International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

# Heat Transfer Application of Nanofluids and Testing of Thermal Conductivity

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## Abstract

In response to the growing demand for more efficient heat transfer technologies in various industrial processes, the development of nanofluids has emerged as a promising solution. Traditional heat transfer fluids like mineral oil, ethylene glycol, and water have relatively low thermal conductivities compared to solids, limiting the compactness and efficiency of heat exchangers. Nanofluids, which are created by suspending ultrafine metallic or nonmetallic solid powders in base fluids, exhibit enhanced thermal properties due to the superior thermal conductivities of solid materials. This paper reviews the preparation, thermal conductivity measurement, and influencing factors of nanofluids, with a focus on the thermal conductivity as the primary driver for improved heat transfer. The preparation of nanofluids involves either a one-step or two-step method, with the two-step method being more commonly used for oxide nanoparticles (NPs) such as Al2O3, ZnO, MgO, TiO2, and SiO2. The study discusses the stabilization techniques like ultrasonication and magnetic force agitation to ensure homogeneous suspension and long-term stability of the nanofluids. The thermal conductivity measurements are conducted using short hot wire (SHW) and transient hot wire (THW) techniques, with considerations on the nonsteady-state nature and potential error sources. The research underscores the importance of rigorous experimental design and accurate data analysis to address the complexities and variability in thermal conductivity measurements, ultimately contributing to the advancement of nanofluid technologies for efficient heat transfer solutions.

**Keywords:** Nano fluids , Thermal Conducitvity , Nanoparticles, stability of nanofluids

## 1. INTRODUCTION

Growing heat flow and rapid shrinking are causing an increasing number of efficient heat transfer technologies to be selected. Mineral oil, ethylene glycol, and water are examples of heat transfer fluids that are continuously needed in many industrial processes, including the manufacturing of microelectronics, power generation, chemical reactions, and heating and cooling. The low heat transfer properties of these common fluids in comparison to most solids are one of the key obstacles to the high compactness and efficiency of heat exchangers. One inventive way to increase the thermal conductivities of working media is to suspend ultrafine metallic or nonmetallic solid powders in regular fluids, as most solid materials have superior thermal conductivities than liquids. These days, the word "nanofluid" is quite noticeable in the field of heat transmission. Thermal qualities, including viscosity, specific heat, convective heat transfer coefficient, and critical heat flow, have been the subject of several research.

Many in-depth and comprehensive review papers and books have been written about the thermal transport characteristics of nanofluids. Of all these, thermal conductivity is the one that is most often discussed and is assumed to be the primary component driving enhanced heat transmission. Research on the thermal conductivity of nanofluids has been the main area of interest. The authors have undertaken multiple investigations on the increase of heat transmission capabilities of nanofluids. Numerous nanofluids have been produced using the one- or two-step technique. The basis fluids that are used are deionized water (DW), ethylene glycol (EG), silicone oil, glycerol, and the binary mixture of DW and EG (DW-EG). Al2O3 NPs in different sizes, SiC NPs in different forms, MgO NPs, ZnO NPs, SiO2 NPs, Fe3O4 NPs, TiO2 NPs, diamond NPs (DNPs), and carbon nanotubes (CNTs) with different pretreatments have all been used as additives. The thermal conductivities of these nanofluids have been assessed using the short hot wire (SHW) methodology or the transient hot wire (THW) approach.One of the hardest problems that thermal engineers always deal with is improving heat transmission[1].Technology development has led to an ongoing increase in the need for more efficient heat transmission from smaller spaces or across lower temperature differences. Consequently, several methods for improving heat transfer have been proposed over the years. These methods can be broadly divided into two groups: active and passive. Active approaches need more maintenance and extra power even though they are more controllable and efficient.

