ENHANCEMENT OF THERMAL CONDUCTIVITY OF WATER-ETHYLENE GLYCOL MIXTURE WITH COPPER OXIDE AND TITANIUM DIOXIDE NANO PARTICLES

A PROJECT REPORT

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in partial fulfilment for the award of the degree

of

BACHELOR OF ENGINEERING

in

MECHANICAL ENGINEERING

JEPPIAAR ENGINEERING COLLEGE, CHENNAI - 600 119

ANNA UNIVERSITY : CHENNAI – 600 025

APRIL 2020

ANNA UNIVERSITY: CHENNAI 600 025

JEPPIAAR ENGINEERING COLLEGE

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BONAFIDE CERTIFICATE

Certified that this Project report **"ENHANCEMENT OF THERMAL CONDUCTIVITY OF WATER-ETHYLENE GLYCOL MIXTURE WITH COPPER OXIDE AND TITANIUM DIOXIDE NANO PARTICLES"** is the bonafide work of **C.AJEETHKUMAR (310816114003), A.ARAVIND (310816114015) , S.ASHWIN (310816114023) , R.JAGADEESH RAHUL (310816114050)** who carried out project under by the supervision.

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ACKNOWLEDGEMENT

We are very much ineffably indebted to (Late) Hon'ble Colonel. **Dr.JEPPIAAR, M.A., B.L., Ph.D**., and Our Chairman and Managing Director **Dr. M. REGEENA JEPPIAAR, B. Tech., M.B.A., Ph.D.,**

We express our sincere thanks to our Principal **Dr. V. NATARAJAN, M.E., Ph.D.,** for the opportunity given to us.

We would like to express our deep sense of gratitude to **Mr. J. PAUL CHANDRA KUMAR, M.E., (Ph.D).,** Head of the Department who has been always a mentor and motivator to complete this project.

We would like to extend our gratitude to our Guide **Mr. M. PURUSHOTHAMAN, M.E., (Ph.D).,** for giving valuable guidance to complete the project.

We feel to acknowledge our indebtedness to our Project Co-ordinator **Mr. N. RAJESHKUMAR, M.E., (Ph.D).,** for giving valuable guidance and kind supervision given to us throughout the project.

We extend our gratitude to our counsellor **Mr. E. JEEVA, M.E.,** for the constant support throughout our academic part.

We also thank the **Teaching and Non -Teaching staff** members of the Department of Mechanical Engineering for their constant Support.

We also acknowledge with a deep sense of reverence, our gratitude towards our Parents and member of our family, who has always supported us morally as well as economically.

ABSTRACT

Coolants with low thermal conductivity limits the efficiency of thermal systems, such as heat exchangers, which require heat transfer fluid with high thermal conductivity. There is a demand to synthesize heat transfer fluids with high thermal conductivity. The emergence of nanoparticles has led to the development of nano-fluids. The study investigates the thermal conductivity characteristics of a copper oxide-titanium dioxide (CuO-TiO2) hybrid nanofluid (Water and Ethylene glycol) with 0.6% and 0.8% concentrations and compared with conventional coolants. In addition, the effects of various factors (weight percentages of the nanoparticles and sonication times) on the thermal conductivity of the CuO-TiO2 hybrid nanofluid were studied. The hybrid nanofluid containing 0.8 wt% of CuO-TiO2 and Sodium Lauryl Sulphate (SLS) as surfactant showed the highest thermal conductivity, exhibiting an improvement of 80% at 40°C compared to that of the base fluid.

KEYWORDS : Thermal Conductivity, Nano-fluids, Nano-particles, Coolant, Efficiency

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ABBREVATION

CuO	Copper (II) oxide
TiO_2	Titanium Di-oxide
$CH_3(CH_2)_{11}SO_4Na$	Sodium Lauryl Sulphate
CO_2	Carbon Di-oxide
$C_2H_6O_2$	Ethylene Glycol
Hy-NF	Hybrid Nanofluid
NO_3	Nitrate ion
HNO_3	Nitric acid
H_2SO_4	Sulfuric acid
$CuSO_4$	Copper (II) sulphate
HCl	Hydrogen Chloride
SDS	Sodium Dodecyl Sulphate
SCS	Sodium Coco Sulphate
CH_3OH	Methanol

CHAPTER 1
INTRODUCTION

Heat exchangers play a vital role in several engineering applications, such as automobile, aerospace, chemical processing, electronic chip cooling, heat pumps, and energy systems. The thermal performance of heat exchangers depends on a variety of factors including geometric, kinetic and spatial aspects, related to the net heat transfer rate encountered between the heat transfer sections and flow of fluids. More often, the fluids subjected to flow in heat exchangers (either parallel or counter or crossed flow methods) would experience transient thermal conditions throughout the heat transfer processes.

Continuous technological development in automotive industries has increased the demand for high efficiency engines. A high efficiency engine is not only based on its performance but also for better fuel economy and less emission. There are many systems which influence the engine performance like fuel ignition system, emission system, cooling system, etc. one of the parameters which affects the performance of engine is the cooling rate of radiator in engine cooling system. Addition of fins is one of the approaches to increase the heat transfer rate of the radiator.

It provides greater heat transfer area and enhances the air convective heat transfer coefficient. However, traditional approach of increasing the cooling rate by using fins has already reached to their limit. As a result, there is a need of new and innovative heat transfer fluids for improving heat transfer rate in an automotive car radiator. In addition, heat transfer fluids at air and fluid side such as water and ethylene glycol exhibit very low thermal conductivity.

With the advancement of nanotechnology, the new generation of heat transfer fluids called, "Nano-fluids" have been developed and researchers found

that these fluids offer higher thermal conductivity compared to that of conventional coolants. Nano-fluids which consist of a carrier liquid, such as water, ethylene glycol dispersed with tiny Nano-scale particles known as nanoparticles. Since the birth of Automobiles, many people try to find new, a different approach to cool down the power-house.

Efforts have been done on the variation in geometry of heat exchanger apparatus using different fin types (or) various tube inserts (or) rough surface to improve the heat transfer rate. Though an improvement in energy efficiency is possible from the topological and configuration points of view, much more is needed from the perspective of the heat transfer fluid. Further enhancement in heat transfer is always in demand, as the operational speed of these devices depends on the cooling rate.

Conventional fluids, such as water, engine oil, ethylene glycol, etc. have poor heat transfer performance and therefore high compactness and effectiveness of heat transfer systems are necessary to achieve the required to achieve an enhancement in their thermal conductivity. For enhancement of the heat transfer the application of additives to coolants is more noticeable.

Recent advances in nanotechnology have allowed development of a new category of fluids termed nano-fluids. Such fluids are liquid suspensions containing particles that are much smaller than 100 nm, and have a bulk solids thermal conductivity higher than the base liquids. nano-fluids are formed by suspending metallic or non-metallic oxide nanoparticles in traditional heat transfer fluids. These so called nano-fluids display good thermal properties compared with fluids conventionally used for heat transfer and fluids containing particles on the micrometre scale. nano-fluids are the new window which was opened recently, which recently has been confirmed by several researchers that the addition of these Nano-sized particles into the conventional working fluid

have considerably enhanced their thermal conductivity or heat transfer performance. And the following slides shows the TiO2 Nano-particles experimental analysis as an automobile coolant.

1.1 NANO-PARTICLES

Nanoparticles are particles between 1 and 100 nanometres (nm) in size with a surrounding inter-facial layer. The inter-facial layer is an integral part of nanoscale matter, fundamentally affecting all of its properties. The inter-facial layer typically consists of ions, inorganic and organic molecules. Organic molecules coating inorganic nanoparticles are known as stabilizers, capping and surface ligands, or passivating agents. In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties. Particles are further classified according to diameter. The most commonly used nano-particles are Cu, CuO, Al2O3, Fe2O3, Fe, SiC, ZnO, etc.

1.1.1.Copper

Copper is a Block D, Period 4 element. It is a ductile metal with very high thermal and electrical conductivity. The morphology of copper nanoparticles is round, and they appear as a brown to black powder. Copper is found to be too soft for some applications, and hence it is often
combined with other metals to form numerous alloys such as brass, which is a copper-zinc alloy. Copper nanoparticles are graded as highly flammable solids; therefore, they must be stored away from sources of ignition. They are also known to be very toxic to aquatic life.

Copper nanoparticles can be manufactured using numerous methods. The electrode position method is considered by many as one of the most suitable and easiest. The electrolyte used for the process is an acidified aqueous solution of copper sulphate with specific additives.

1.1.2.Copper Oxide

This article discusses about the properties and applications of copper oxide nanoparticles. Copper is a Block D, Period 4 element, while oxygen is a Block P, Period 2 element. Copper oxide nanoparticles appear as a brownish-black powder. They can be reduced to metallic copper when exposed to hydrogen or carbon monoxide under high temperature. They are graded harmful to humans and as dangerous for the environment with adverse effect on aquatic life.

Copper oxide nanoparticles can be synthesized using the aqueous precipitation method. In this method, copper acetate is used as a precursor and sodium hydroxide as a stabilizing agent.

1.1.3.Aluminium Oxide

Aluminium nanoparticles are produced using the laser evaporation process. Using high purity aluminium as raw material, high active aluminium nanoparticles of high purity and small particle size, can be produced in large quantities at low cost. Aluminium nanoparticles are highly effective catalysts. When they are added into solid rocket fuel, it helps improve combustion speed and considerably increases combustion heat and combustion stability. The burning rate of solid propellant can be

5-20 times higher using aluminium Nano-powder compared to powders with larger particle sizes. The preparation methods are listed out down below to as how TiO_2. Each preparation method is adopted for certain use cases or used for production accordingly to its environmental.

