

THERMAL CONDUCTIVITY ENHANCEMENT AND IMPROVEMENT OF STABILITY OF NANOPARTICLES BY SURFACTANT IN HEAT TRANSFER FLUIDS

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Mechanical engineering

By

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DECLARATION

We M THULASI RAM (37150111) and R MANJUNATHA REDDY (37150151) hereby declare that the Project Report entitled **“THERMAL CONDUCTIVITYENHANCEMENT AND IMPROVEMENT OF STABILITY OF NANOPARTICLES BY SURFACTANT IN HEAT TRANSFER FLUIDS”** done by us under the guidance of Dr.G.SENTHILKUMAR M.E. Ph.D.at SATHYABAMA Institute of Science and Technology, Chennai is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical engineering

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bon work of M THULASIRAM(37150111), R MANJUNATHA REDDY(37150151) who carried out the project entitled “**THERMAL CONDUCTIVITY ENHANCEMENT AND IMPROVEMENT OF STABILITY OF NANOPARTICLES BY SURFACTANT IN HEAT TRANSFER FLUIDS**” under our supervision fromFebruary 2020 to March 2021.

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ABSTRACT

Use of Nanofluids is widely adopted to enhance the thermal performance of conventional fluids. Numerous experiments have been done on Nanofluid to increase the heat transfer in which different nanoparticles and base fluids are selected. Here, three different nanoparticles Titanium dioxide (TiO_2), Magnesium oxide (MgO), Copper oxide (CuO) with 1-5% by volume are introduced in different base fluids to make Nanofluids, and then thermal property of Nanofluid is inspected. Two distinct correlations are used to investigate the thermal property of Nanofluids of which one is theoretical and other is experimental. Results are compared with both the correlations. Also, it is observed that increasing the concentration of nanoparticles increases the thermal conductivity of Nanofluids.

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LIST OF SYMBOLS AND ABBEREVIATIONS

MEMS	Micro-Electro-Mechanical Systems
ANL	Argonne National Laboratory
THW	Transient hot-wire
IGC	Inert-gas condensation
DEC	Direct evaporation condensation
Nu	Nusselt number
TiO ₂	Titanium dioxide
CO	Copper oxide
MgO	Magnesium oxide
mV	Millivolts
DL	Double interfacial layer (DL)
EG	Ethylene glycol
pH	Potential of hydrogen

CHAPTER 1

INTRODUCTION

1.1 HISTORY AND BACKGROUND OF NANOFLUIDS

The exponential growth of these technologies and their devices through reduction and an improved rate of operation and storage of data has brought about thoughtful problems in the thermal management of these devices. Another important area that has experienced an identical problem in thermal management is that the area of optical devices. The increasing power of these devices with decreasing size also calls for innovative cooling technology. Microscale heat transfer is an area of research that has been effectively revised by texts such as those by "Duncan and Peterson" and "Majumdar" et al. However, all of those texts indicate that the traditional fin-and-microchannel technology appears to be inadequate for the new generation of electronic and optical devices. Choi et al. micro-channel heat exchangers have shown that power densities of 2000 W/cm^2 can be managed that use subcooled liquid nitrogen. An increasing number of studies on microchannel boiling, like those by "Kandlikar", "Bergles et al", and "Thome et al", also indicates the necessity for an alternate thanks to cool micro-size devices. The advent of nanotechnology and Micro-Electro-Mechanical Systems (MEMS) has only intensified this need, asking for a revolution in cooling technology to keep pace with the new revolution in device technology.

It's important to note, however, that miniaturized devices aren't the only ones looking for new cooling solutions. Large devices (such as transportation trucks) and modern energy technologies (such as fuel cells) necessitate more powerful cooling systems with higher cooling capacities and smaller dimensions.

Thus, whether large or small, modern and improved cooling technology is the order of the day. This demand must be met in two ways: by developing new cooling devices, such as microchannels and miniature cry devices, and by improving the fluid's heat transfer capability. The second choice is the subject of this study.

Nanofluids are made by mixing nanoparticles with base fluids in a traditional way. Before delving into the nitty gritty of nanofluids and their thermodynamic potential in

cooling technology, it's important to understand the fundamentals of nanofluids. Many studies of the thermal properties of liquids used as coolants show that they have a very low thermal conductivity. (with the exception of liquid metal, which can't be used at the most of the pertinent useful temperature ranges). For example, Water as a base fluid has a low heat transfer capacity from high to low, whereas Grace lubricating liquids are used in engines. It goes without saying that any attempt to increase heat transfer by increasing turbulence, increasing area, or other means would be constrained by the fluid's inherent thermal conductivity. As a result, it's only natural that attempts would be made to raise the bar. Using the suspension of solids is an option that came to mind quite a century ago. Maxwell was a pioneer during this area who presented a theoretical basis for calculating the effective thermal conductivity of suspension. His efforts were followed by numerous theoretical and experimental studies, like those by Hamilton-Crosser and Wasp. These models work very well in predicting the thermal conductivity of slurries. However, all of these studies and testing carried out are very less because of high price nanoparticles is the major disadvantage.

1. The particles settle quickly, forming a layer on the surface and reducing the heat transfer capacity of the fluid.
2. If the circulation rate of the fluid is increased, sedimentation is reduced, but the erosion of the heat transfer devices, pipelines, etc., increases rapidly.
3. The large size of the particles tends to clog the flow channels, particularly if the cooling channels are narrow.
4. The pressure drop in the fluid increases considerably.
5. Finally, conductivity enhancement based on particle concentration is achieved (i.e., the greater the particle volume fraction is, the greater the enhancement—and greater the problems, as indicated in 1–4 above).

As a result, the method of suspending particles in liquid was a well-known but rejected alternative for heat transfer. However, the advent of nanofluids aided in the reconsideration of this alternative. Modern materials science has made it possible to create nanometer-sized particles that are mechanically, thermally, electrically, and optically distinct from the parent material. Thus, nanofluid technology coupled with new heat-transfer-related studies on microchannel flow has provided a new option of

revisiting suspensions of nanoparticles. The first proposition in this area was from Argonne National Laboratory (ANL) through the seminal work of Choi, who designated the nanoparticle suspension a nanofluid. From a purist's point of view, this designation may not be acceptable every fluid is “nano” because of its molecular chains but the term has been accepted and become popular in the scientific community. It must be kept in mind that biologists have been using the term nanofluid for different types of particles, such as DNA, RNA, proteins, or fluids contained in nanopores

The large surface area, low particle momentum, and high mobility of nanoparticles made them attractive candidates for suspension in fluids. Starting with copper, one may progress to Magnesium oxide, Copper oxide, Titanium Dioxide, which have 20,000 times the conductivity of engine oil at room temperature.

When the particles are properly dispersed, these features of nanofluids are expected to give the following benefits:

1.1.1 Higher heat conduction

The large nanoparticle surface area allows more heat transfer. Particles less than 20 nm contain 20% of their atoms and are available in CAM for thermal interaction at an instant. The mobility of the particle due to its small size is another advantage, which can lead to fluid transmission and thus an increased heat transfer. The micro convection and heat transfer can also increase heat distribution in the fluid at a faster rate. The thermal conductivity of nanofluids has already been found to increase significantly with an increase in temperature, which could be attributed to the above reasons.

1.1.2 Stability

Since the particles are thin, they weigh less and are therefore less likely to sediment. This decreased sedimentation can solve one of the main disadvantages of suspension, particle settlement and stabilize nanofluids.

1.1.3 Microchannel cooling without clogging

Nanofluids are not only a safer medium for heat transfer in general, they are also suitable for applications on microchannels that have heavy heat loads. The combination of the microchannels and nanofluids provides a large heat transfer region and highly conductive fluoride. This cannot be achieved by meso- or micro-

particles, because microchannel are blocked by them. Smaller orders of magnitude have nanoparticles, which are just a few hundred or thousands of atoms.