When compared to solid metals, the thermal conductivity of the majority of heat transfer fluids is orders of magnitude lower. The thermal conductivity of the resulting fluids increases when micro- or milli-sized solid metal or metal oxide particles are added to the base fluids. However, there are several issues when there are milli- or micro-sized particles present in a fluid. They tend to settle down and do not establish a solid solution. In addition to being used in the heat transfer industry, nanofluids can be created for specialized uses in the fields of biology, chemistry, electrical, and magnetic fields. A fluid that contains suspended nanoparticles, creating a stable colloid and a quasi-single phase medium, is referred to as a nanofluid. At least one of the critical dimensions of the nanoparticles scattered in the nanofluids must be less than or equal to 100 nm, which is one of the most crucial requirements [2].

## 2. PREPARATION OF NANOFLUIDS

In our research, we have utilized both one-step and two-step methods to create nanofluids. The two-step method was used to prepare the majority of the nanofluids under study. The two-step methodology involves first preparing the dispersed NPs using chemical or physical means, and then adding the NPs to a designated base fluid—with or without pretreatment and surfactant, depending on the situation. A one-step procedure was used to prepare the nanofluids containing metallic NPs.The method for creating nanofluids with oxide NPs, such as Al2O3, ZnO, MgO, TiO2, and SiO2 NPs, was rather straightforward. The NPs were mixed with a base fluid in a mixing container after being purchased commercially. After mixing the NPs with the base fluid, they were deagglomerated using intense ultrasonication, and the suspensions were subsequently homogenized using magnetic force agitation.The method for creating nanofluids with oxide NPs, such as Al2O3, ZnO, MgO, TiO2, and SiO2 NPs, was rather straightforward. The NPs were mixed with a base fluid in a mixing container after being purchased commercially. After mixing the NPs with the base fluid, they were deagglomerated using intense ultrasonication, and the suspensions were subsequently homogenized using magnetic force agitation.The most important stage in using nanoparticles to increase fluids' thermal conductivity is creating nanofluids. Two different techniques have been used to create nanofluids. Two steps are involved in one approach, while one is done in one step [3]. The addition of nanoparticles to nanofluids is a significant factor in modifying the fluids' thermal transport characteristics. Currently, a variety of nanoparticle forms, including metallic and ceramic forms, have been employed [4].

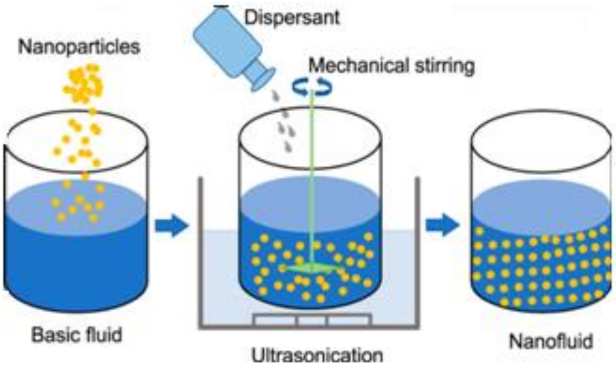


**Figure-1Nanofluids Process**

A stable Fe3O4 magnetic nanofluid based on kerosene was created using the phase transfer method. Fe3O4 NPs are first created in water through coprecipitation. The NPs were changed by adding oleic acid. The phase transition process occurred naturally when kerosene was added to the mixture while stirring slowly. The aqueous and kerosene phases had a clear phase interface. Following the aqueous phase's removal with a pipette, kerosene-based Fe3O4 nanofluid was produced. The direct chemical reduction approach was used to create nanofluids containing copper nanoparticles. Following the addition of poly(vinylpyrrolidone) (PVP), stable nanofluids were produced. The chemical reduction process yields copper nanoparticles (NPs) with dimensions between 5 and 10 nm. These particles diffuse easily and do not exhibit obvious aggregation.

