Heat Transfer Enhancement & Effect on Thermal Conductivity by Nano Fluids

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Abstract: The aim of this paper is to present the broad range of nanofluid based current and future applications. This gives a brief description of how heat transfer enhances using Nanofluid? And its application in various fields viz. heat transportation, military applications, medical, etc. This paper focuses one explaining the basic mechanisms of improvement in heat transfer by addition nano particles. It is an overview of systematic studies that address the complexity of nanofluid systems and advances the understanding of nanoscale contributions to viscosity, thermal conductivity, and cooling efficiency of nanofluids is presented. A nanoparticle suspension is considered as a three phase system including the solid phase (nanoparticles), the liquid phase (fluid media), and the interfacial phase, which contributes significantly to the system properties because of their extremely high surface-to-volume ratio in nanofluids.

Keywords: Nanomaterials, Nanofluids, Properties, Heat Transfer Enhancement.

1. Introduction

Very small particles suspension in saturated liquids (water, ethylene glycol, engine oil) is defined as nanofluids may constitute a very interesting alternative for advanced thermal applications. It has been found that important heat transfer enhancement may be achieved while using nanofluids compared to the use of conventional fluids; some oxide nanoparticles exhibit an excellent dispersion properties in traditional cooling liquids. Scientists have been quite active in the past few decades in the search of novel approaches to increase heat dissipation of various cooling devices. Heat transfer through a fluid medium is important in several engineering applications including heat exchangers, refrigerators, automobiles, and power plants. The ability of a fluid medium to transfer heat across a small temperature difference enhances the efficiency of energy conversion and improves the design and performance of automobile engines, heat transfer devices, and micro-electro-mechanical systems (MEMS). In recent years, modern technologies have permitted the manufacturing of a new class of fluids, called nanofluids. In this paper we present a summary of systematic experimental studies of both thermophysical properties and heat transfer in nanofluids. We believe that the underestimated complexity and the controversy of nanofluid systems are related to the solid/liquid boundary.

2. What are nanofluids

A Nanofluid is a dilute liquid suspension of particles with at least one critical dimension smaller than ~100 nm. A Nanofluid is the promising heat and mass transfer medium in which nanoparticles are dispersed. It is known that the thermal conductivity of the nanofluids is considerably higher than that of the corresponding base fluids. The enhancement depends on several factors such as particle shape, particle size, volume fraction of particles, and thermal properties of solid and liquid. Researches so far suggest that nanofluids offer excellent heat transfer enhancement over conventional base fluids. However due to the wide variety and the complexity of the nanofluid systems, no agreement has been achieved on the magnitude of potential benefits of using nanofluids for heat transfer applications. Evaluation of cooling efficiency, i.e. ability to remove heat from the heat source, includes assessing contributions from thermal conductivity, viscosity, specific heat, and density of the fluid and also depends on the applied flow regime. The studies devoted to evaluation of the heat transfer performance of nanofluids are scarce and inconclusive compared to the studies on the thermo-physical properties of various nanofluids indicating a significant gap between fundamental research and practical applications of nanofluids for thermal management.

3. Types of nanofluids

The range of potentially useful combinations of nanoparticle and base fluids is enormous. Nanofluids can be classified broadly by the type of particles into four groups: ceramic, pure metallic, alloy, and some allotropes of carbon or carbon-based nanofluids.

4 .Preparation of nanofluids

Nanofluids made from metals, oxides, carbides and carbon nanotubes can be dispersed in heat transfer fluids, such as water, ethylene glycol, hydrocarbons, and fluorocarbons with the addition of stabilizing agents. Nanoparticles can be produced from several processes, such as gas condensation, mechanical attrition or chemical precipitation . The particles can be produced under cleaner conditions and their surface can be protected from undesirable coatings during the gas condensation process. There are two primary methods to prepare nanofluids: A two-step process in which nanoparticles or nanotubes are first produced as a dry powder. Chemical vapour deposition has also been used to produce materials for use in nanofluids, particularly multiwalled carbon nanotubes. The nanoparticles or nanotubes are then dispersed into a fluid in a second processing step. Simple techniques such as ultrasonic agitation or the addition of surfactants to the fluids are sometimes used to minimize particle aggregation and improve dispersion behaviour.

5. Thermal conductivity of nanofluids

Maxwell initiated a novel concept of dispersing solid particles in base fluids to break the fundamental limit of HTF having low thermal conductivities. Most of these earlier studies on this concept used millimeter or micrometer solid particles, which led to major problems such as rapid settling of the solid spherical particles in the fluids, clogging in micro channels and surface abrasion. In addition, the high pressure drop caused by these particles limited their practical applications. Low thermal conductivity of conventional fluids improves when the solid particles are added. However the magnitudes of the effects reported in the literature are scattered from few percent (as predicted by effective medium theory (EMT)) to hundred percents per volume fraction of nanoparticles (i.e. abnormal enhancements). Increasing the flow rate of working fluid (or equally Re) enhances the heat transfer coefficient for both pure water and nanofluid considerably. It seems that the increase in the effective thermal conductivity and the variations of the other physical properties are not responsible for the large heat transfer enhancement. Brownian motion of nanoparticles may be one of the factors in the enhancement of heat transfers. Although there are recent advances in the study of heat transfer with nanofluids, more experimental results and theoretical understanding of the mechanisms of the particle movements are needed to explain heat transfer behavior of nanofluids.

