical shape factor given by n ¼ 3=c and c is the sphericity, defined by the ratio of the surface area of a sphere, having a volume equal to that of the particle, to the surface area of the particle. Xuan and Li used the Hamilton–Crosser model to obtain a rough estimation of the thermal conductivity of the nanofluids for different values of c from 0.5 to 1.0.

An alternative expression for calculating the effective thermal conductivity of solid–liquid mixtures was introduced by Yu and Choi . They proposed that a structural model of nanofluids might consist of a bulk liquid, solid nanoparticles and solid like nanolayers.

keff ;Yu=$= \frac{kp+2k1+2(kp-k1)(1+\beta)^3\emptyset}{kp+2k1-(kp-k1)(1+\beta)^3\emptyset}\, k1$

where b is the ratio of the nanolayer thickness to the original particle radius and kp is the equivalent thermal conductivity of the equivalent particle. In this model, the prediction is most effective when the nanoparticles have a diameter less than 10 nm.

4. APPLICATIONS OF NANOFLUIDS-

Very high thermal conductivity and extreme stability have always been desired for heat transfer fluids with particles. Fluids having this important combination of features did not exist till the advent of nanofluids. Nanofluid technology could make the process more energy efficient and costeffective. These nanofluids could be used in a wide range of industrial applications. Demand for ultra-high-performance cooling in electronics has been increasing, and conventional enhanced surface techniques have reached their limit with regard to improving heat transfer. Since nanofluids can flow in microchannels without clogging, they would be suitable coolants. These could enhance cooling of MEMS under extreme heat flux conditions. Engine coolants (ethylene glycol/water mixtures), engine oils, automatic transmission fluids, and other synthetic high-temperature heat transfer fluids currently possess inherently poor heat transfer capabilities, they could benefit from the high thermal conductivity offered by nanofluids. Nanofluids could be used as metalworking coolant fluids for grinding and polishing components. Solar energy systems could take advantage of nanofluids to enhance heat transfer from solar collectors to storage tanks. Nanofluids could improve the heat transfer capabilities of current industrial HVAC and refrigeration systems. Many innovative concepts are being considered; one involves the pumping of coolant from one location, where the refrigeration unit is housed to another location

5. CONCLUSION-

Most systems/processes whose performance is affected by heat generation could benefit from nanofluid coolants. Nanofluids have great potential for thermal management and control involved in a variety of applications such as electronic cooling, microelectro mechanical systems (MEMS) and spacecraft thermal management. The miniaturization of mechanical and electrical components creates a need for heat transfer fluids with improved thermal characteristics over those of conventional coolants. The significant growth in performance and functionality of microelectronics combined with a miniaturisation trend in MEMS has resulted in an unprecedented increase in heat loads that presents a great challenge to thermal engineers. Nanofluids have the potential to meet these challenges. It is expected that nanofluids can be utilised in airplanes, cars, micro machines in MEMS, microreactors among others. Nanofluid spreading and adhesion on solid surface can yield materials with desirable structural and optical properties. Several investigations focused upon the energy transport enhancement inside stationary nanofluids show substantial augmentation of heat transport in the nanofluid consisting of copper or aluminium nanoparticles in water or mineral oils. Such enhancement of energy transport is dependent on component fractions and physical properties of fluid.

6. CURRENT RESEARCH DIRECTIONS AND FUTURE SCOPE-

At present, fundamental and quantitative understanding of the thermal conductivity mechanisms in nanofluids is in the initial stage. Thus, current research is focused on theoretical and experimental studies to answer the question, "How does particle size affect thermal conductivity?" Researchers are working to build a structural model that can help explain the thermal conductivity of nanofluids. There is a need for atomic and microscale-level understanding of heat transfer in nanofluids. The knowledge of heat transfer at micro or nanoscale contacts is, however, still limited. Thermal conductivity has received the most attention, but several groups have recently initiated studies of other heat-transfer properties. Few studies have been conducted on the rheology of nanofluids, even though the viscosity of a nanofluid is as important as thermal conductivity when it comes to practical applications. Previous experimental results are not reproducible by other researchers, posing the question as to why nanofluids behave differently. Little is known about how nanofluids behave over time, at elevated temperatures, or what the ultimate physical limits are. A better understanding of the mechanisms behind the thermal conductivity enhancement would likely lead to recommendations for nanofluid design and engineering for industrial applications. On the basis of the promising results to date, nanofluid research could lead to a major breakthrough in solid/liquid composites for numerous engineering applications, such as coolants for automobiles, airconditioning, and supercomputers, manufacturing. The use of nanofluids in a wide variety of applications appears promising. Comprehensive and systematic experimental measurements will characterise heat transfer and flow friction properties on the macroscale, as well as chemistry, structure and dynamics on the nanoscale.

REFERENCES

1. Choi, S. Enhancing thermal conductivity of fluids with nanoparticles. *In* Development and applications of non-newtonian flows, edited by D.A. Siginer and H.P Wang, New York: ASME, 1995, pp. 99-105.

2. Phelan, P.E.; Bhattacharya, P. & Prasher, R.S. Nanofluids for heat transfer applications. *Annu. Rev. Heat Transfer,* 2005, **14**, 255-75.

3. Lee, S.; Choi, S. U. S.; Li, S. & Eastman, J. A. Measuring thermal conductivity of fluids containing oxide nanoparticles., *J. Heat Transfer*, 1999, **121**, 280-289.

4. Masuda, H.; Ebata, A. ; Teramae, K. & Hishinuma, N. Alteration of thermal conductivity and viscosity of liquid by dispersing ultra-fine particles (dispersion and *Al2O3, SiO2*, and *Tio2* ultra-fine particles), Netsu Bussei (Japan), 1993, **7**(4) 227-33.

5. Eastman, J. A. ; Choi, S. U. S.; Li, S.; Thompson, L. J. & Lee, S. Enhanced thermal conductivity through the development of nanofluids. *Mater. Res. Soci. Symp. Proceedings*, Pittsburgh, PA, 1997, **457**, 3-11.

6. Xie, H.; Wang, J.; Xi, T., Liu, Y.; Ai, F. & Wu, Q. Thermal conductivity enhancement of suspensions containing nanosized alumina particles. *J. Appl. Phys.*, 2002, **91**(7), 4568-572.

7. Xuan, Y. & Le, Q. Heat transfer enhancement of nanofluids. *Int. J. Heat Fluid Flow*, 2000, **21**, 58-64.

8. Keblinski, P.; Phillpot, S. R.; Choi, S. U. S. & Eastman, J. A. Mechanisms of heat flow in suspensions of nanosized particles nanofluids. *Int. J. Heat Mass Transfer*,2002, **45**, 855-63.

9. Chopkar, M.; Kumar, S.; Bhandar, D.R.; Das, P.K. & Manna, I. Development and characterization of *Al2O3* and *Ag2Al* nanoparticle dispersed water and ethylene glycol based nanofluid., *Mat. Sci. Engg. B*, 2007, **139**, 141-48.

10. Das, S.K.; Putra, N.; Thiesen, P. & Roetzel, W. Temperature 606 DEF SCI J, VOL. 58, NO. 5, SEPTEMBER 2008

dependence of thermal conductivity enhancement for nanofluids. *J. Heat Tr.*, 2003, **125**, 567-74.

11. Patel, H.E.; Das, S.K.; Sundararajan, T. & Pradeep, T. A micro convection model for thermal conductivity of nanofluids. *Pramana-J. Phys*., 2005, **65**(5), 863-69.

12. Gandhi, K.S. Thermal properties of nanofluids:controversy in making. *Current Science*, 2007, **92**(6), 717-18.