## 3. CONSIDERATION OF THE THERMAL CONDUCTIVITY MEASUREMENT

The examination of particulate matter's thermal conductivity, with a focus on low air pressures,and a reliability review of previously published data. The benefits, drawbacks, and error sources of steady-state and nonsteady-state thermal conductivity measuring techniques are discussed. In general, nonsteady state techniques are easier to use and more effective [5].The intricacy of heat transport in nanofluids is demonstrated by the recurrent emergence of contentious debates and inconsistent experimental results from various groups studying nanofluids. Investigations have shown that the experimental data that have been made available in the public domain exhibit a significant amount of randomness and scatter. It is impossible to create a compelling and all-inclusive physical-based model that can anticipate every trend given the inconsistent facts. It is preferable to screen the measuring technique and procedure to ensure the accuracy of the obtained data in order to dispel any doubts regarding the disparate and broad experimental results of the thermal conductivity obtained by various groups.The "time-dependent characteristic" of thermal conductivity was noted by several researchers; in other words, thermal conductivity peaked immediately following the creation of the nanofluid and subsequently significantly declined with time. We think that the "time-dependent characteristic" is not the fundamental property of nanofluids' ability to conduct heat.

A nanofluid is always subjected to intense agitation, including magnetic stirring and sonication to break up the aggregation of the suspended NPs, in order to make it homogenous and long-term stable. The NPs continue to move in the base fluid in a relatively short amount of time following the production of the nanofluid (unlike Brownian motion). Convection would result from the remaining particle's motion, which would improve the nanofluids' ability to transmit energy. Secondly, the temperature of a nanofluid would rise during prolonged sonication. The temperature gradually drops to the ambient temperature or the temperature used for measuring thermal conductivity.In conclusion, a number of techniques have been explored and shown for determining a bulk solid-state material's thermal conductivity experimentally. The apparatus's experimental design and the analysis of the obtained data require great care. Along with concerns about the proper heat sinking of the sample and matching measurement lead wires, questions pertaining to comprehending loss words like radiation or heat conduction were covered [6].

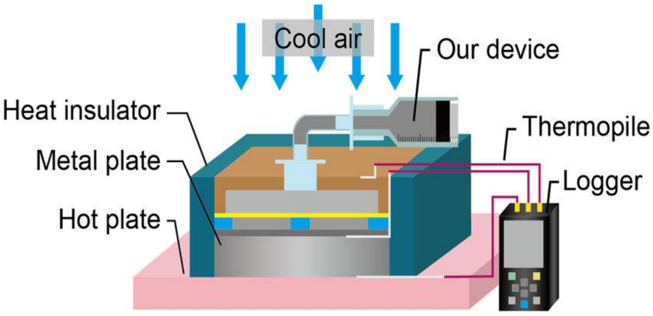


**Figure: 2 Thermal conductivity measurements**

## 4 . INFLUENCING FACTORS OF THERMAL CONDUCTIVITY ENHANCEMENT

Experiments have found that the volume fraction of dispersed nanoparticles can be affected by many factors, such as temperature, thermal conductivity of the base liquid, size of dispersed nanoparticles, pretreatment methods, and liquid additives. Scientific Research This explains the effects of various factors.