1.1.4 Reduced chances of erosion

Nanoparticles are very thin and they are much smaller in their velocity than a solid wall. This decreased momentum decreases the likelihood that components like heat exchangers, pipelines and pumps.

1.1.5 Reduction in pumping power

Pumping power must usually be increased by a factor of ten to increase the heat transfer of traditional fluid by a factor of two. It has been demonstrated that increasing the conductivity by a factor of three doubles the heat transfer in the same apparatus. Unless there is a significant increase in fluid viscosity, a moderate increase in pumping power will be needed. Thus, a very large savings in pumping power can be achieved if a large thermal conductivity increase can be brought about with a small volume fraction of particles.

Nature, more often than not, proves to be more thrilling than imagination. Henry Becquerel believed that uranium ore absorbs light and then radiates it back until he discovered radioactivity, which radiates without any light absorption. Similarly, the first test with nanofluids revealed more promising characteristics than previously believed. The four distinct characteristics observed are described below.

Thermal conductivity is abnormally enhanced. The most striking characteristic of nanofluids was an abnormal increase in thermal conductivity that was much higher than expected and predicted by any theory. Stability is essential. Using a stabilizing agent, nanofluids have been stated to be stable for months.

Newtonian action and a small concentration with a very limited concentration of particles, a large increase in conductivity was achieved while maintaining the fluid's Newtonian behavior. Since the increase in viscosity was nominal, the pressure drop was only slightly increased. The size of the particles has an effect. Unlike the situation with micro- slurries, the enhancement of conductivity was found to depend not only on particle concentration but also on particle size. In general, a decrease in particle size was associated with an increase in

enhancement. The above potentials provided the impetus needed to begin nanofluid research, with the hope that these fluids would play a key role in the development of the next generation of cooling technology. The end result may be a nanofluid that is both highly conducting and stable, with exciting new applications in the future. Before delving into how many of these dreams have been realized as a result of the preliminary findings, it's important to note that this field of study is interdisciplinary, involving contributions from chemistry, mechanical and chemical engineering, physics, and material science; therefore, it's worth delving into the specifics of not only applications but also synthesis and characterization. Ceramic nanofluids were the first type of nanofluid investigated by the ANL group. The first major publication in this area presented conductivity measurements on fluids that contained TiO_2 , MgO and CuO nanoparticles in water and ethylene glycol. Conductivity was measured by the traditional transient hot-wire (THW) method. The results clearly indicated that the thermal conductivity enhancement of the TiO_2 , MgO and CuO nanofluids were high. They used volume fractions of only 1– 5%. The enhancement was higher when ethylene glycol was the base fluid. An enhancement of 20% was observed at 4% volume fraction of CuO . The enhancement when water was the base fluid was lower but still substantial, with 12% enhancement at 3.5% CuO , and 10% enhancement with 4% TiO_2 , MgO . (shows the original publication's measurements). These results were high when compared with the model for suspensions proposed by Maxwell, which was improved in 1962 to include the effect of particle shape. These models predict the effective thermal conductivity as essentially a weighted average of solid and liquid conductivity derived from a point source method. The original Maxwell model reads as follows:

Even though stainless steel has a higher corrosion resistance than other metals, it still corrodes when exposed to an aggressive environment. Despite the broad range of stainless-steel grades available, SS-304 is one of the most widely used due to its applications in chemical processing units, nuclear reactors, the medical industry, the marine climate, and the power industries. The high melting point of stainless steel (on the order of 1500°C) makes it ideal for use in high-temperature applications. Nickel is one of the best coating materials for coating over the

substrate because of its high thermal and corrosion resistance and the fact that it imparts a non-magnetic structure to the substrate. Copper and silver were used in the majority of the applications because they have high electrical and thermal conductivity as well as good corrosion resistance. Cupronickel (Ni-Cu) alloys have increased tensile strength, high resistance to macro fouling, and improved ductility after heat treatment, allowing them to be used in a variety of heat exchange processes. Silver is an excellent antibiotic as well as a radiation-resistant material. Toxin toxicity can be reduced when they come into contact with silver. In marine assemblies, Ni-Ag was widely used. Ni-Ag coatings were applied to SS-304 substrates in our experiment to enhance antimicrobial activity. The focus of the study is on the field of marine application and there is a formation of silver nano particles from silver due to the sponges and marine plants. Hence it is suggested to experiment Ni-Ag coating over the substrate in order to minimize the degradation issues. The microstructure and corrosion behavior of Ni-Ag and Ni-Cu composite coatings were studied across 25Ni-50Cu, 25Ni-50Ag, 10Ni-50Cu and 10Ni-50Ag combinations over SS-304 as base material. Huang et al. (2004) proposed that the presence of sulfate reducing bacteria (SRB) accelerated the corrosion rate of the 70/30 Cu-Ni alloy due to the formation of a poor protective cuprous sulfide layer on the metal surface. In his results it was evident that copper showed comparatively less resistance to corrosion in sea water environment. S. J. Yuan et al (2004) worked on the influence of the marine aerobic pseudomonas strain on the corrosion of 70/30 Cu-Ni alloy. Both the charge transfer resistance R_{ct} , and the resistance of the porous oxide film R_{po} , decreased with exposure time, indicating an acceleration of corrosion due to the marine bacteria. Bacteria attached to the alloy surface were found to form blotchy biofilms, as observed by fluorescent microscopy. These results show how Ni-Cu alloy behavior

1.2 CERAMIC NANOFLUIDS

The first kind of nanofluid investigated by the ANL community were ceramic nanofluids. Conductivity measurements for liquids containing Al_2O_3 and CuO nanoparticles in water and ethylene glycol have been presented in the first major publication in this field. The Transient hot-wire (THW) system was used to calculate the conductivity. The findings showed specifically that Al_2O_3 and CuO nanofluids were higher in their thermal conductivity. They used only 1–5% volume

fractions. When ethylene glycol was the basic solvent, the improvement was high. At 4 percent of CuO, an increase of 20 percent was observed. The increase in the water content of basic liquids, with a 12% increase at 3.5% CuO, and a 10% improvement at 4% Al₂O₃, is smaller but still important. Compared with the suspension model that Maxwell proposed, which was enhanced in 1962 to take the impact of particulate form into account, these results were strong. These models estimate the effective thermal conduction as a weighted average conductivity of solid and liquid products from a point source system. The original model of Maxwell reads:

$$\frac{k_{eff}}{k_f} = 1 + \frac{3(k_p/k_f - 1)\phi}{(k_p/k_f + 2) - (k_p/k_f - 1)\phi} \quad --(1)$$

whereas the Hamilton-Crosser model reads as

$$\frac{k_{eff}}{k_f} = \frac{k_p + (n-1)k_f - (n-1)\phi(k_f - k_p)}{k_p + (n-1)k_f + \phi(k_f - k_p)} \quad --(2)$$

The key explanation for the numerous studies on oxide nanoparticles is that oxide nanoparticles are accessible. Murshed et al. Measuring spherical and cylindrically-formed TiO₂ nanoparticles' thermal conductivity found that the marginally lower enhancement of 15 nm-size spherical particles compared to 10 to 40 nm rods was observed with a 33 percent increase for a volume fraction of 5 percent. However, the change was even more than the Hamilton-Crosser model expected. The nonlinear dependency of improving thermal conductivity on the particle concentration at lower volume fractions was another characteristic of this work.