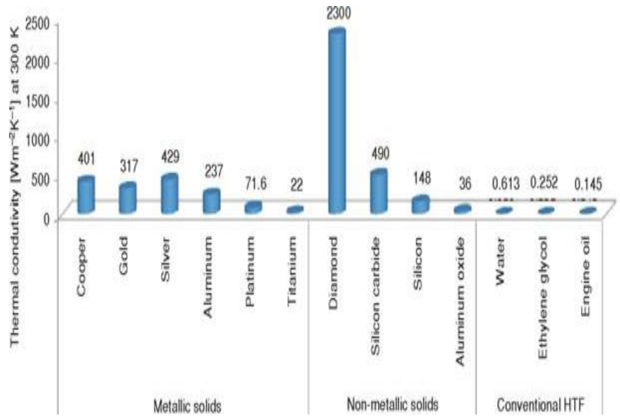

Fig : Thermal conductivity of Metals

Reference	Base fluid	Nanoparticle	Temp.	Size in nm	concentra- tion [vol.%]	Enhance - ment ratio of k [%]
Masuda	Water	$A1_2O_3$	31.85 ºC	13	1.3-4.3	1.109-1.32
			46.85 ºC	13	1.3-4.3	1.1-1.296
			66.85 ºC	13	1.3-4.3	1.092-1.26
	Water	SiO_2	46.85 ºC	13	1.1-2.3	1.01-1.01
			66.85 ºC	13	1.1-2.4	1.005-1.00
	Water	TiO_2	31.85 ºC	13	3.25-4.3	1.08-1.10
			46.85 ºC	13	3.25-4.3	1.084-1.10
			86.85 ºC	13	3.1-4.3	1.075-1.09

Table 1. Summary of the maximum measured thermal conductivity enhancement fornanofluids containing nanoparticles

Ref.	Base fluid	Nano particle	Size of nano particle	Maximum concentrate -ion [vol.%]	Maximum enhancement in k[%]
Masuda	Water	$A1_2O_3$	13nm	4.3	30
Wang	Water	$A1_2O_3$	28nm	4.5	14
	Ethylene glycol	$A1_2O_3$	28nm	8	40
	Pump oil	$A1_2O_3$	28nm	7	20
	Engine oil	$A1_2O_3$	28nm	7.5	30
	Water	CuO	23nm	10	35
	Ethylene glycol	CuO	23nm	15	55
	Ethylene glycol	CuO	18.6nm	4	20
	Pump oil	$A1_2O_3$	60nm	5	40
Murshed	Water	TiO_2	15nm	5	33

Table 2. Enhancement of thermal conductivity influenced by change in temperature

6. Effects of Some Parameters on Thermal Conductivity of Nanofluids

- Particle Volume Fraction
- Particle Material
- Particle Size
- Particle Shape
- Particle Material and Base Fluid
- Temperature
- Effect of Acidity (PH)

7. Effect of temperature on thermal conductivity of nanofluids.

Change of temperature affects the Brownian Motion of nanoparticles and clustering of nanoparticles, which results in dramatic changes of thermal conductivity.

8.Advantages

- Abnormal Rise in Thermal Conductivity
- Tremendous increase in Viscosity
- Unbelievable Stability
- Microchannel cooling without Clogging
- Reduced chances of erosion
- Reduced friction coefficient
- Cost & Energy saving
- Environmental control & cleanup

9.Applications

- Heat transfer in microelectronics
- Pharmaceutical processes
- Hybrid-powered engines
- Engine cooling
- Domestic refrigerator
- Nuclear reactor coolant
- Grinding machining
- Space technology

Boiler flue gas temperature reduction

10.Case studies

i. Masuda *et al* dispersed Al_2O_3 nanoparticle of size 13nm in diameter in water with a volume fraction upto 4.3%, and obtained an enhancement in thermal conductivity of up to 30%, and continued experiments with SiO_2 and TiO_2 of particle size 12nm and 27nm with maximum concentrations of upto 2.4 and 4.3%, and obtained thermal conductivity enhancement of upto 15-30%.

ii. Wang *et al* dispersed Al_2O_3 of 8nm particle size with water, Ethylene glycol, pump oil, and engine oil with different concentrations, resulting in the enhancement of 14-30%. Wang *et al* also dispersed CuO of 28nm particle size in both water and ethylene glycol and predicted an enhancement of 35-55%.

iii. Murshed *et al* measured the thermal conductivity of aqueous nanofluids containing both spherical and cylindrical TiO_2 particles. He found that nanofluids containing 15nm spherical nanoparticles showed slightly lower enhancements than those containing 40nm by 10 nm nanorods. As high as 33% enhancement was achieved in nanofluids containing nanorods.

11.Conclusion

- We can conclude that nanofluids are useful in day to day life.
- They are also used in bulk and other microelectronics.
- Ill effects of nanofluids like clustering of nanoparticle, coagulation should be avoided.
- It is seen that there are lot of controversies in the results.
- Still we can conclude that nanofluids thermal conductivity increases with increment in particle volume fraction and temperature.
- The chaotic movement of nano particles increases fluctuation and turbulence of the fluids, which increases the heat exchange process.
- Convective heat transfer coefficient is enhanced by increasing the particle concentration and the Reynolds number.

12.Scope

There is always a chance of development of some new experimental or new numerical methods which can give the new height in this field.

- This research requires examine in various field like synthesis, characterization, thermo-physical properties, heat and mass transport, modelling, and device- as well as system-level applications.
- A number of Nanotechnology products are available and a tremendous amount of researches are still going on in universities, government and research laboratories.
- Nanotechnology applications are being developed that could impact the global market for agricultural, mineral, and other non-fuel commodities. Nanotechnology is described as revolutionary discipline in terms of its possible impact on industrial applications. Nanotechnology offers potential solutions to many problems using emerging nanotechniques.

13. References

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