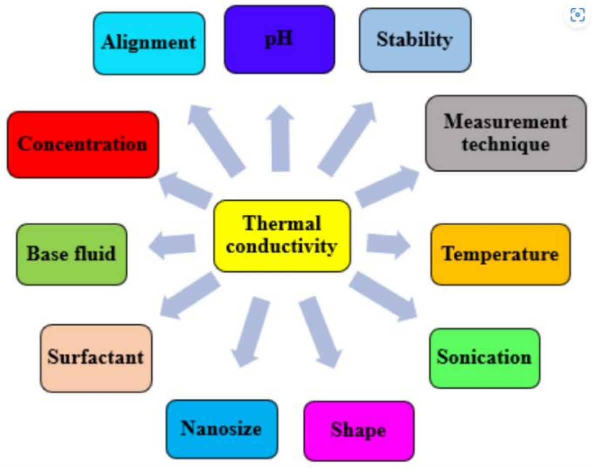


**Figure-3 Affected Thermal Conductivity**

### 4.1 Particle Loading-

The fact that solids have higher thermal conductivity than liquids gives rise to the idea of using nanofluids. For example, the thermal conductivity of water, the most popular heat exchanger, at room temperature is 0.6 W/m K, but the thermal conductivity of copper is more than 400 W/m - K. Particle loading. As expected, adding an appropriate amount of nanoparticles to the base fluid can increase the thermal conductivity of the nanofluid.Graphene is a one-atom-thick; flat sheet of sp2-bonded carbon atoms tightly packed in a honeycombshaped lattice. When graphite is chemically oxidize d using strong oxidants, the perfect structure of graphene is disrupte.There is no doubt that the defect reduces the thermal conductivity and the defect directly affects the transport of the 2D structure.

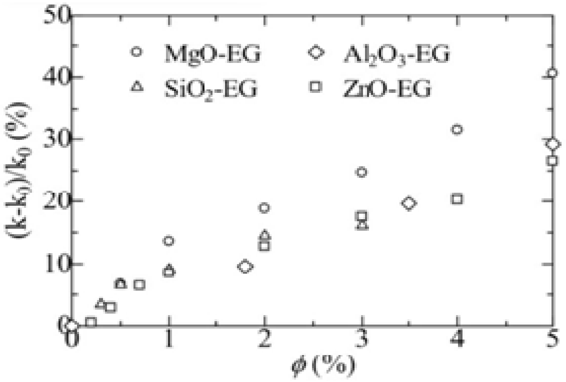


Figure: 4 Results of different Nano fluids (A)

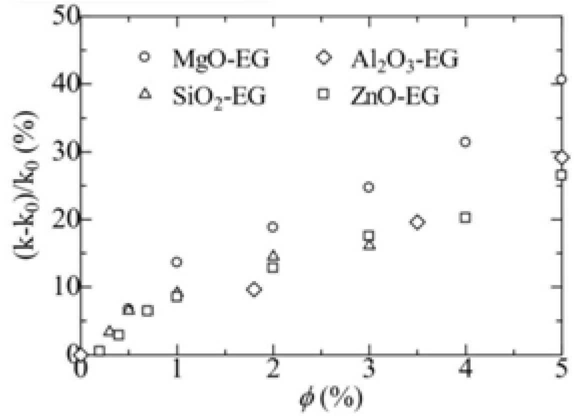


Figure: 5 Results of different Nano fluids (B)

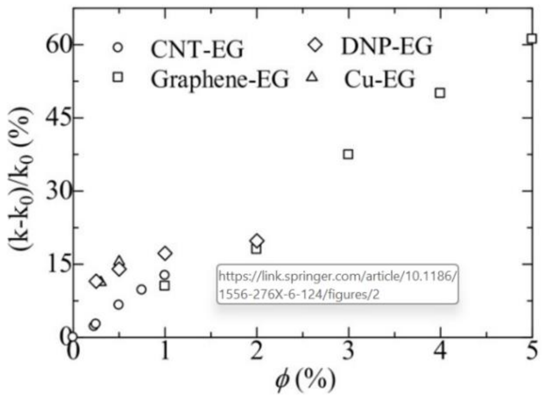


Figure : 6 Results of different Nano fluids (C)

### 4.2 Temperature

Research shows that temperature affects the thermal conductivity of nanofluids. However, there is much debate in the literature regarding their thermal conductivity as a function of temperature. For example, Das et al found that waterbased $Al_2O_3$ and CuO nanofluids have temperaturedependent thermal conductivity. FC72 and nanofluids containing $Bi_2Te_3$ nanorods in oil were tested to see whether the improvement in thermal conductivity decreases with temperature. The thermal conductivity of EGbased $Al_2O_3$ nanofluids was studied by Micael et al. At temperatures between 298 and 411 K.The thermal conductivity of EG nanofluid containing MgO, ZnO, $SiO_2$ and graphene nanoparticles almost improves and remains cons tant when the temperature changes (see Figure 2a). This shows that the thermal conductivity of the nanofluid changes to a liquid basis above the temperature examined. The behavior of the thermal conductivity of DWEG based nanofluids with graphene nanoparticles, MgO, ZnO, SiO2, Al2O3, Fe2O3 and TiO2 seems similar.Large cylindrical nanotube samples for EGbased CNT nanofluids. Brownian motion is less efficient. Most models use the formula (k - k0) / k0 for efficiency regardless of temperature. On the other hand, the data in Figure 2b show that (k0)/k0 increases with temperature, although not much. The changes can be explained by changes in carbon nanotube aggregation.