1.1.4.Ferric Oxide

Iron oxide Nano-particles are iron oxide particles with diameters between about 1 and 100nm. The two main forms are magnetite (Fe_3O_4) and its oxidized form maghemite (γ-Fe_2O_3). They have attracted extensive interest due to their superparamagnetic properties and their potential applications in many fields (although Co and Ni are also highly magnetic materials, they are toxic and easily oxidized). Applications of Iron-oxide Nano-Particles include terabit

magnetic storage devices, catalysis, sensors, Super Para-Magnetic Relaxometry (SPMR), and high-sensitivity biomolecular Magnetic Resonance Imaging (MRI) for medical diagnosis and therapeutics. These applications require coating of the nanoparticles by agents such as long chain fatty acids, alkyl-substituted amines and diols. They have been used in formulations for supplementation. It has an inverse spinel structure with oxygen forming a face-cantered cubic crystal system. In magnetite, all tetrahedral sites are occupied by Fe^{3+} and octahedral sites are occupied by both Fe^{3+} and Fe^{2+}. Maghemite differs from magnetite in that all or most of the iron is in the trivalent state (Fe^{3+}) and by the presence of cation vacancies in the octahedral sites. Maghemite has a cubic unit cell in which each cell contains 32 O ions, $21\frac{1}{3}$ Fe^{3+} ions and $2\frac{2}{3}$ vacancies. The cations are distributed randomly over the 8 tetrahedral and 16 octahedral sites.

1.1.5.Iron

Iron is a Block D, Period 4 element. It is the fourth most abundant element found in the Earth's crust. It is found in minerals such as hematite and magnetite. It is a strong, ductile and malleable metal. Nano-iron particles are sub-micrometre particles of iron metal. Iron is highly reactive to both air (oxygen) and water, and in nanoparticles it is even more rapid than the bulk material. These characteristic limits its use to inert environments. Iron nanoparticles are not toxic. Iron nanoparticles can be manufactured using several methods. They can be prepared using wet chemical processes such as colloid chemical or sol-gel methods; or by dry processes such as vapor deposition methods.

1.1.6.Zinc Oxide

Zinc oxide is an inorganic compound with the formula ZnO. ZnO is a white powder that is insoluble in water, and it is widely used as an additive in numerous materials and products including rubbers, plastics, ceramics, glass, cement, lubricants, paints, ointments, adhesives, sealants, pigments, foods,

batteries, ferrites, fire retardants, and first-aid tapes. Although it occurs naturally as the mineral zincite, most zinc oxide is produced synthetically.

ZnO is a wide-band gap semiconductor of the II-VI semiconductor group. The native doping of the semiconductor due to oxygen vacancies or zinc interstitials is n-type. This semiconductor has several favourable properties, including goods transparency, high electron mobility, wide band-gap, and strong room temperature luminescence. Those properties are valuable in emerging applications for: transparent electrodes in liquid crystal displays, energy-saving or heat-protecting windows, and electronics as thin-film transistors and light-emitting diodes.

1.1.7.Silicon Carbide

Nano particle research has provided numerous innovative and unexpected solutions in the field of ceramics, electronics, pharmaceuticals and optics. This article will look into the properties and applications of silicon carbide.

Silicon carbide (SiC) nanoparticles exhibit characteristics like high thermal conductivity, high stability, high purity, good wear resistance and a small thermal expansion co-efficient. These particles are also resistant to oxidation at high temperatures. Silicon belongs to Block P, Period 3 while carbon belongs to Block P, Period 2 of the periodic table. An important point to be noted about their storage is that they must be kept away from moisture, heat and stress.

The Nano-particles used in this experiment is "CuO & TiO2" in rutile phase. Its chosen because of its Thermal Conductivity Enhancement properties.

1.2.BASE FLUID

A type of fluid which is a solvent used to dissolve the Nano-particles. It is used to provide the particles with fluid motion and to improve the heat transfer efficiency substantially.

Properties

• It is used as a solvent for the Nano-particles required for the coolant's specifications.

• It enhances thermal conductivity of the product, overall.

• It shows improved heat transfer co-efficient.

• It provides the fluid motion required for heat transfer for the engine to the radiator fins.

1.2.1.Ethylene Glycol

Ethylene glycol (IUPAC name: ethane-1,2-diol) is an organic compound with the formula $(CH_2OH)_2$. It is mainly used for two purposes, as a raw material in the manufacture of polyester fibers and for antifreeze formulations. It is an odourless, colourless, sweet-tasting, viscous liquid. Ethylene glycol is toxic. Household pets are especially susceptible to ethylene glycol poisoning from vehicle antifreeze leaks.

1.2.2.Propelene Glycol

Propylene glycol (IUPAC name: propane-1,2-diol) is a synthetic organic compound with the chemical formula $C_3H_8O_2$. It is a viscous, Colour-less liquid which is nearly odour-less but possesses a faintly sweet taste. Chemically it is classed as a diol and is miscible with a broad range of solvents, including water, acetone, and chloroform. The compound is sometimes called (alpha) α-propylene glycol to distinguish it from the isomer propane-1,3-diol, known as (beta) β-propylene glycol.

1.2.3.Distilled Water

Distilled water is water that has been boiled into vapor and condensed back into liquid in a separate container. Impurities in the original water that do not boil below or near the boiling point of water remain in the original container. Thus, distilled water is one type of purified water.

Most commonly used Base fluids are ethylene glycol, distilled water & propylene glycol used here are distilled water and ethylene glycol.

1.3. COOLANT

A coolant is a substance, typically liquid or gas, that is used to reduce or regulate the temperature of a system. An ideal coolant has high thermal capacity, low viscosity, is low-cost, non-toxic, chemically inert and neither causes nor promotes corrosion of the cooling system.

While the term "coolant" is commonly used in automotive and HVAC applications, in industrial processing heat transfer fluid is one technical term more often used in high temperature as well as low temperature manufacturing applications. The coolant can either keep its phase and stay liquid or gaseous, or can undergo a phase transition, with the latent heat adding to the cooling efficiency. The latter, when used to achieve below-ambient temperature, is more commonly known as refrigerant.

PREPARATION OF COOLANT

1.3.1. Magnetic Stirrer

A magnetic stirrer or magnetic mixer is a laboratory device that employs a rotating magnetic field to cause a stir bar (or *flea*) immersed in a liquid to spin very quickly, thus stirring it. The rotating field may be created either by a rotating magnet or a set of stationary electromagnets, placed beneath the vessel with the liquid.

1.3.2. Stir Bars

A stir bar is the magnetic bar placed within the liquid which provides the stirring action. The stir bar's motion is driven by another rotating magnet or assembly of electromagnets in the stirrer device, beneath the vessel containing the liquid.

1.3.3. Ultrasonication

Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes such as the extraction of multiple compounds from plants, microalgae and seaweeds. The enhancement in the extraction of

bioactive compounds achieved using sonication is attributed to cavitation in the solvent, a process that involves nucleation, growth, and collapse of bubbles in a liquid, driven by the passage of the ultrasonic waves. Ultrasonic frequencies (>20 kHz) are usually used, leading to the process also being known as ultrasonication.

1.3.4.Thermal Conductivity Tests

➢ **KD2 Pro Thermal Property Analyzer**

The KD2-Pro is a fully portable field and lab thermal properties analyser. It uses the transient line heat source method to measure thermal diffusivity, specific heat (heat capacity), thermal conductivity and thermal resistivity.

The KD2 Pro has three interchangeable sensors which measure thermal conductivity, thermal diffusivity and specific heat (heat capacity) along with data storage capabilities and an automatic data collection mode.It allows unattended (user programmable) measurements and on-board data storage with space for over 4,000 measurements.

➢ **Transient Hot-Wire**

Standard instruments using this THW method has been manufactured over the years. In general, a transient hot-wire instrument consists of a probe which is to be inserted into the nanofluid for the measurement.

A metallic wire functions as the probe which is used as a line heat source as well as a thermometer. A constant current is supplied to the wire to raise its temperature.

The heat dissipated in the wire increases the temperature of the wire as well as that of the nano-fluid. This temperature rise depends on the thermal conductivity of the Nano-fluid sample in which the hot-wire is inserted. Several researchers across the world have used transient hot-wire technique for the measurement of thermal conductivity of nano-fluids.

Several variations of the transient hot-wire method, namely the liquid metal transient hot-wire technique and the transient short hot-wire have been used to

measure the thermal conductivity of liquids. The liquid metal transient hot-wire method is used for electrically conducting liquids. A mercury-filled glass capillary is suspended in the fluid or dispersion, with the glass capillary serving to insulate the mercury ''hot-wire'' from the electrically conducting fluid or dispersion.

The mercury wire forms one resistor in a Wheatstone bridge circuit and is heated when a constant voltage is applied to the bridge. The temperature rise of the wire is calculated from the change in the resistance of the mercury with time, obtained by measuring the voltage offset of the initially balanced Wheatstone bridge.

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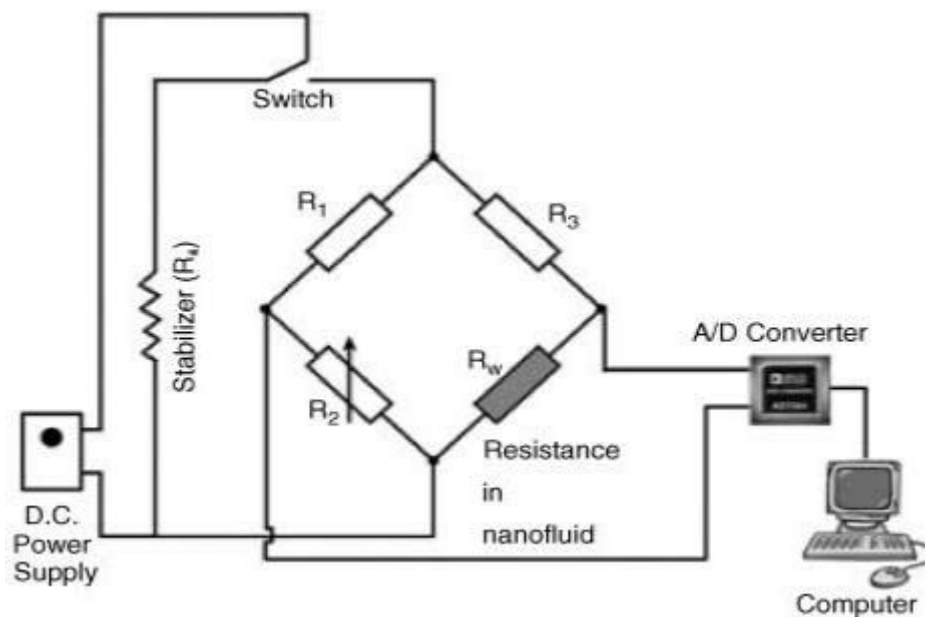
Figure 1.1.Transient Hot-wire circuit diagram

For measuring the thermal conductivity of highly corrosive liquids, such as molten carbonates, it is very difficult to keep the samples molten for such a long zone at a homogeneous initial temperature which is critical to obtain reasonable results. This disadvantage of TWH method can be solved by using a shorter probe (10 mm height) to measure the thermal conductivity of nano-fluids using a smaller sample cell. The transient short hot-wire (SHW) technique is based on

the numerical solution of two-dimensional transient heat conduction for a short wire with the same length to diameter ratio and boundary conditions as those used in the actual measurements

In addition, this method is very fast compared to other techniques. The conceptual design of the hot-wire apparatus is also simple compared to the arrangements needed for other techniques. In this method, a platinum wire is used for the measurement. The wire is used both as a heater and as a thermometer. This method is based on the principle of measurement of temperature and time response of the wire subjected to an abrupt electrical pulse.