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

Liquids in heat transfer equipment are also used as heat carriers. The thermal conductivity of heat transfer fluids plays an important role in the construction of energy-efficient heat transfer equipment and its numerous applications. Due to growing global competition, industry needs advanced heat transfer fluids with considerably greater thermal conductivity than is currently available to produce (Stephen, Choi and Eastman, 1995). As shown in the table, the more commonly used fluids like water, ethylene glycol and oil have comparatively limited heat conductivity. New approaches to improve the heat transfer are to use new liquids called "nano-fluids." The nanofluids are colloidal, metal nanoparticle suspended nanometrically in a base liquid the concept of using metallic particles to improve fluid thermal conductivity is not new. Knowing that solid-shape metals had a much higher thermal conductivity compared with fluids, Maxwell (1873) initially suggested that metal particles be used to improve fluid thermal properties. After this several tests were carried out, millimeter and meter particles were dispersed into liquids. However, these vast particles had many challenges, such as sedimentation of particles, passage blocking, erosion and decrease in high pressure. However, the latest advancement of nano Technology opened the way to revisit Maxwell's concept through the use of particles nanometrically (a billionth of a meter) (Mohammed & others, 2011).

Compared with the current heat transfer methods, nanofluids are expected to be better suited for practical application by adding millimeter and/ or micrometer-size particles to the fluids and with low or no pressure decrease, since the nanoparticles

are so thin, as a pure fluid. Increased turbulence or eddy, suppression or disruption of the boundary layer as well as the dispersion or remixing of the nano-particles suspended, in addition to significantly increase the heat conductivity and heat power of this fluid, are predicted to be major factors of the heat transfer improvement for nanofluids. The heat transfer coefficient in convective nanofluids therefore functions according to the characteristics, dimensions, and volume of the nanoparticles suspended, and the flow rate.

2.1.1 study of properties nanofluids

Eastman et al (2004) gives a good idea about nanotubes and function of the contact resistance in thermal nanofluid transport, in addition to solving thermal conductivity problems and additional nanofluid characteristics. The thermal conductivity of metallic nanoparticles seems to be improving anomaly, and very significant improvement at a low volume. The improvement of the thermal conductivity of fluids by oxide nanoparticle-based nanofluids is comparatively less promising. There seems to be disagreement regarding efforts in order to include specific motion in Brownian motion, and these efforts must be checked, especially as regards the temperature effect. The particles carry some heat and contribute to the overall heat transfer through agitation in the liquid.

A numerical analysis was submitted by **Purohit et al.** (2015), which included three MgO/water and TiO₂/water and a laminar convective heat transfer in a circular channel. It has been shown that the heat transfer increase for all three nanofluids ranged from 8–30 per cent, but this improvement has not been shown if tests with the same mass flow and discharge rate was carried out. The Author has also suggested that nanofluids have demonstrated a greater increase in heat transfer when tested on the same basis in Reynolds rather than above.

Li et al. (2015) experimentally studied the thermal transition and lowering pressure properties in transient flow conditions of copper oxide/ethylene glycol-water. The greatest increase in the heat transfer coefficient was 2.5 wt. percent of the nanofluid as compared to the base liquid. Any conflicting conduct was observed that the coefficient of heat transfer was reduced at 5 wt. percent. In the case of laminar flow conditions, the pressure decreased did not demonstrate substantial changes, although, as opposed to the simple fluid, the importance of

pressure decreased during turbulent flow speeds.

2.1.2 Study of properties of nanoparticles

Mojarrad et al. (2014) performed experiments to find laminar heat transfer and pressure penalty of nanofluids (copper oxide/water and MgO/ water-ethylene glycol) in the inlet of a round tube. The nanofluids had more thermal conductivity and viscosity in contrast to base fluids and this enhanced with enhancing nanoparticles.

Sadeghinezhad et al. (2015) researched a performance analysis and a numerical study, all in order for nanofluids under turbulent flow to be improving the heat transfer of GNP. Nusselt count, output and pressure loss ranged from 3-83 percent in comparison with base fluid, to 7,96-25 percent in contrast to 0,4-14,6 percent at various weight concentrations.

Stephen, Choi and Eastman, the feasibility of the concept of highthermal-conductivity nanofluids has been demonstrated by applying the Hamilton and Crosser (1962) model to copper nanoparticles in water, together with some experimental results of Masuda, et al. (1993) for TiO_2 particles in water.

2.1.3 Study on behavior of hybrid nanofluids

Azmi et al. (2016) analyzed heat transfer by volume for $\text{TiO}_2 + \text{CuO}$ / water ethylene glycol in various basic fluids ratios 60:40, 50:50 and 40:60. With a 60:40 base fluid ratio of nanotubes, 7 characteristics is superior to base fluid heat transfer. For this specific ratio, the change in the heat transfer coefficient was 24.6 percent at 1 vol.% and at temperature of 70 degrees and friction was marginally increased.

Yu et al. (2009) studied nanofluid CuO conductivity thermal improvement EGs, depending on the temperature. Thermal conductivity rose from 10 to 60°C, although the improved ratios remained unchanged. CuO-EG nanofluids also boost thermal conductance depending on the concentration of the particles, which increases in linear ways with the volume fractions of nanoparticles. The largest rise of 26.5% was observed for nanofluids CuO– EG, at 5.0 vol percent of nanoparticles.

Murshed et al. used TiO_2 nanoparticles and prepared nanofluids in rod-shaped spherical form by their distribution in deionized water. These nanoparticles are not

used. The experimental findings show that thermal conductivity is increased with increasing particle loads and is influenced by particle size and shape. Thermo-conductivity findings for TiO_2 nanofluids (15 nm) revealed a 29.70% increase with a 5% particulate volume fraction and a 32.80% increase for TiO_2 water nanofluids at the same volume fraction. There were 32.80% improvements. Nanoparticles made from Rod have demonstrated more changes than a rounded sph

CHAPTER 3

AIM AND SCOPE OF THE PROJECT

3.1 AIM OF THE PROJECT

Aim of the project is to prepare the nanofluids by using the selected nano particles in such a way that is Thermal conductivity enhancement and improvement of stability of nanoparticles by surfactant in Heat transfer fluids will be increased compared with normal fluids.

3.2 SCOPE OF THE PROJECT

The scope of the project is to increase the thermal conductivity of nanofluids and test the nanofluids in different heat transfer applications and used for in different fields like industrial applications and car radiators

They are also used in bulk and other microelectronics.

Its effects of nanofluids like agglomeration, coagulation should be avoided. 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.

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

CHAPTER 4

MATERIALS AND METHODS

4.1 SYNTHESIS AND PREPARATION OF NANOPARTICLES

To make various types of nanoparticles and nanosuspensions, various methods have been attempted. Glitter gives an excellent description of synthesis processes. Oxide particles were the first materials tried for nanofluids, largely because they were simple to make and chemically stable in solution. Various researchers used an inert-gas condensation (IGC) method to make TiO_2 , MgO and CuO nanopowder with particle sizes ranging from 2 to 200 nm. The main drawback of this process is its proclivity for forming agglomerates, as well as its inability to produce pure metallic nanopowder. Agglomeration would be greatly reduced if a direct evaporation condensation (DEC) method is used. The DEC method is a tweaked version of the IGC procedure used at ANL. Despite the limitations of low vapor-pressure fluids and the oxidation of pure metals, this process offers excellent particle size control and generates particles for stable nanofluids. without surfactant or electrostatic stabilizers.

The laservapor deposition technique, which is used to make CuO nanoparticles from MgO and TiO_2 , is another process. Carbon nanotubes have recently been used to create nanofluids. Using ethylene glycol as a copper source and ferrocene as a catalyst, the copper oxide used for this purpose can be made using the chemical vapor deposition technique. Another method for making metal cluster nanoparticles is pure chemical synthesis. Patel et al. identify two of the

methods for directly producing nanofluids. Zhu et al. used a one-step chemical method to make nanofluids of metallic Cu nanoparticles dispersed in ethylene glycol. As a result, there are a number of physical, chemical, and laser-based approaches to choose from required for nanofluids. However, the task to characterize and disperse them in fluid remains.