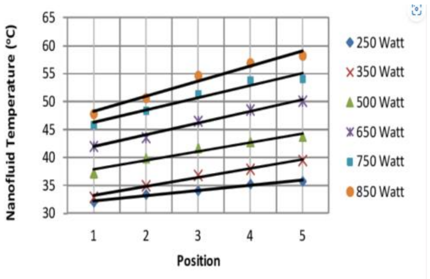
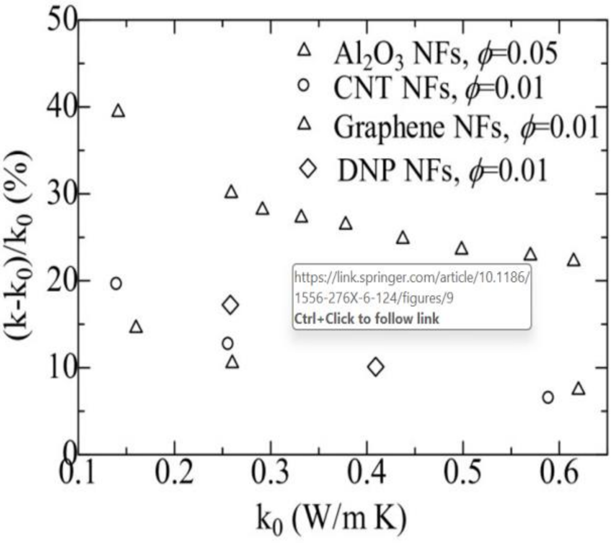


Figure : 7 Results of different Nano fluids (C)

The increase in thermal conductivity will vary depending on temperature. Cu-EG, CNT-EG, and DNP-EG are examples of non-oxide nanofluids. (a) Oxide nanofluids: MgO-EG, ZnO-EG and graphene-EG.