CHAPTER 2
LITERATURE REVIEW

Rasmika H.Patel et al (2017) studied the synthesis of highly pure CuO nanoparticles their use as a nano-fluid for high thermal conduction applications. The CuO synthesized is characterized by XRD, TEM, EDAX. The synthesized CuO was added in different concentrations in the base fluid thereby using the KD2 Pro thermal property analyser, the thermal conductivity of the fluid is found. From the study, it is concluded that nano-fluid with 0.05% concentration of CuO showed that the highest thermal conduction of 0.69% and 2.30% at 25°C and 65°C.

V.Salamon et al (2017) studied the heat transfer characteristics of water and propylene glycol based TiO2 nano-fluid. It was analysed experimental and compared with pure water and propylene glycol mixture. The different concentrations of nano fluid was prepared by adding 0.1% and 0.3% of TiO2 nanoparticle in the ratio of 70:30 water and propylene glycol mixture. The experimental w conducted by varying coolant flow rate at 3 to 6 litre/minute at various temperature (50°C,60°C,70°C,80°C).The result shows that Nusselt number increases with increase in flow rate. At higher operating temperature and max coolant flow rate 0.3% of TiO2 nano-fluid enhance the heat transfer rate by 8.5% to base fluid.

Kin Yuen Leong et al (2018) investigated the thermal conductivity characteristics of copper - titanium dioxide hybrid nano-fluid and compared it with the non-fluid (Cu and TiO2) nano-fluid. The study also investigates (weight percentage type of surfactant, ph values of base fluid and sonication times). The weight percentage of 0.2% , 0.4% , 0.6% and 0.8% of nanoparticles were studied in adding the base fluid in the ratio of 50:50 water and ethylene glycol. The result shows that the thermal conductivity of the hybrid nano-fluid increases with increase in weight percentage of nanoparticle. The hybrid nano-

fluid containing 0.8 weight percentage of Cu-TiO2 and SLS as a surfactant, showed highest thermal conductivity of 9.8% compared to base fluid.

Mohammad Rafiqul Islam et al (2016) studied the properties of Electrical and Thermal conductivities of 50/50 water and ethylene glycol with TiO2 in the range of 0.05 - 0.5%. The result shows the thermal conductivity increases with increase of concentration of particle. The enhancement of thermal conductivity was found to 10% when temperature varied between 20°C to 70°C, while for 0.5% concentration. The enhancement was found to be 52%.The enhancement of nano-fluid is found to be almost linear with increase in temperature and concentration.

Kumar Nishant et al (Aug 2016) investigated the effect of CuO and TiO2 nanoparticles on thermal conductivity and overall heat transfer co-efficient of base fluid like water and ethylene glycol. The result shows, the thermal conductivity of base fluids without addition of nanoparticles was found to be 2.61 W/mK and 0.268 W/mK. The addition of highest volume was found to 0.7265W/mK and 0.406 W/mK for CuO and 0.7 W/mK and 0.406 W/mK for TiO2 of water and ethylene glycol.

J.A.Eastman et al (2001) investigated nano-fluid consisting of copper Nano-meter-sized particles dispersed in ethylene glycol has a much higher effective thermal conductivity than either pure ethylene glycol or ethylene glycol containing the same volume fraction of dispersed oxide nanoparticles. The effective thermal conductivity of ethylene glycol is shown to be increased by up to 40% for a nano-fluid consisting of ethylene glycol containing approximately 0.3 vol% Cu nanoparticles of mean diameter 10nm. The results are anomalous based on previous theoretical calculations that had predicted a strong effect of particle shape on effective nano-fluid thermal conductivity, but no effect of either particle size or particle thermal conductivity.

Y.Veramahmoudi et al (2012) investigated the overall heat transfer coefficient of CuO/water nano-fluids is investigated experimentally under laminar flow regime (100 < Re < 1000) in a car radiator. The experimental system is quite similar to cars' cooling system. The nano-fluids in all the experiments have been stabilized with variation of pH and use of suitable surfactant. The results show that the overall heat transfer coefficient with nano-fluid is more than the base fluid. The overall heat transfer coefficient increases with the enhancement in the nano-fluid concentration from 0 to 0.4 vol.%. Conversely, the overall heat transfer coefficient decreases with increasing the nano-fluid inlet temperature from 50 to 80°C. The implementation of nano-fluid increases the overall heat transfer coefficient up to 8% at nano-fluid concentration of 0.4 vol.% in comparison with the base fluid. In addition, the results are statistically analysed using Taguchi method by implementing Qualitek-4 software. The maximum value of the overall heat transfer coefficient with nano-fluid, effect of each operating parameter on the overall heat transfer coefficient and the optimum values of each parameter are determined.

CHAPTER 3
MATERIALS USED

3.1.COPPER OXIDE (CuO)

Copper(II) oxide or cupric oxide is the inorganic compound with the formula CuO. A black solid, it is one of the two stable oxides of copper, the other being Cu_2O or cuprous oxide. As a mineral, it is known as tenorite.

This article discusses about the properties and applications of copper oxide nanoparticles. Copper is a Block D, Period 4 element, while oxygen is a Block P, Period 2 element.

Copper oxide nanoparticles appear as a brownish-black powder. They can be reduced to metallic copper when exposed to hydrogen or carbon monoxide under high temperature. They are graded harmful to humans and as dangerous for the environment with adverse effect on aquatic life.


Figure 3.1.Copper oxide

Copper oxide nanoparticles can be synthesized using the aqueous precipitation method. In this method, copper acetate is used as a precursor and sodium hydroxide as a stabilizing agent.

3.1.1.PRODUCTION

It is produced on a large scale by pyrometallurgy, as one stage in extracting copper from its ores. The ores are treated with an aqueous mixture of ammonium carbonate, ammonia, and oxygen to give copper(I) and copper(II) ammine complexes, which are extracted from the solids. These complexes are decomposed with steam to give CuO.

It can be formed by heating copper in air at around 300–800°C:

$$2\ Cu + O_2 \rightarrow 2\ CuO$$
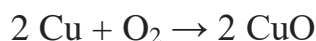
For laboratory uses, pure copper(II) oxide is better prepared by heating copper(II) nitrate, copper(II) hydroxide, or basic copper(II) carbonate:

$$2\ Cu(NO_3)_{2(s)} \rightarrow 2\ \mathbf{CuO}_{(s)} + 4\ NO_{2(g)} + O_{2(g)}\ (180°C)$$

$$CuCO_{3(s)} \rightarrow \mathbf{CuO}_{(s)} + CO_{2(g)}$$

$$2\ Cu(OH)_{2(s)} \rightarrow 2\ \mathbf{CuO}_{(s)} + 2\ H_2O_{(l)} + O_{2(g)}$$
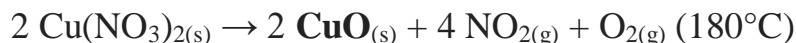
3.1.2.REACTIONS

Copper(II) oxide dissolves in mineral acids such as hydrochloric acid, sulfuric acid or nitric acid to give the corresponding copper(II) salts:

$$CuO + 2\ HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$$

$$CuO + 2\ HCl \rightarrow CuCl_2 + H_2O$$

$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$$
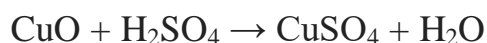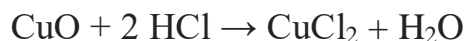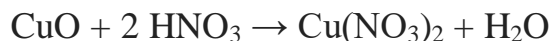
It reacts with concentrated alkali to form the corresponding cuprite salts:

$$2\ MOH + CuO + H_2O \rightarrow M_2[Cu(OH)_4]$$

It can also be reduced to copper metal using hydrogen, carbon monoxide, or carbon:

$$CuO + H_2 \rightarrow Cu + H_2O$$

$$CuO + CO \rightarrow Cu + CO_2$$

$$2\ CuO + C \rightarrow 2Cu + CO_2$$
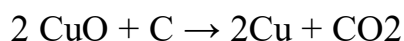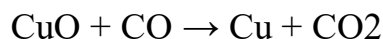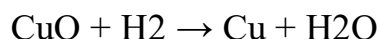
When cupric oxide is substituted for iron oxide in thermite the resulting mixture is a low explosive, not an incendiary.

3.1.3.PROPERTIES

Table 3.1.Properties of copper oxide

Formula	CuO
Molar mass	79.545 g/mol
Boiling point	2000 °C
Density	6.31 g/cm³
Melting point	1326 °C
IUPAC ID	Copper(II) oxide
Appearance	Black to Brown powder
Solubility in water	soluble
Viscosity	6.12×10^{-2} Pa.s
Flash point	Non-flammable
Thermal conductivity	33 W/mK

3.1.4.APPLICATIONS

● Copper oxide is a semiconductor metal with unique optical, electrical and magnetic properties and it has been used for various applications, such as the development of supercapacitors, near-infrared filters, in magnetic storage media, sensors, catalysis, semiconductors, etc

● Copper oxide is used as a pigment in ceramics to produce blue, red, and green, and sometimes Gray, pink, or black glazes. It is also incorrectly used

as a dietary supplement in animal feed. Due to low bioactivity, negligible copper is absorbed. It is also used when welding with copper alloys.