The particles should be distributed with no or very little agglomeration to achieve a stable nanofluid with true "nano" behavior. This can be accomplished in a variety of ways, including electrical, physical, and chemical ones. The most widely used dispersion techniques in the literature are ultrasonic or stator rotor methods. In some case During dispersion, stabilizing agents are also used. However, a single-step process in which nanofluids are directly formed instead of nanoparticles, minimizing the risk of agglomeration, could be the safest way to manufacture them.

4.1.1 SELECTION OF NANO PARTICLES

Selection of nanoparticles plays an important role in preparation of nanofluids here we have selected two metal nanoparticles and one nonmetal nano particles

Metal nanoparticles are Titanium dioxide

Magnesium oxide

Nonmetallic nanoparticles are Copper oxide

Selection of fluids to suspend the nanoparticle for preparing nanofluids

Base fluids: - Demineralized Water

Ethylene glycol (coolant oil)

Selection of Surfactant: - Surfactant in nanofluid preparation take an important role to decrease the surface tension between two liquids in also avoid agglomeration structure and help nanoparticles not to settle at one position

Surfactant: -Sodium dodecyl sulfate (SDS)

4.1.2 PREPARATION OF NANOFLUIDS

TWO STEP METHOD

The composition taken to prepare nano fluids are

First composition is 10ml Water +10ml ethylene glycol

Second composition is 10ml Water +10ml ethylene glycol + 1mg copper oxide + Magnesium oxide

Third composition is 10ml Water +10ml ethylene glycol + 1mg copper oxide + Titanium dioxide

The two-step method is used for preparing nanofluids is the most widely employed method. First chemical or physical methods produce nanoparticles, nanofibers, nanotubes or other nanomaterials that are used with this method powder. In a second processing phase, the nanosized powder is then method.



Fig 4.1: Nano Particles

For preparing nano fluids we have selected three nanoparticles Copper oxide, Magnesium oxide, Titanium dioxide for preparing the nanofluids



Fig 4.2: Weighing machine for nano particles

In the preparation of nanofluids the nanoparticles are taken by measuring the exact quantity which we want to prepare first nanoparticles are measured in the weighing machine and then it mixed in the water and ethylene glycol solution



Fig 4.3: Weighing machine, beaker, nanofluids

In this figure the solution is measured by using the weighing machine the solution is taken in the beaker and the whole solution with beaker is measured and later in weight of the beaker is subtracted



Fig 4.4: Ultrasonication

Sonication in the laboratory is commonly used to disperse nanotubes into the matrix of polymers. Ultrasound energy is used for the agitation of nanoparticles in the polymer matrix. It is usually done by an ultrasound bath or a horn/sample, known as a sonicator. In the ultrasonicator the solution containing beaker is placed in kept it for 30 min for each solution

4.2 Heat transfer enhancement

Table 4.1: Properties of Nanofluids

Sample	Temperature (°C)	Thermal conductivity $K_{eff}(W/m^{\circ}C)$	$Nus = k_{eff} / k_f$ ($\partial T / \partial r$) T	Heat flux $Q/A (W/m^2)$
H₂O +EG +MgO + CuO	28	0.761	67.56	1.62
	30	0.774	69.12	1.68
	32	0.792	72.3	1.81
	34	0.799	74.7	1.94
	36	0.816	78.3	2.01

H₂O +EG+TiO₂+CuO	28	0.776	60.80	1.592
	30	0.812	62.21	1.625
	32	0.823	65.07	1.791
	34	0.844	67.23	1.8
	36	0.861	70.47	1.96

Preparation of nanofluids is not easy because of external reaction of nanoparticles while preparing of nanofluids. The nanofluids are taken for different test for testing at different temperatures with different compositions. They are different types of nanofluids they are Thermal conductivity, Nusselt number, Heat flux, Zeta potential, particle size distribution. in the figure show the properties of nanofluids at different temperature and composition. The samples that are taken for testing are Water + Ethylene glycol + Magnesium oxide + Copper oxide and the other composition are Water + Ethylene glycol + Titanium dioxide + Copper oxide. In this we have certain temperatures for the solution we have taken from 28 to 36 with 2 degrees difference between them. For the solution H₂O +EG +MgO + CuO the first temperature is at 28 degrees the thermal conductivity (K_{eff}) is 0.761 and the Nusselt number is 67.56 and the heat flux is 1.62. The thermal conductivity of the solution is 0.774 and the Nusselt number is 69.12 and heat flux is 1.68 at the temperature of 30 degrees.in this properties of nanofluids the thermal conductivity, Nusselt number and heat flux are continuously increasing at the temperature of 32 thermal conductivity has increased by 0.792 and same in Nusselt number has also increased 72.3 and the heat flux is 1.81 at the temperature of 36 degrees thermal conductivity of the solution is 0.816 and the Nusselt number is 78.3 heat flux is 2.01 in this thermal conductivity of the solution highly increased

In this experiment isW+EG+TiO₂+CuO same temperature are used as the other solution at 28 degrees of temperature thermal conductivity of solution is 0.776 and Nusselt number is 60 and heat flux is 1.592w/m²at 30 degrees of temperature thermal conductivity of solution is 0.812 and Nusselt number is 62.21 and heat flux is 1.625w/m² as compared to Magnesiumoxide andTitanium has better thermal

conductivity at 32 degrees of temperature thermal conductivity of solution is 0.884 and Nusselt number is 65.07 and heat flux is 1.8 W/m^2 . 81 at the temperature of 36 degrees thermal conductivity of the solution is 0.861 and the Nusselt number is 70.47 heat flux is 1.96 in this thermal conductivity of the solution highly increased

4.3 THERMAL CONDUCTIVITY

Table 4.2: THERMO-PHYSICAL PROPERTIES OF NANOFLUIDS

S.No	Material	Thermal conductivity K in $\text{W/m}^\circ\text{C}$	Dynamic viscosity μ in mPa.S	Density ρ in kg/m^3	Specific heat Cp in J/kgK
1	TiO ₂	11690	-	4220	712
2	MgO	52	-	3565	882
3	CuO	34	-	3738	891

4	Water	0.59	0.0009	1000	4185
5	Ethylene Glycol	0.25	0.00016	1110	3850

CHAPTER 5

RESULTS AND DISCUSSION

5.1 THERMAL CONDUCTIVITY ENHANCEMENT IN NANOFLUIDS

The thermal conductivity of nanofluids is much improved when compared with usual suspensions. The enhancement of the thermal conductivity of nanofluids over that of the base fluid is often a few times better than what would have been given by micrometer-sized suspensions. So far, the base fluids used include water, ethylene glycol, transformer oil, and toluene. Ceramic particles, pure metallic particles, and carbon nanotubes are the three types of nanoparticles that are commonly used (CNTs). Different nanofluids are generated by combining the above particles and fluids. This analysis, on the other hand, will categorize them

primarily by particle form.

5.1.1 pH Measurement

pH is the measure which gives whether the solution is acidic or basic in nature. It has the range between 0-14 values means from the value lie in between 0 to 7 means acidic in nature, whereas 7 means neutral in nature where if pH lies above 7 to 14 which means basic in nature.

pH is the measure of free hydrogen ion or hydroxyl ion in the water.