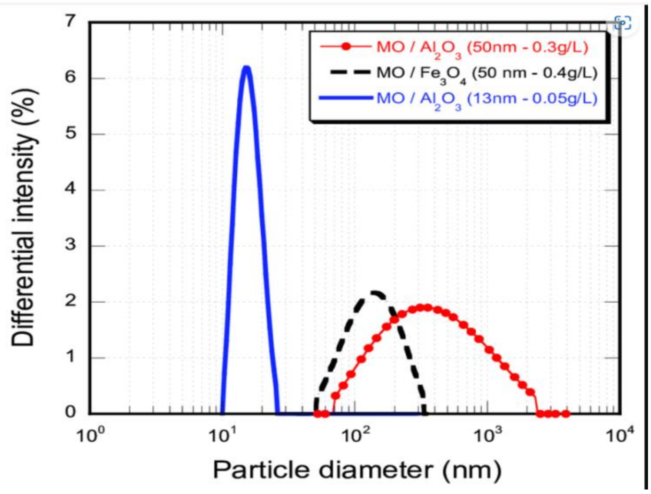
**4.3 Base Fluid**

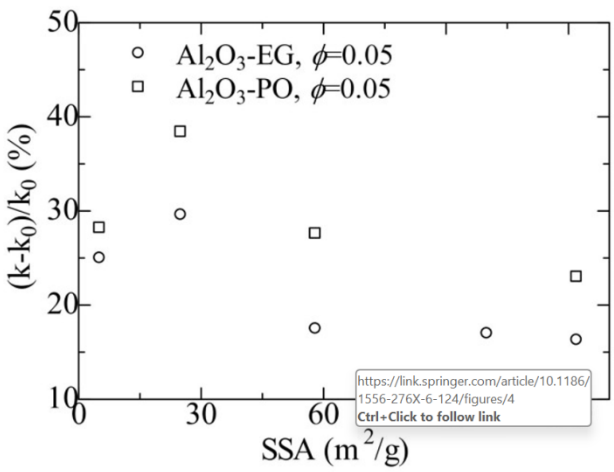
Regardless of the type of nanoparticles used, the improvement in thermal conductivity decreases when the thermal conductivity of the liquid base increases. Compared with pump oil (PO), the thermal conductivity of Al2O3 nanofluid with 5.0% nanoparticle loading can be increased by more than 38%. When water is used instead of the liquid base, the increase in thermal conductivity is only around 22.0%.For base fluids with low thermal conductivity, a larger and significant improvement in the thermal conductivity of carbon nanotube nanofluids was observed. Regardless of the base fluid used, the improved thermal conductivity of CNT nanofluids was greater than that of Al2O3 nanoparticle suspensions with the same volume fraction. This is mainly due to the significant difference in shape and thermal conductivity between carbon nanotubes and alumina nanoparticles.

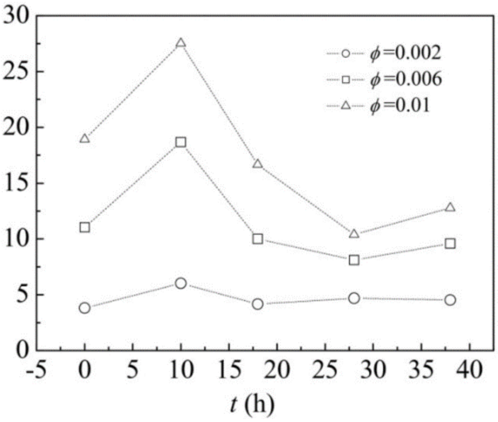


### 4.4 Particle Size-

With a rise in the SSA, the thermal conductivity enhancement is observed to grow first, and then to decrease. The maximum thermal conductivity is observed at a particle SSA of 25 m2 â€ ¢ g-1. We attribute the behavior of the change in thermal conductivity to two causes. First, the particle's SSA increases proportionately with decreasing particle size. At the particle-fluid contact, heat transmission between the particle and the fluid occurs. Because a reduction in particle size might produce a high interfacial area, a substantial gain in thermal conductivity is anticipated. Second, the estimated mean free path in polycrystalline Al2O3 is around 35 nm, which is in line with the particle size that was employed. The Al2O3 particle's intrinsic thermal conductivity at the nanoscale could.







Effect of grinding time on improving the thermal conductivity of floating carbon nanotubes in nanofluis.

### 4.5 Ph Value

The increase in thermal conductivity of some nanofluids is directly affected by the pH of the suspension. Improved thermal conductivity. The properties of the particle surface determine the overall behavior of nanoparticles at the particle-liquid interface as they diffuse into the liquid base. The isoelectric point (pHiep) of Al2O3 particles is 9.2; this means that at this pH there is no interaction between the particles and they will aggregate together

## CONCLUSION

The thermal conductivity of various nanofluids containing different fluids and nanoparticles. Through careful analysis of factors such as particle charge, temperature, fluid base, particle size, pretreatment method, and pH, important information is obtained regarding the complex behavior of nanofuids in improving heat transfer. It is the main effect of particle loading on the improvement of Thermal conductivity(TC). The addition of nanoparticles to the base fluid leads to important developments that reveal the potential of nanofluids as energy transfer materials. It has also been shown that temperature plays an important role, with different effects depending onthe composition of the nanofluid and the type nanoparticles used. While some base fluids show more improvement, the yields of some may decrease as their thermal conductivity increases.

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