3.2. TITANIUM DIOXIDE (TiO_2)

Titanium dioxide, also known as titanium(IV) oxide or titania, is the naturally occurring oxide of titanium, chemical formula TiO_2. When used as a pigment, it is called titanium white, Pigment White 6, or CI 77891. Generally, it is sourced from ilmenite, rutile, and anatase.

Titanium oxide (TiO2) is available in the form of nanocrystals or nanodots having a high surface area. They exhibit magnetic properties. Titanium belongs to Block D, Period 4 while oxygen belongs to Block P, Period 2 of the periodic table. Titanium oxide is also known as flamenco, rutile, titanium dioxide and dioxo-titanium.

Titanium oxide nanoparticles are known for their ability to inhibit bacterial growth and prevent further formation of cell structures. It is chosen because it has higher thermal conductivity with respective to surface area. It has the most effective heat transfer rate with respective to the cost. It is easy to manufacture and produce in large quantities.

The preparation methods are listed out down below to as how TiO2. Each preparation method is adopted for certain use cases or used for production accordingly to its environmental.

Titanium dioxide (TiO2) is a transition metal oxide with two main applications as either pigment or photocatalyst, in many sectors including buildings, paper industry, cosmetics, pharmaceutics, food and others (air-purification system, rubbers, inks and ceramics).

3.2.1.PRODUCTION

The production method depends on the feedstock. The most common mineral source is ilmenite. The abundant rutile mineral sand can also be purified with the chloride process or other processes. Ilmenite is converted into pigment grade titanium dioxide via either the sulphate process or the chloride process. Both sulphate and chloride processes produce the titanium dioxide pigment in the rutile crystal form, but the Sulphate Process can be adjusted to produce the anatase form. Anatase, being softer, is used in fibre and paper applications. The Sulphate Process is run as a batch process; the Chloride Process is run as a continuous process.

Plants using the Sulphate Process require ilmenite concentrate (45-60% TiO2) or pre-treated feedstocks as suitable source of titanium. In the sulphate process Ilmenite is treated with sulfuric acid to extract iron(II) sulphate pentahydrate. The resulting synthetic rutile is further processed according to the specifications of the end user, i.e. pigment grade or otherwise.

An alternative process, known as the chloride process converts ilmenite or other titanium sources to titanium tetrachloride via reaction with elemental chlorine, which is then purified by distillation, and reacted with oxygen to regenerate chlorine and produce the titanium dioxide. Titanium dioxide pigment can also be produced from higher titanium content feedstocks such as upgraded slag, rutile, and leucoxene via a chloride acid process.

3.2.2.SPECIALIZED METHODS

For specialty applications, TiO2 films are prepared by various specialized chemistries. Sol-gel routes involve the hydrolysis of titanium alkoxides, such as titanium ethoxide:

This technology is suited for the preparation of films. A related approach that also relies on molecular precursors involves chemical vapor deposition. In

this application, the alkoxide is volatilized and then decomposed on contact with a hot surface:

$Ti(OEt)4 + 2 H2O \rightarrow TiO2 + 4 EtOH$

$Ti(OEt)4 \rightarrow TiO2 + 2 Et2O$
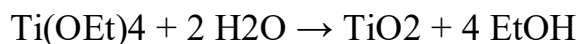
3.2.3.PROPERTIES

Table 3.2.Properties of Titanium dioxide

Formula	$TiO2$
Molar mass	79.866 g/mol
Boiling point	2,972 °C
Density	4.23 g/cm³
Melting point	1,843 °C
IUPAC ID	Titanium(IV) oxide
Appearance	White solid
Solubility in water	Insoluble
Viscosity	6×10^6 Pa.s
Flash point	Non-flammable
Odour	Odourless
Shear modulus	90GPa
Modulus of elasticity	230GPa
Thermal conductivity	11.7 W/mK

3.2.4.APPLICATIONS

● Titanium dioxide is odourless and absorbent. Its most important function in powder form is as a widely used pigment for lending whiteness and opacity. Titanium dioxide has been used as a bleaching and opacifying agent in porcelain enamels, giving them brightness, hardness, and acid resistance.

- In the pharmaceutical industry, titanium dioxide is used in most sunscreens to block UVA and UVB rays, similar to zinc oxide. It is also commonly used as pigment for pharmaceutical products such as gelatine capsules, tablet coatings and syrups.

- Pigments and oxides are one of the most popular colorant options for cold process soap. It's commonly used to transform soap from cream to white, or to lighten other colours. A natural white opaque pigment, titanium dioxide is used in a wide variety of applications including paints, cosmetic products and food.

Figure 3.2.Titanium Dioxide

3.3.SODIUM LAURYL SULPHATE

Sodium dodecyl sulphate or sodium lauryl sulphate, sometimes written sodium laurel sulphate, is a synthetic organic compound with the formula $CH_3(CH_2)_{11}SO_4Na$. It is an anionic surfactant used in many cleaning and hygiene products. This molecule is an organo sulphate and a salt.

It consists of a 12-carbon tail attached to a sulphate group, that is, it is the sodium salt of dodecyl hydrogen sulphate, the ester of dodecyl alcohol and sulfuric acid.

Its hydrocarbon tail combined with a polar "headgroup" give the compound amphiphilic properties and so make it useful as a detergent. Also derived as a component of mixtures produced from inexpensive coconut and palm oils, SDS is a common component of many domestic cleaning, personal hygiene and cosmetic, pharmaceutical, and food products, as well as of industrial and commercial cleaning and product formulations.

Figure 3.3.Sodium lauryl sulphate

3.3.1.PRODUCTION

SDS is synthesized by treating lauryl alcohol with sulphur trioxide gas, oleum, or chloro sulfuric acid to produce hydrogen lauryl sulphate. The resulting product is then neutralized through the addition of sodium hydroxide or sodium carbonate. Lauryl alcohol can be used in pure form or may be derived from either coconut or palm kernel oil by hydrolysis (which liberates their fatty acids), followed by hydrogenation. When produced from these sources, commercial samples of these "SDS" products are actually not pure SDS, rather a mixture of various sodium alkyl sulphates with SDS being the main component. For instance, SDS is a component, along with other chain-length amphiphiles, when produced from coconut oil, and is known as sodium coco sulphate (SCS). SDS is available commercially in powder, pellet, and other forms (each differing in rates of dissolution), as well as in aqueous solutions of varying concentrations.

Sodium lauryl sulphate (SLS) is a surfactant that can have a variety of uses, but in cleaning products, it is often used to break water tension and attract dirt and grime away from the material it is intended to clean. We use SLS that is derived from coconut or palm kernel oil from renewable carbon plant-derived materials.

The amount of SLS found in your personal care products is limited in concentration. For people who simply don't believe that SLS is safe, or don't want to try their luck, an increasing number of products that don't contain SLS are appearing on the market.

3.3.2.PROPERTIES

Table 3.3.Properties of Sodium lauryl sulphate

Formula	$NaC_{12}H_{25}SO_4$
Molar mass	288.372 g/mol
Density	1.01 g/cm³
Melting point	206 °C
IUPAC ID	Sodium lauryl sulphate
Appearance	white or cream-colored solid
Solubility in water	soluble
Viscosity	1.39 MPa.s
Flash point	Non-flammable
Odour	Odourless

3.3.3.APPLICATIONS

● Grooming products, such as shaving cream, lip balm, hand sanitizer, nail treatments, makeup remover, foundation, facial cleansers, exfoliants, and liquid hand soap.

● Hair products, such as shampoo, conditioner, hair dye, dandruff treatment, and styling gel.

● Dental care products, such as toothpaste, teeth whitening products, and mouthwash.

● Bath products, such as bath oils or salts, body wash, and bubble bath.

● Creams and lotions, such as hand cream, masks, anti-itch creams, hair-removal products, and sunscreen.

3.4.DISTILLED WATER

Distilled water is water that has been boiled into vapor and condensed back into liquid in a separate container. Impurities in the original water that do not boil below or near the boiling point of water remain in the original container. Thus, distilled water is one type of purified water.

All of water's unique physical properties are caused by water's, water molecules stick to each other. This is caused by hydrogen bonds that form between the slightly positive and negative ends of neighbouring molecules. This is the reason why water is found in drops; perfect spheres. It's hard to imagine water behaving any other way. water has the ability to support small objects. The hydrogen bonds between neighbouring molecules cause a "film" to develop at the surface. Water is one of the few substances that remain a liquid at such a large range of temperatures (O-100 °C).

Figure 3.4.Distilled water

A large amount of energy must be invested to overcome the hydrogen bonds in liquid water to change it to the gas phase. water is considered to be the universal solvent.

More substances will dissolve in water than any other liquid. This includes other polar substances (such as sugar) and ionic compounds (such as salt). It is chosen because it is a universal solvent. It is highly viscous fluidity motion when added are not restricting its motion of flow. It has high thermal heat transfer rate therefore when used with other solute particles increases its transfer rate furthermore.

3.5.ETHYLENE GLYCOL

Ethylene glycol (IUPAC name: ethane-1,2-diol) is an organic compound with the formula $(CH_2OH)_2$. It is mainly used for two purposes, as a raw material in the manufacture of polyester fibres and for antifreeze formulations. It is an odourless, colourless, sweet-tasting, viscous liquid. Ethylene glycol is toxic. Household pets are especially susceptible to ethylene glycol poisoning from vehicle antifreeze leaks.

Ethylene glycol is a chemical commonly used in many commercial and industrial applications including antifreeze and coolant. Ethylene glycol helps keep your car's engine from freezing in the winter and acts as a coolant to reduce overheating in the summer.