Examples: Lemon juice has pH value is 2, saliva has pH value lies in between 6.7-7.3 mostly maintained neutral, baking soda (NaHCO_3) has around 8.3 etc.

pH is measurement of decimal logarithm of the reciprocal of the hydrogen ions.

$$\text{pH} = -\log_{10}(\text{H}^+)$$

pH can be measured by litmus paper most of the pH measurement done by using pH paper the pH is used in way that the pH takes the pH paper strip and dip the paper in the solution which we want to test after 2 to 3 seconds take the paper out and measure the color of the strip that changed after dipping and compare with pH color paper and know the solution is whether acidic or alkaline or neutral

Here we took 3 type of solutions

- Demineralized Water + Ethylene Glycol
- Demineralized Water + Ethylene Glycol + CuO + MgO
- Demineralized Water + Ethylene Glycol + CuO + TiO_2



Fig 5.1: pH value OF W+EG

The pH value of the demineralized water and ethylene glycol is measured by using pH paper.

By using the pH paper dip the paper for 2-3 seconds and match the color of the paper with pH Chart The pH value of water and ethylene glycol is 6

It is acidic solution.

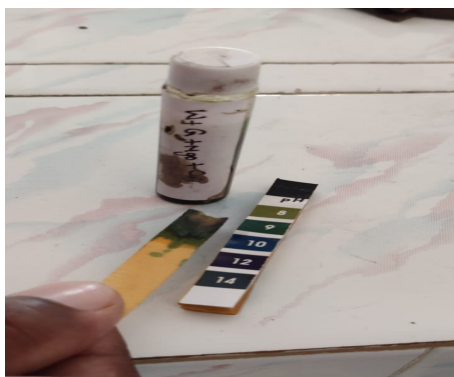


Fig 5.2: pH value of W+EG+ CuO +MgO

The pH value of the demineralized Water, Ethylene glycol, Copper oxide and Magnesium dioxide is measured by using pH paper.

By using the pH paper dip the paper for 2-3 seconds and match the color of the paper with pH chart

The pH value of water and ethylene glycol is 14

It is basic solution.



Fig 5.3 pH value of W+EG+ CuO+TiO₂

The pH value of the demineralized Water, Ethylene glycol, Titanium dioxide and Copper oxide is measured by using pH paper.

By using the pH paper dip the paper for 2-3 seconds and match the color of the paper with pH chart

The pH value of water and ethylene glycol is 14

It is basic solution.

Table 5.1: pH value of the solution

SL NO	SOLUTION	pH value	Acidic	basic
1	W + EG	6	✓	
2	W+EG+CuO+MgO	14		✓
3	W+EG+CuO+TiO ₂	14		✓

The above table show the pH value of the solution taken for as a sample for the experimental work. The solution taken that the composition is W + EG, W+EG+ CuO +MgO, W+EG+CuO+TiO₂, as per the table the first solution got the PH value of 6 which is acidic in nature, and the second solution Water +Ethylene glycol+ Copper oxide+ Magnesium oxide got the pH value of 14 which is basic solution in nature and the third solution Water +Ethylene glycol+ Copper oxide+ Titanium dioxide has got the pH value of 14 which is basic in nature.

5.2 ZETA POTENTIAL AND PARTICLE SIZE DISTRIBUTION

5.2.1 Zeta potential

Zeta potential is an effective measure of the power charge on the surface of nanoparticles. The size of Zeta Potential offers information on the stability of particles with higher zeta potential particles showing increased stability due to a greater electrostatic repulsion between particles.

The zeta potential is the potential difference between solids and fluids across phase

boundaries. It's an electric charging measure of the particles suspended in fluid. In colloids, zeta potential represents the electrical potential difference across the ionic layer.

Zeta potential in colloidal dispersions is a scientific term for electrokinetic potential. It is normally indicated by the Greek letter zeta (ζ), hence, ζ -potential in colloidal chemistry literature. The standard units are V or millivolts (mV). The zeta potential is from the theoretical point of view the electrical potential of the double interfacial layer (DL) at the slippery plane position relative to a point away from the interface in the bulk fluid. In other words, the potential difference between the dispersion medium and the fluid layer that is attached to the dispersed particle is zeta potential.



Fig 5.4: Dynamic light scattering machine

The zeta potential comes from the net electric charge contained within the sliding plane region, and also depends on where the plane is located. It is therefore widely employed to quantify the size of the load. The zeta potential in the double layer,

however, is not equal to the stern potential or electrical surface potential because they are defined at different places. Such equality assumptions should be applied cautiously. However, the only way to characterize double-layer properties is often to provide a zeta potential.

A key indicator of colloidal dispersion's stability is the Zeta potential. The magnitude of the zeta potential shows the degree of electrostatic repulsion in an adjacent dispersion between the equally charged particles. A high zeta potential provides stability for small molecules and particles; i.e., a solution or dispersion resists aggregation. If the potential is small, this repulsion may be exceeded by attractive forces and dispersion breaks and flows. High-zeta-potential colloids are therefore electrically stabilized, while low-zeta-potential colloids tend to coagulate or flow as described in the table.

PROPERTIES OF W+EG+CuO+TiO₂

Zeta Potential

Zeta Potential (mv):	5.8
Polarity:	Negative
Mobility (uS/V/cm):	0.45
Conductivity (uS/cm):	394
Field Strength(kV/m):	9.7

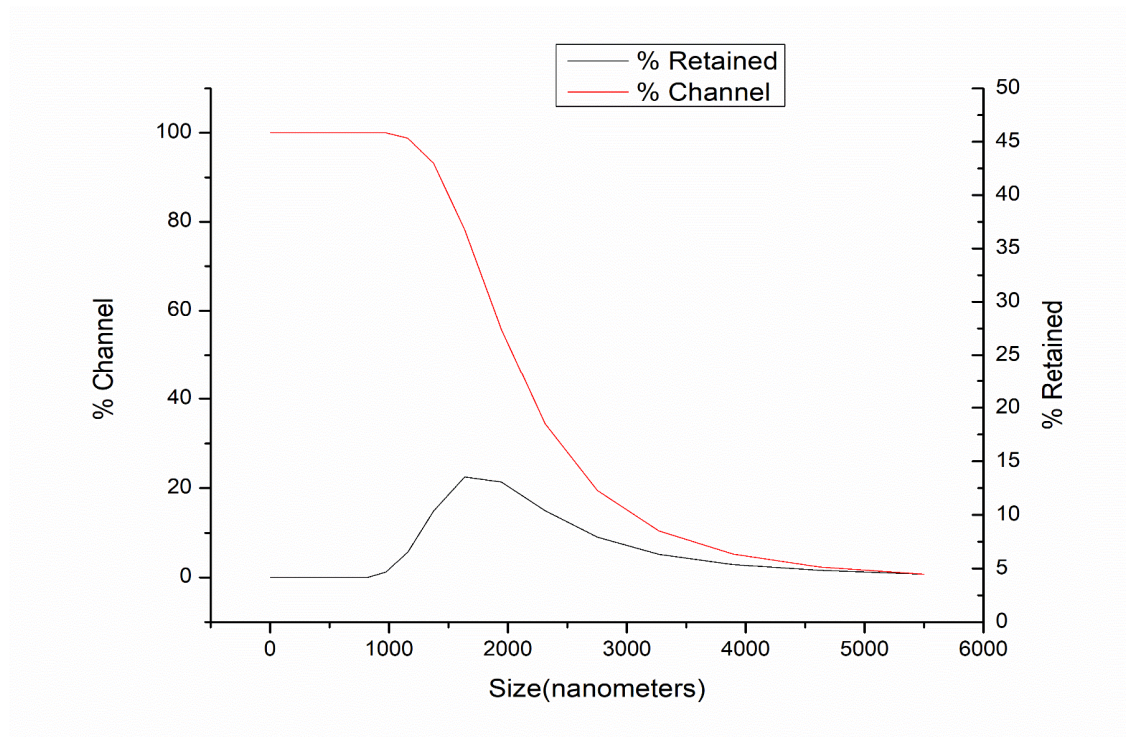


Fig5.1: particle size distribution of CuO + TiO₂

The Figure 2 showed that the variation of size of nanoparticles with the chemical proposition in percentage. The black colored curve represented the percentage composition in channel and the red one explained the same retained. The spread of nanoparticles was from 1000 nm to 6000 nm. The peak in channel and retained % was depicted at 1500 nm size. The minimum variation was observed at 5400nm. The value of the zeta potential is observed that size of particle is 5.8mv. The polarity of zetapotential is negative. The mobility of zeta potential is 0.45u/s/v/cm is retained of start of peak point. The conductivity of maximum point is 394 us/cm. The field strength of peak in channel and retained % was depicted at point is 9.7kv/m. The graph shows the particle size distribution of the solution and zeta potential of the solution which contains of nanoparticles water + ethylene glycol+ copper oxide + Titanium dioxide ,are used in this solution .The graph explain the size of the particle in the solution in this the retained % starts from 0nm and the channel % starts from 100nm the retained % tends be stable up to 1000 nm of size and from 1000nm it's got peak up to 20 nm in channel and 17% in retained % and comes to stable from 2000 nm and channel starts from 100 nm and continuous to be stable

up to 1000 nm size and peak suddenly falls to 0 nm

It was concluded that lesser the size of nanoparticles, more uniform particle size distribution as the test performed at central Instrumentation laboratory, Vel's University, Chennai.

PROPERTIES OF W+EG+ CuO+MgO

Zeta Potential

- Zeta Potential (mv): 20.7
- Polarity: Negative
- Mobility (u/S/V/cm): 1.62
- Conductivity (uS/cm): 1483
- Field Strength(kV/m): 8.8

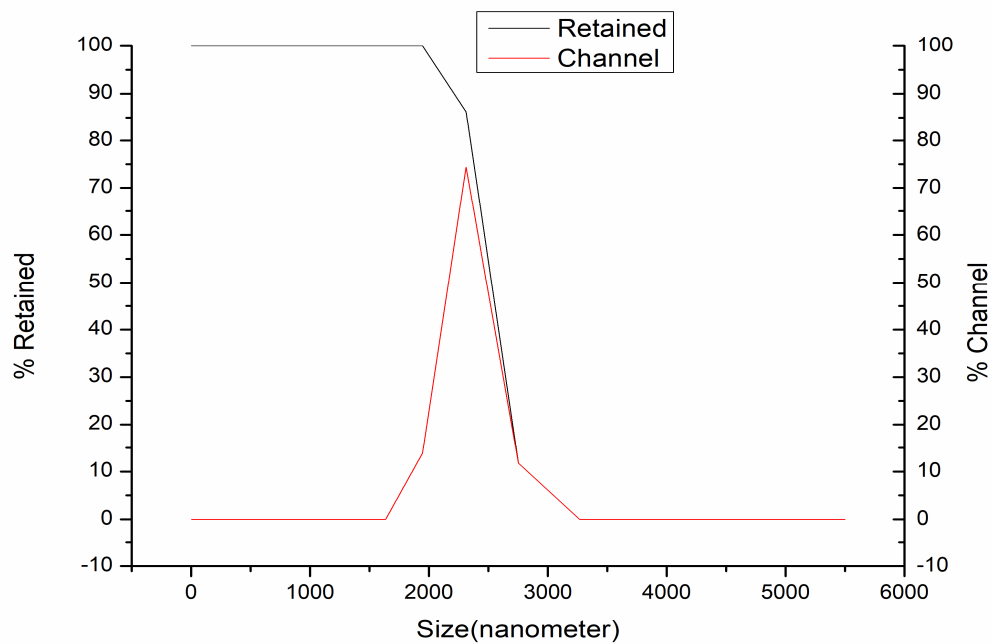


Fig 5.2: variation in the particle size distribution of CuO+ MgO

The Figure 5.6 showed that the variation of size of nanoparticles with the chemical proposition in percentage. The black colored curve represented the percentage composition in channel and the red one explained the same retained. The spread of nanoparticles was from 1000 nm to 6000 nm. The peak in channel and retained % was depicted at 1500 nm. The minimum variation was observed at 5400nm. The value of the zeta potential is observed that size of particle is 20.7mv. The polarity of zetapotential is negative. The mobility of zeta potential is 1.62u/s/V/cm is retained of start of peak point. The conductivity of maximum point is 1483 us/cm. The field strength of peak in channel and retained % was depicted at point is 8.8kv/m. In this graph shows that the potential of particle size distribution of the solution which is consist of water + ethylene glycol+ magnesium oxide + copper oxide the graph has two portions channel and retained values in this the channel has started form 0 and unto 1600 there is no peak in the graph from their peak started up to 20 slate increase and from retained percentage 20 channel high peak to the percentage of 75 and from 75% the peak of channel falls to retained 20% again decreases to zero and the minimum variation was absorbed at 5700 nm and the maximum peak variation was at 75% retained and 35% channel at the size of 1500 nm.

It was concluded that lesser the size of nanoparticles, more uniform particle size distribution as the test performed at central Instrumentation laboratory,Val'sUniversity, Chennai.

5.3 Heat transfer enhancement

Table 5.2: Properties of Nanofluids

Sample	Temperature (°C)	Thermal conductivity $K_{eff}(w/m^{\circ}C)$	Nus = k_{eff} / k_f ($\partial T \partial r$) T	Heat flux Q/A (w/m ²)
H ₂ O +EG +MgO	28	0.761	67.56	1.62
	30	0.774	69.12	1.68

+ CuO	32	0.792	72.3	1.81
	34	0.799	74.7	1.94
	36	0.816	78.3	2.01
H ₂ O +EG+TiO ₂ +CuO	28	0.776	60.80	1.592
	30	0.812	62.21	1.625
	32	0.823	65.07	1.791
	34	0.844	67.23	1.8
	36	0.861	70.47	1.96

Preparation of nanofluids is not easy because of external reaction of nanoparticles while preparing of nanofluids. The nanofluids are taken for different test for testing at different temperatures with different compositions. They are different types of nanofluids they are Thermal conductivity, Nusselt number, Heat flux, Zeta potential, particle size distribution. in the figure show the properties of nanofluids at different temperature and composition. The samples that are taken for testing are Water + Ethylene glycol + Magnesium oxide + Copper oxide and the other composition are Water + Ethylene glycol + Titanium dioxide + Copper oxide. In this we have certain temperatures for the solution we have taken from 28 to 36 with 2 degrees difference between them. For the solution H₂O +EG +MgO + CuO the first temperature is at 28 degrees the thermal conductivity (K_{eff}) is 0.761 and the Nusselt number is 67.56 and the heat flux is 1.62. The thermal conductivity of the solution is 0.774 and the Nusselt number is 69.12 and heat flux is 1.68 at the temperature of 30 degrees.in this properties of nanofluids the thermal conductivity, Nusselt number and heat flux are continuously increasing at the temperature of 32 thermal conductivity has increased by 0.792 and same in Nusselt number has also increased 72.3 and the heat flux is 1.81 at the temperature of 36 degrees thermal conductivity of the solution is 0.816 and the Nusselt number is 78.3 heat flux is 2.01 in this thermal conductivity of the solution highly increased

In this experiment isW+EG+TiO₂+CuO same temperature are used as the other

solution at 28 degrees of temperature thermal conductivity of solution is 0.776 w/m K and Nusselt number is 60 and heat flux is 1.592w/m² at 30 degrees of temperature thermal conductivity of solution is 0.812 w/m K and Nusselt number is 62.21 and heat flux is 1.625w/m² as compared to magnesium oxide titanium has better thermal conductivity at 32 degrees of temperature thermal conductivity of solution is 0.884 and Nusselt number is 65.07 and heat flux is 1.8w/m². At the temperature of 36 degrees thermal conductivity of the solution is 0.861 w/m K and the Nusselt number is 70.47 heat flux is 1.96 w/m² in this thermal conductivity of the solution highly increased

5.3.1 NUSSELT NUMBER (Nu)

The Nusselt number is the ratio of convective and conductive heat transfer. The heat flows of the convectors and conductors are parallel to one another and to the regular surface of the frontier surface, and in the simple case both are dependent on the mean fluid flow.