The colour of healthy engine coolant is green (for ethylene glycol) or orange (for Dexcol). A rusty colour indicates that the rust inhibitor in the coolant has broken down and it can no longer control rust and scale build-up.

3.5.1.PRODUCTION

Ethylene glycol is produced from ethylene (ethene), via the intermediate ethylene oxide. Ethylene oxide reacts with water to produce ethylene glycol according to the chemical equation:

$C_2H_4O + H_2O \rightarrow HO-CH_2CH_2-OH$
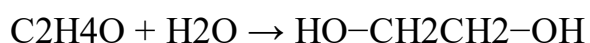
This reaction can be catalysed by either acids or bases, or can occur at neutral pH under elevated temperatures. The highest yields of ethylene glycol occur at acidic or neutral pH with a large excess of water. Under these conditions, ethylene glycol yields of 90% can be achieved. The major by-products are the oligomers diethylene glycol, tri-ethylene glycol, and tetra-ethylene glycol. The separation of these oligomers and water is energy-intensive. About 6.7 million tonnes are produced annually.
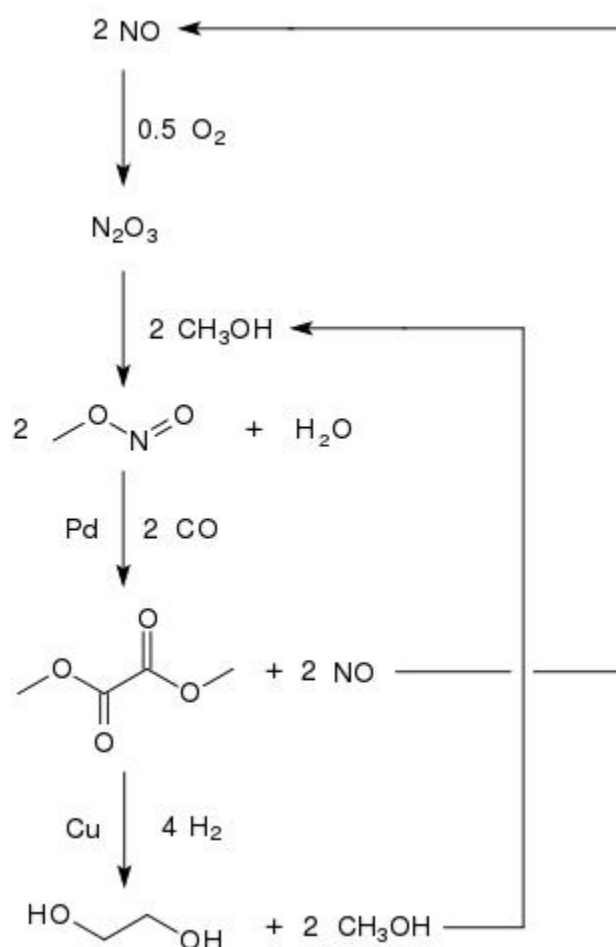
A higher selectivity is achieved by use of Shell's OMEGA process. In the OMEGA process, the ethylene oxide is first converted with carbon dioxide (CO2) to ethylene carbonate. This ring is then hydrolysed with a base catalyst in a second step to produce mono-ethylene glycol in 98% selectivity. The carbon dioxide is released in this step again and can be fed back into the process circuit.

The carbon dioxide comes in part from the ethylene oxide production, where a part of the ethylene is completely oxidized.

Ethylene glycol is produced from carbon monoxide in countries with large coal reserves and less stringent environmental regulations. The oxidative carbonylation of methanol to dimethyl oxalate provides a promising approach to the production of C1-based ethylene glycol. Dimethyl oxalate can be converted into ethylene glycol in high yields (94.7%) by hydrogenation with a copper catalyst:

Figure 3.5.Ethylene glycol

Methanol is recycled. Therefore, only carbon monoxide, hydrogen, and oxygen are consumed. One plant with a production capacity of 200 000 tons ethylene glycol per year is in Inner Mongolia, a second plant in China with a capacity of 250 000 tons per year was scheduled for 2012 in the province of Henan. As of 2015, four plants in China with a capacity of 200 000 t/a each were operating with at least 17 more to follow.

3.5.2.PROPERTIES

Table 3.4.Properties of Ethylene glycol

Formula	$C_2H_6O_2$
Molar mass	62.07 g/mol
Boiling point	197.6 °C
Density	1.1132 g/cm³
Melting point	-12.9 °C
IUPAC ID	Ethane-1,2-diol
Appearance	Clear, colourless liquid
odour	odourless
Solubility in water	Miscible
Vapour pressure	0.06 mm-Hg (20°C)
Viscosity	1.61×10^{-2} Pa.s
Flash point	111°C (384 K) closed cup
Auto-ignition temperature	410°C (683 K)
Explosive limits	3.2 - 15.2%
Thermal Conductivity	0.254 W/mK

3.5.3.APPLICATIONS

● Ethylene glycol is a chemical commonly used in many commercial and industrial applications including antifreeze and coolant. Other important uses of ethylene glycol include heat transfer fluids used as industrial coolants for gas compressors, heating, ventilating, and air-conditioning systems, and ice skating rinks.

● Ethylene glycol (antifreeze) is used in the cooling of a car radiator during the winter because it has a much lower freezing point than water. Its role in an automobile is to absorb heat from the engine. When the temperature of the coolant increases to its boiling point, the system boils over.

- Ethylene glycol nor Propylene glycol are main ingredients in hand sanitizer. And even if propylene glycol were included as an additive, it is not nearly as harmful in certain amounts. It's also incorrect that hand sanitizer poses a danger to pets who lick their owner's hand.

- When ethylene glycol breaks down in the body, it forms chemicals that crystallize, and the crystals can collect in your kidneys and affect kidney function. Ethylene glycol also forms acidic chemicals in the body, which can change the body's acid/base balance and affect your nervous system, lungs, and heart.

CHAPTER 4
EQUIPMENTS USED

4.1.MAGNETIC STIRRER

A magnetic stirrer or magnetic mixer is a laboratory device that employs a rotating magnetic field to cause a stir bar (or flea) immersed in a liquid to spin very quickly, thus stirring it. The rotating field may be created either by a rotating magnet or a set of stationary electromagnets, placed beneath the vessel with the liquid. They can be used inside hermetically closed vessels or systems, without the need for complicated rotary seals. They are preferred over gear-driven motorized stirrers because they are quieter, more efficient, and have no moving external parts to break or wear out (other than the simple bar magnet itself). Magnetic stir bars work well in glass vessels commonly used for chemical reactions, as glass does not appreciably affect a magnetic field.

Figure 4.1.Magnetic Stirrer

The limited size of the bar means that magnetic stirrers can only be used for relatively small experiments, of 4 litres or less. Stir bars also have difficulty in dealing with viscous liquids or thick suspensions. Because of its small size, a stirring bar is more easily cleaned and sterilized than other stirring devices.

They do not require lubricants which could contaminate the reaction vessel and the product. Magnetic stirrers may also include a hot plate or some other means for heating the liquid.

4.1.1.Applications

A magnetic stirrer is a device widely used in laboratories and consists of a rotating magnet or a stationary electromagnet that creates a rotating magnetic field. This device is used to make a stir bar, immerse in a liquid, quickly spin, or stirring or mixing a solution.

4.2.STIR BARS

A stir bar is the magnetic bar placed within the liquid which provides the stirring action. The stir bar's motion is driven by another rotating magnet or assembly of electromagnets in the stirrer device, beneath the vessel containing the liquid.

Figure 4.2.Stir bars

Stir bars are typically coated in PTFE, or, less often, in glass; the coatings are intended to be chemically inert, not contaminating or reacting with the

reaction mixture they are in. Glass coatings are used for liquid alkali metals (except lye, which will eat through glass) and alkali metal solutions in ammonia.

They are bar shaped and often octagonal in cross-section (sometimes circular), although a variety of special shapes exist for more efficient stirring. Most stir bars have a pivot ring around the centre on which they rotate. The smallest are only a few millimetres long and the largest a few centimeters. A stir bar retriever is a separate magnet on the end of a long stick (usually coated with PTFE) which can be used to remove stir bars from a vessel.

4.2.1.Applications

A stir bar, or spin bar, is a small white oblong Teflon-covered magnet. These bars have only one purpose: to stir solutions. They are used in conjunction with a stir motor. You place the stir bar in a container of liquid, then place the container over a stir motor.

4.3.ULTRASONICATOR

Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes such as the extraction of multiple compounds from plants, microalgae and seaweeds. The enhancement in the extraction of bioactive compounds achieved using sonication is attributed to cavitation in the solvent, a process that involves nucleation, growth, and collapse of bubbles in a liquid, driven by the passage of the ultrasonic waves.

Ultrasonic frequencies (>20 kHz) are usually used, leading to the process also being known as ultrasonication or ultra-sonication. In the laboratory, it is usually applied using an ultrasonic bath or an ultrasonic probe, colloquially known as a sonicator. In a paper machine, an ultrasonic foil can distribute

cellulose fibres more uniformly and strengthen the paper. Sonication has numerous effects, both chemical and physical. The chemical effects of ultrasound are concerned with understanding the effect of sonic waves on chemical systems, this is called sonochemistry. The chemical effects of ultrasound do not come from a direct interaction with molecular species. Studies have shown that no direct coupling of the acoustic field with chemical species on a molecular level can account for sonochemistry. Instead, in sonochemistry the sound waves migrate through a medium, inducing pressure variations and cavitation's that grow and collapse, transforming the sound waves into mechanical energy.

Figure 4.3.Ultrasonicator

4.3.1.Applications

Sonication can be used for the production of nanoparticles, such as nano emulsions, nanocrystals, liposomes and wax emulsions, as well as for waste water purification, degassing, extraction of seaweed polysaccharides and plant

oil, extraction of anthocyanins and antioxidants, production of biofuels, crude oil desulphurization, cell disruption, polymer and epoxy processing, adhesive thinning, and many other processes. It is applied in pharmaceutical, cosmetic, water, food, ink, paint, coating, wood treatment, metalworking, nanocomposite, pesticide, fuel, wood product and many other industries.