Nusselt numbers are determined by multiplying the thermal conductivity rate and temperature gradient (conductivity of the nanofluid to the conductivity of the base fluid).

Nusselt number is instead a non-dimensional coefficient of heat flow. It is used to decide whether heat flow is a convection or conduction.

In this graph the red curve denotes the solution of water + ethylene glycol + copper oxide + titanium dioxide and the black curve denotes the solution of water + ethylene glycol + copper oxide + magnesium oxide in this both the curve starts at the temperature of 28 degrees with different Nusselt number the red curve starts at 60.80 Nusselt number and end rises to 36 degrees at Nusselt number of 70.47 whereas the black starts from 67.56 Nusselt number and end at 36 degrees temperature at Nusselt number of 78.3 the graph explain the Nusselt number value at different temperature the Nusselt number of the black curve starts from 28 degrees at Nusselt number of 67.56 and at the temperature of 30 degrees the

Nusselt number is 69.12. the Nusselt number is 72.3 at the temperature of 32 degrees at the temperature of 34 degrees the Nusselt number is 74.7 and at the temperature of 36 degrees the Nusselt number is 78.3 whereas the other red curve has a Nusselt number starts from 28 degrees at Nusselt number of 60.80 and at the temperature of 30 degrees the Nusselt number is 62.21. the Nusselt number is 65.02 at the temperature of 32 degrees at the temperature of 34 degrees the Nusselt number is 67.23 and at the temperature of 36 degrees the Nusselt number is 70.47.

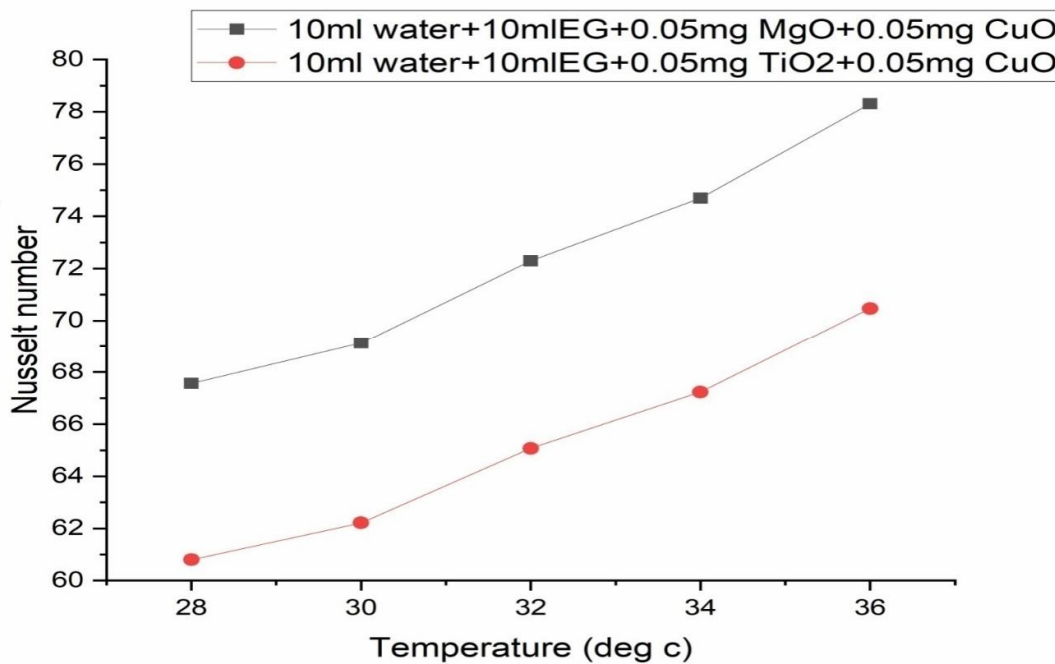


Fig 5.3: Effect of surfactants on the Nusselt number of CuO+TiO₂ ethylene glycol/water-based nanofluids

5.3.2 HEAT FLUX

Heats or thermal flux is a distribution of energy per unit of area per unit of time, often often referred to as heatstrom density, heat flow density or heat flow speed. In

SI the watts per m² (W/m²) are mounted. It has a direction and a size, and then it is a quantity of the vector. In order to describe the heat flow in any space point, the boundary case is taken if the surface area is limited in an infinite quantity.

The heat flux calculation can be carried out in various ways. A widely known, but sometimes unpractical, procedure is used by calculating a variation in temperature over a substance with known thermal leading characteristics. This approach is similar to the traditional way of measuring an electric current, in which a voltage decrease is measured by a defined resistor. This technique is usually very difficult to use since the substance being measured is mostly unknown to thermal resistance. To decide thermal resistance, exact values for material thickness and thermal conductivity are required. Thermal tolerance and calculation of temperature on either side of the material

$$\phi q = -k \frac{dT(X)}{DX}$$

ϕ_q = heat flux

k = thermal conductivity(w/m K)

T = temperature (K)

In this graph the two curve explain the heat flux of the solution here the black curve represent solution of water + ethylene glycol + copper oxide + magnesium oxide and the red curve denotes the graph of water + ethylene glycol + copper oxide + titanium dioxide hear the both graph starts at 28 degrees where the black graph is at 1.62 and the black graph starts from 1.592 hear the heat flux between two solution is very less at the temperature of 30 degrees the heat flux of the black and red solution is the black curve is at 1.68 and the red graph is at 1.625 here the heat flux distribution of the solution is better in magnesium oxide than titanium dioxide at the temperature of 32 degrees the black graph is at1.81 and red graph is at 1.791 and at 34 degrees the black graph is at 1.94 and red graph is at 1.8 and at the temperature of 36 degrees there is no much difference between the graph of two solution where the black graph is at 2.01 and 1.96 is where the red is curve.

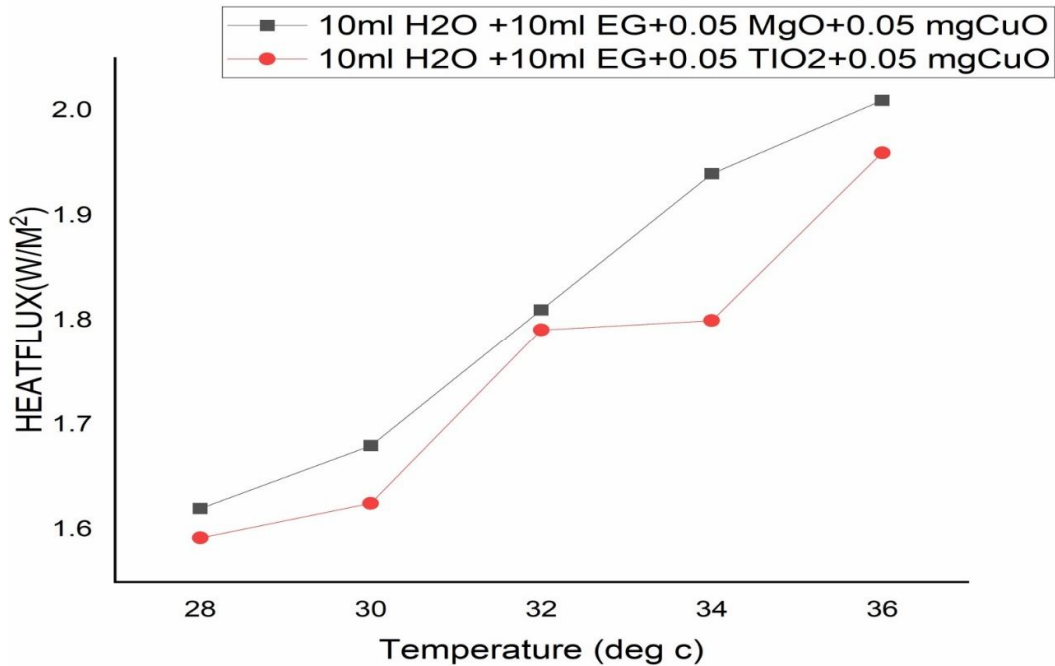


Fig5.4:Effect of surfactants on the heat flux of CuO+TiO₂ ethylene glycol/water-based nanofluids