4.4. KD2 PRO THERMAL PROPERTY ANALYZER

The KD2-Pro is a fully portable field and lab thermal properties analyser. It uses the transient line heat source method to measure thermal diffusivity, specific heat (heat capacity), thermal conductivity and thermal resistivity.

Sophisticated data analysis is based on 30+ years of research experience on heat and mass transfer in soils and other porous materials. Complies with ASTM, IEEE, SSSA Standards.

The KD2 Pro has three interchangeable sensors which measure thermal conductivity, thermal diffusivity and specific heat (heat capacity) along with data storage capabilities and an automatic data collection mode. It allows unattended (user programmable) measurements and on-board data storage with space for over 4,000 measurements.

4.4.1. Corrects for Temperature Drift

Temperature changes of a thousandth of a degree per second (the sun warming the soil, for example, or someone walking into the lab) destroy the accuracy of thermal properties calculations. Unlike other thermal needle systems, the KD2 Pro corrects for linear temperature drift that can account for large errors.

4.4.2. Excellent Accuracy

The compact KD2 Pro controller is much more than a simple readout for time and temperature. A proprietary algorithm fits time and temperature data with exponential integral functions using a non-linear least squares method. This full mathematical solution delivers thermal resistivity to within ±10%.

Figure 4.4.KD2 Pro thermal property analyzer

4.4.3.Features

- Heated needle technology

- Requires no calibration

- Displays in engineering units

- Small needle minimises soil disturbance

4.4.4.Supplied with

- KS-1 Thermal Conductivity/Resistivity sensor (for liquids)

- TR-1 Thermal Conductivity/Resistivity sensor (for solids)

- SH-1 Dual-needle Thermal Properties sensor

- User's manual

- Pelican carrying case

- Readout stand

- Performance verication standards

- Thermal grease

- Drill bit for drilling pilot holes in materials

4.4.5.Specifications

Table 4.1.Specifications of KD2 Pro Thermal Property Analyzer

Accuracy	● ±5 to ±10% Thermal Conductivity/Resistivity ● ±10% Specific Heat ● ±10% Thermal Diffusivity
Measurement speed	1, 2, 5, & 10 min. read times
Data storage	4,095 readings, flash memory
Compliance to Standards	IEEE Standard 442-1981 and ASTM Standard D5334-08
Operating Environment of Sensors	-50 to 150°C
Battery Source	4 x AA
Auto-Read Mode	Users can collect unattended data at user-defined intervals in the auto-read mode
Type	Ultra low-power 16-bit micro-controller w/ 24-bit A/D converter
Display	Liquid Crystal Display (LCD) 7.5 cm x 4 cm
Case Dimensions	15.5 x 9.5 x 3.5 cm
Clibration	Each KD2 Pro comes factory calibrated and includes performance verification standards
Range of Measurements	K: 0.02 to 4 Wm-1 C-1 D: 0.1 to 1.0 mm2s-1 R: 0.25 to 50mC W-1 C: 0.5 to 4 MJ m-3 C-1

4.4.6. Types of Supplied Sensors

(i) KS-1 6cm Sensor

The KS-1 is ideal for measuring thermal resistivity. It is 60mm long, 1.27mm diameter.

(ii) TR-1 10cm Sensor

The TR-1 measures thermal conductivity and thermal resistivity and conforms to IEEE Standard 442-1981 and ASTM Standard D5334-00. 100mm long, 2.4mm diameter.

(iii) SH-1 30mm Dual Sensor

The SH-1 is the only sensor that measures thermal diffusivity and specific heat. 30mm long, 1.28mm diameter, 6mm spacing.

CHAPTER 5

METHODOLOGY

MEASURE TiO$_2$－0.4g AND CuO－3.007g and STABLIZING AGENT 0.35g IN WEIGHING SCALE

MIX 50 ml OF WATER AND 50 ml OF ETYLENE GYCOL IN MAGNETIC STIRRIER FOR 1/2 HOUR

INITIALLY ADD CuO AND STIR FOR 1/2 HOUR

THEN ADD TiO$_2$ TO THE MIXTURE AND STIR FOR 1/2 HOUR

ADD STABILIZER 1/10th OF WEIGHT OF SLS AND MIX FOR 1 HOUR

NOW PLACE THE MIXTURE IN PROBE SONICATOR FOR 4 HOURS

THE MIXTURE CONTAINING ETHYLENE GYCOL AND WATER WITH 0.6% NANO PARTICLES (TiO$_2$ AND CuO) IS NOW PREPARED

Figure 5.1.Preparation of Sample-1

MEASURE TiO$_2$—0.8g AND CuO—3.605g and STABLIZIER AGENT 0.45g IN WEIGHING SCALE

MIX 50 ml OF WATER AND 50 ml OF ETYLENE GYCOL IN MAGNETIC STIRRIER FOR 1/2 HOUR

NOW ADD THE MEASURED CuO TO THE MIXTURE AND STIR FOR 1/2 HOUR

THEN ADD TiO$_2$ TO THE MIXTURE AND STIR FOR ANOTHER 1/2 HOUR IN MAGNETIC STIRRER

FINALLY ADD STABILIZER 1/10th of WEIGHT OF SLS TO THE SAMPLE AND MIX FOR 1 HOUR

NOW PLACE THE MIXTURE IN PROBE SONICATOR FOR 4 HOURS

THE MIXTURE CONTAINING ETHYLENE GYCOL AND WATER WITH 0.8% NANO PARTICLES IS OBTAINED

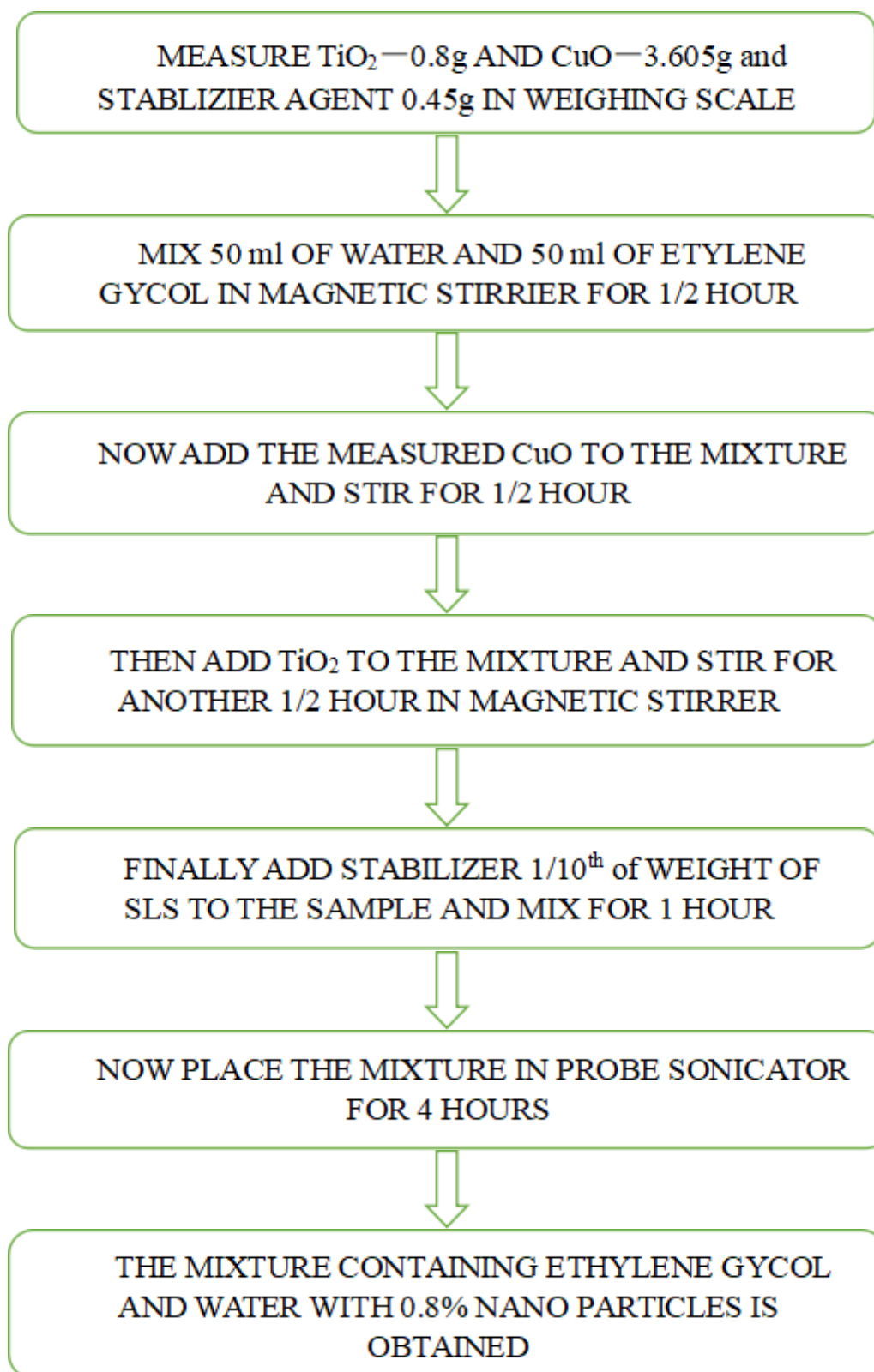**Figure 5.2.Preparation of Sample-2**

CHAPTER 6

CALCULATIONS

Density of Ethylene glycol and water mixture $= (v_a\alpha_a + v_b\alpha_b) / v_a + v_b$

$$= \frac{(50 \times 997) + (50 \times 1110)}{50 + 50}$$

Density of Ethylene glycol and water mixture = 1053.500 Kg / m^3

Where,

V_a - volume of water

V_b - volume of ethylene glycol

α_a - density of water

α_b - density of ethylene glycol

AT ROOM TEMPERATURE - 30°C

Table 6.1.Density and Thermal Conductivities of components used

Density of Distilled water	997 Kg/m^3
Density of ethylene glycol	1110 Kg/m^3
Thermal conductivity of Distilled water	0.607 W/mK
Thermal conductivity of ethylene glycol	0.254 W/mK
Thermal conductivity of copper oxide	33 W/mK
Thermal conductivity of Titanium dioxide	11.5 W/mK
Thermal conductivity of Distilled water and ethylene glycol	0.315 W/mK
Thermal conductivity of Distilled water and syn.ethylene glycol	0.475 W/mK