5.3.3 THERMAL CONDUCTIVITY

The material's thermal conductivity is an indicator of its thermal conduction. It is sometimes referred to as K. The rate of thermal transfer is lower for low thermal conductivity materials than for high thermal conductivity materials. Metals, for example, are normally highly thermal conductive and very effective in heating whereas isolating materials such as steel foam have the opposite effect. High thermal conductivity materials are still commonly used in applications of thermal sinks, and thermal insulation materials of low thermal conductivity. Thermal resistivity is the reciprocal of thermal conductivity.

$$K = \frac{Qd}{A\Delta T}$$

K =thermal conductivity(w/m K)

Q =amount of heat transfer (w)

d =distance between two isothermal planes (m)

A =area of surface (m^2)

ΔT =difference in temperature (K)

Thermal conductivity depends largely on the temperature, composition of particulate matter and form of base fluid. The definition of variance in thermal conductivity and particle concentration is then more precisely defined in the temperature effect, the error bars are presented. Top and lower ends display the thermal conductivity values compared to the temperature values for high and minimum values. The following deductions can be taken from all the aforementioned discussions

The temperature specifically links the thermal conductivity of the TiO_2 nanofluids. The change in particle concentration affects the thermal conductivity of the nanofluid directly. In various trials, the findings were higher relative to ethylene glycol with water as a base water fluid. In the below graph it show the thermal conductivity of nanofluids contains the compositions of Water + Ethylene glycol + Copper oxide + Magnesium oxide and Water + Ethylene glycol + Copper oxide + Titanium dioxide as of composition of solutions at temperature of 28 degrees the black curve is at 0.61 and red curve is at 0.776 and the temperature of 30 degrees the black curve is at 0.774 and red graph is at 0.812 and at the temperature of 32 degrees the thermal conductivity of the black curve is 0.792 and thermal conductivity of red graph is 0.823 and at the temperature of 34 degrees the thermal conductivity of the black curve is 0.799 and thermal conductivity of red graph is 0.844 and at the temperature of 36 degrees the thermal conductivity of the black curve is 0.816 and thermal conductivity of red graph is 0.861

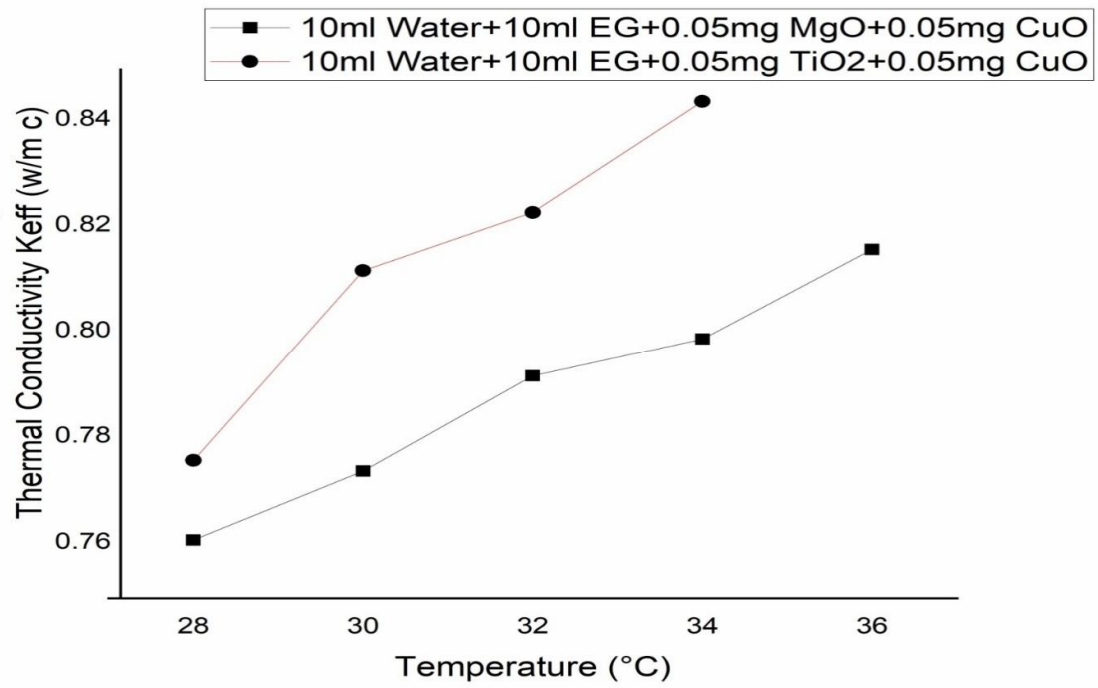


Fig 5.5: Effect of surfactants on the thermal conductivity of CuO+TiO₂ ethylene glycol/water-based nanofluids

CHAPTER 6

CONCLUSION AND FUTURE RECOMMENDATIONS

6.1 Conclusion

To put our work in a few words, the project was intended to design an experiment to study the enhancement of heat transfer rate in car radiator systems using nanoparticles. We were required to complete the experiment within 4 months and provide a detailed report illustrating our work into it. The main aim of this project is to prove experimentally what already has been proved theoretically that Nanofluids increase the heat transfer rate with no pressure drop. Despite facing some inconsistencies of results due to environment conditions, the goal of the project has been achieved. Another important outcome of this project is that adding nanoparticles to fluids does not affect friction between the layers of fluids.

Based on the research and the experiment performed Thermal conductivity enhancement and improvement of stability of nanoparticles by surfactant in Heat transfer fluids Best increase in thermal conductivity (9.8 percent) with the addition of sodium Surfactant was shown with Cu-TiO₂, accompanied by the hybrid nanofluid relative to that of the basis fluid.

In line with an increase in sonication time during preparation of nanofluids, the thermal conductance of CuO+ TiO₂ and CuO + MgO improved, irrespective of the surfactant form added. The hybrid nanofluid with high thermal conductance did not result in a sonication period of 10 min.

The final conclusion of the work done in this project is using the nanofluids containing nanoparticles of titanium dioxide + copper oxide and magnesium oxide + copper oxide with base fluid as water + ethylene glycol has been increased

Thermal properties of this nano fluids have increased 40 -50 % compared to the normal base fluids

6.2 Future recommendations

In order to further study the behavior of heat transfer in Nanofluids, other types of nanoparticles are advice to be used. Also, to get the best and most accurate results, environment's conditions have to be monitored in a way that

they do not affect the experiment negatively, giving misleading data. Furthermore, using a metallic water tank would decrease the use of ultrasound waves. Finally, we recommend experimenting Nanofluids in power plants applications.

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