6.1.CALCULATION OF SAMPLE-1

Volume fraction of 0.5% CuO in 100ml base fluid

$$\frac{\text{weight of CuO}/6300}{(\text{weight of CuO}/6300) + (100/1055)} = 0.5/100$$

$$\frac{\text{weight of CuO}/6300}{\dfrac{(\text{weight of CuO}+597.156)}{6300}} = 0.005$$

$$\text{weight of CuO} = 0.005(\text{WCuO}+ 597.156)$$

$$\text{WCuO} - 0.005\ \text{WCuO} = 2.9858$$

$$\text{WCuO} = 2.9858/0.995 = 3.007\ g$$

Weight of Copper oxide = 3.007 g

Volume fraction of 0.1% of TiO_2 in 100ml of base fluid

$$\frac{\text{weight of TiO}_2/6300}{(\text{weight of TiO}_2/4230) + (100/1055)} = 0.1/100$$

$$\frac{\text{weight of TiO}_2/6300}{\dfrac{(\text{weight of TiO}_2+400.948)}{4230}} = 0.001$$

$$\text{weight of TiO}_2 = 0.001(\text{WTiO2}+400.948)$$

$$\text{WTiO}_2 - 0.001\ \text{WTiO}_2 = 0.400948$$

$$\text{WTiO}_2 = 0.400948/0.999$$
$$\mathbf{= 0.4013\ g}$$

Weight of Titanium Dioxide= 0.4013 g

6.2. CALCULATION OF SAMPLE-2

Volume fraction of 0.6% CuO in 100ml base fluid

$$\frac{\text{weight of CuO}/6300}{(\text{weight of CuO}/6300) + (100/1055)} = 0.6/100$$

$$\frac{\text{weight of CuO}/6300}{\dfrac{(\text{weight of CuO}+597.156)}{6300}} = 0.006$$

weight of CuO $= 0.006(\text{WCuO}+ 597.156)$

WCuO $- 0.006$ WCuO $= 3.583$

WCuO $= 3.583/0.994 = 3.605$ g

Weight of Copper oxide = 3.605 g

Volume fraction of 0.2% of TiO$_2$ in 100ml of base fluid

$$\frac{\text{weight of TiO}_2/4230}{(\text{weight of TiO}_2/4230) + (100/1055)} = 0.2/100$$

$$\frac{\text{weight of TiO}_2/4230}{\dfrac{(\text{weight of TiO}_2+400.948)}{4230}} = 0.002$$

weight of TiO$_2$ $= 0.002(\text{WTiO2} + 400.948)$

WTiO$_2$ -0.002 WTiO$_2$ $= 0.0.801896$

WTiO$_2$ $= 0.801896/0.998 = 0.804$ g

Weight of Titanium Dioxide = 0.804 g

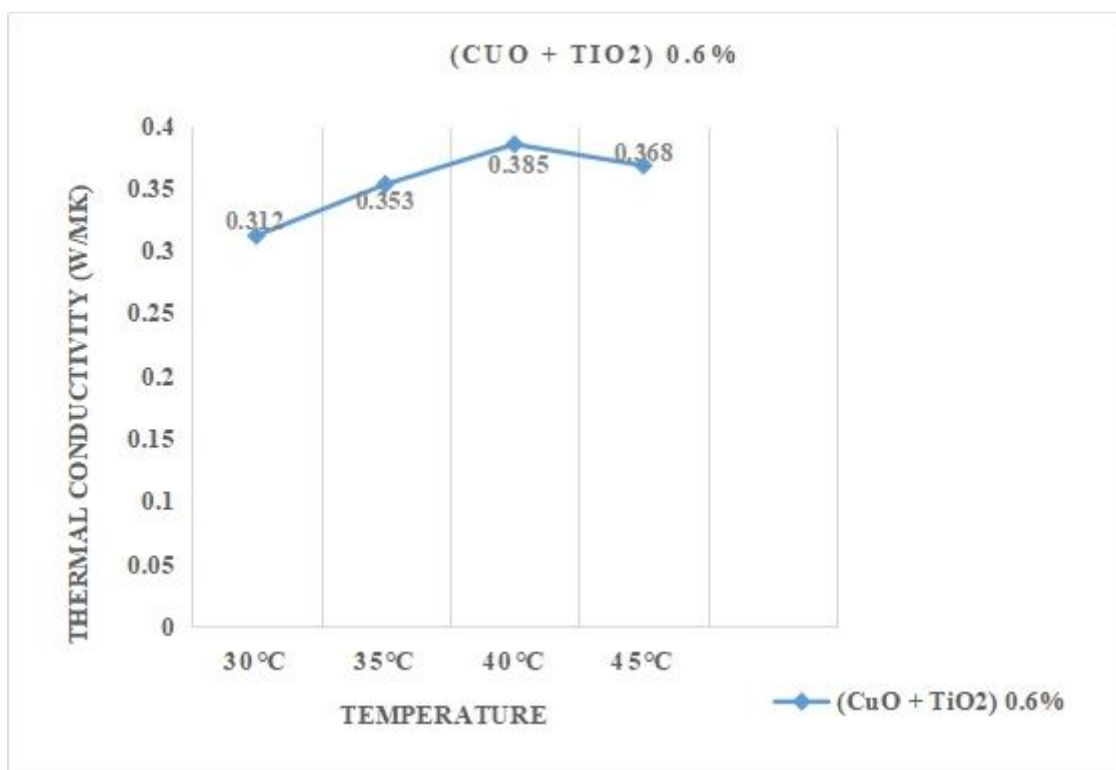# CHAPTER 7

RESULTS AND DISCUSSION

Figure 7.1.Temperature Vs Thermal Conductivities with Pure Ethylene Glycol @ 0.6%

Table 7.1.Temperature Vs Thermal Conductivities with Pure Ethylene Glycol @ 0.6%

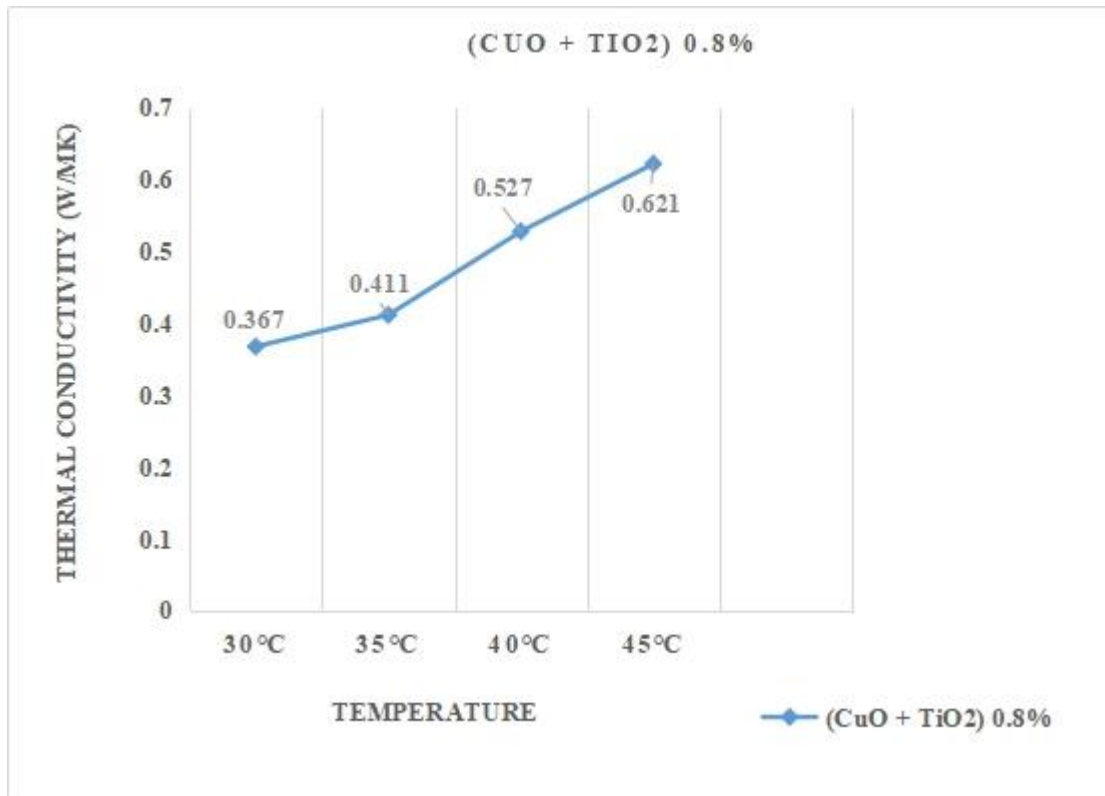| S.NO	TEMPERATURE(°C)	THERMAL CONDUCTIVITY(W/mK)
1	30	0.312
2	35	0.353
3	40	0.385
4	45	0.368

Figure 7.2.Temperature Vs Thermal Conductivities with Pure Ethylene Glycol @ 0.8%

Table 7.2.Temperature Vs Thermal Conductivities with Pure Ethylene Glycol @ 0.8%

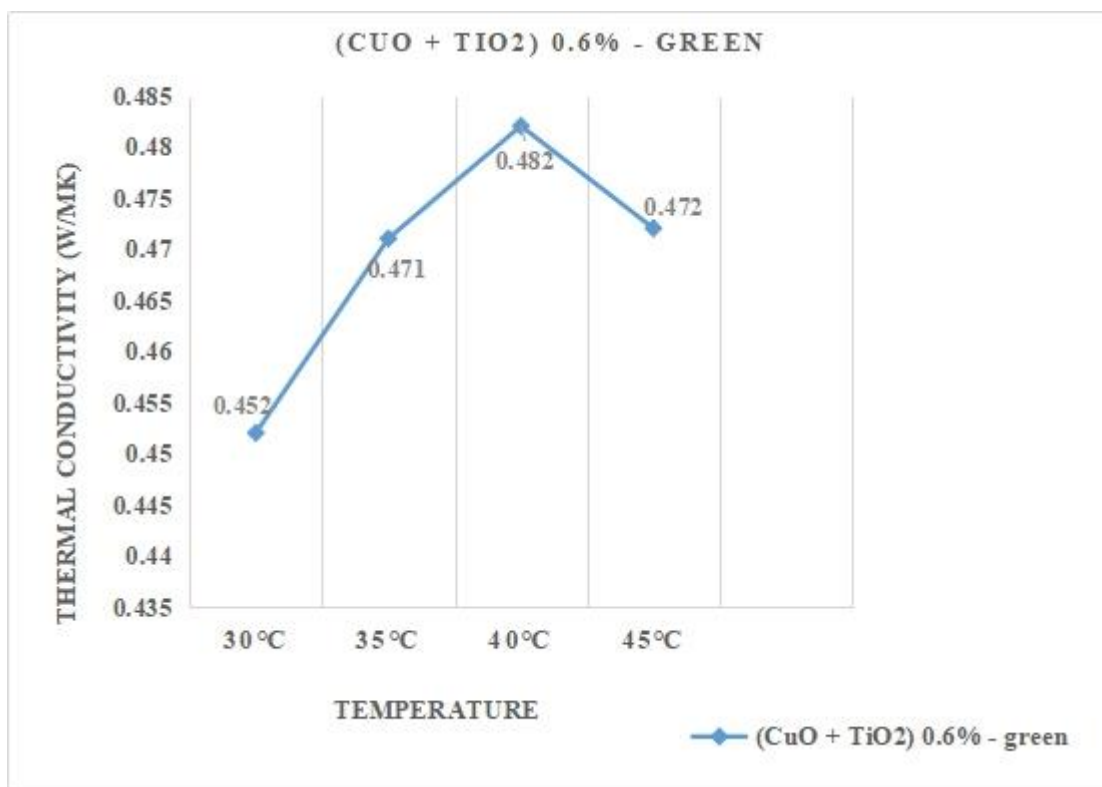| S.NO	TEMPERATURE(°C)	THERMAL CONDUCTIVITY(W/mK)
1	30	0.367
2	35	0.411
3	40	0.527
4	45	0.621

Figure 7.3.Temperature Vs Thermal Conductivities with synthetic Ethylene Glycol @ 0.6%

Table 7.3.Temperature Vs Thermal Conductivities with synthetic Ethylene Glycol @ 0.6%

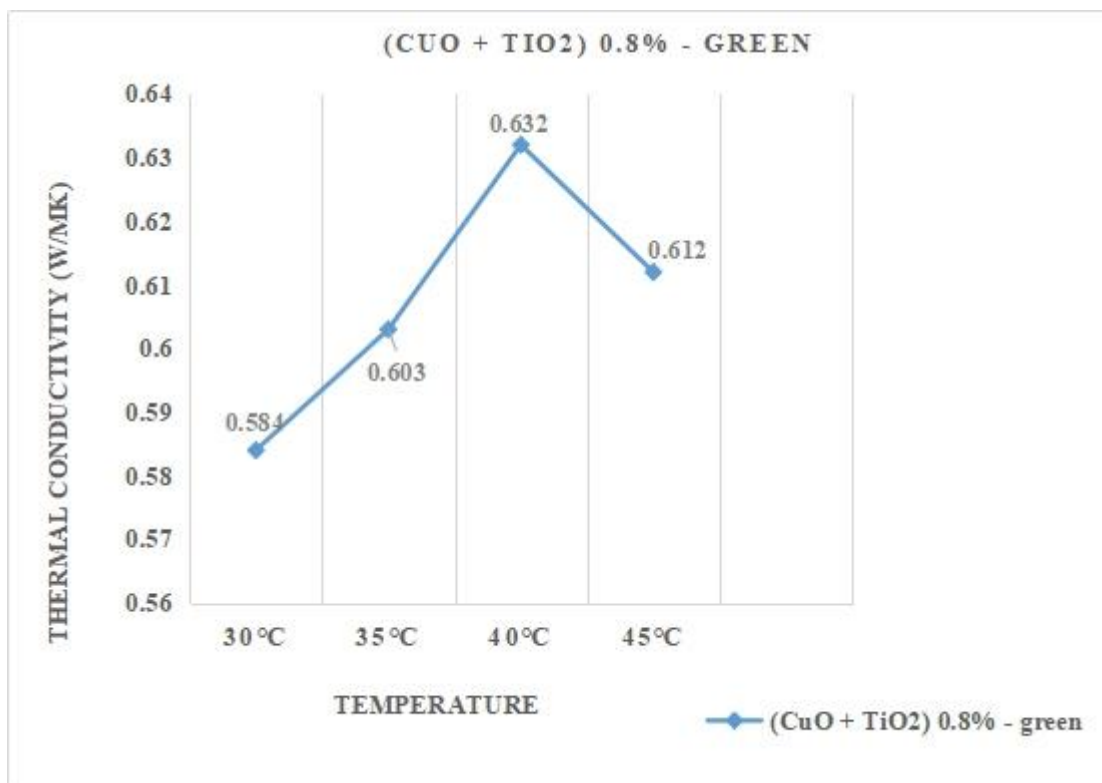| S.NO	TEMPERATURE(°C)	THERMAL CONDUCTIVITY(W/mK)
1	30	0.452
2	35	0.471
3	40	0.482
4	45	0.472

Figure 7.4.Temperature Vs Thermal Conductivities with synthetic Ethylene Glycol @ 0.8%

Table 7.4.Temperature Vs Thermal Conductivities with synthetic Ethylene Glycol @ 0.8%

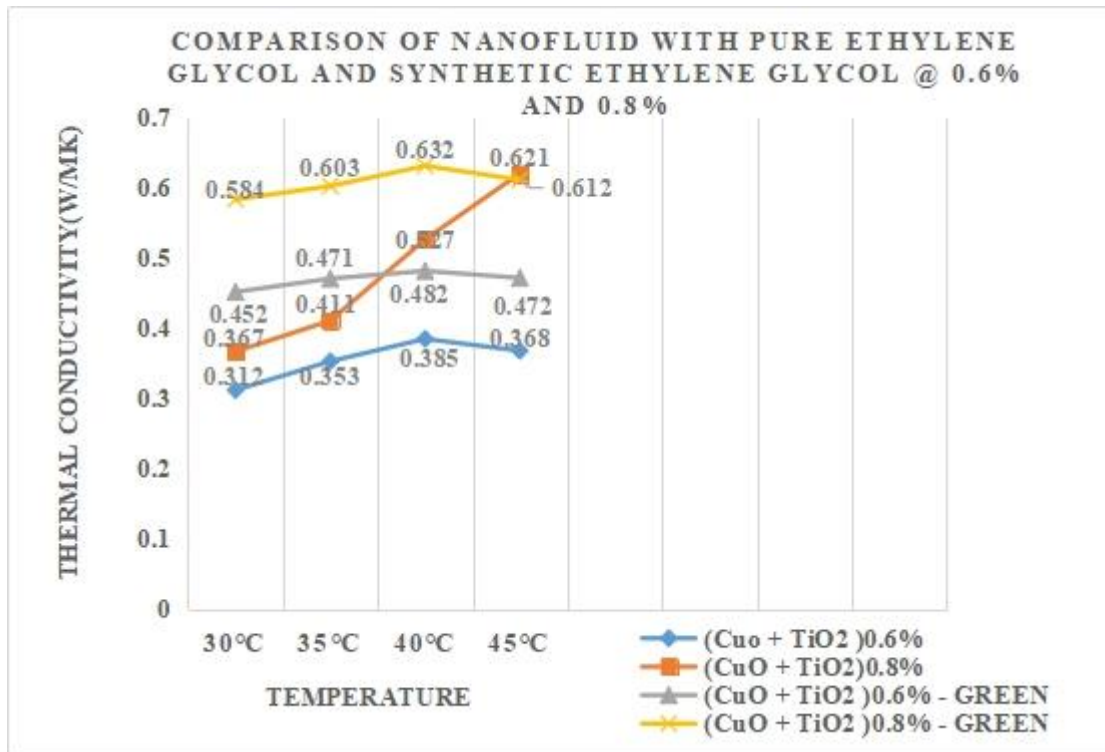| S.NO	TEMPERATURE(°C)	THERMAL CONDUCTIVITY(W/mK)
1	30	0.584
2	35	0.603
3	40	0.632
4	45	0.612

Figure 7.5.Temperature Vs Thermal Conductivities with pure ethylene glycol and synthetic ethylene glycol @ 0.6% and 0.8%

Table 7.5.Temperature Vs Thermal Conductivities with pure ethylene glycol and synthetic ethylene glycol @ 0.6% and 0.8%

TEMPERATURE	THERMAL CONDUCTIVITY			
	$(CuO+TiO_2)$ 0.6%	$(CuO+TiO_2)$ 0.8%	$(CuO+TiO_2)$ 0.6%-Green	$(CuO+TiO_2)$ 0.8%-Green
30	0.312	0.367	0.452	0.584
35	0.353	0.411	0.471	0.603
40	0.385	0.527	0.482	0.632
45	0.368	0.621	0.472	0.612

CHAPTER 8
CONCLUSION

In this study, the thermal conductivity of CuO - TiO$_2$ Hy-NF with volume concentration of 0.6% and 0.8% under different base fluids were experimentally investigated using KD2Pro thermal property analyzer. The analysis has lead to the conclusion that:

i. The CuO - TiO2 Hy-NF with 0.8% volume concentration in both the fluids has increased the thermal conductivity of about 85% at 45°C when compared to the base fluid (i.e., water mixture)

ii. The Thermal conductivity increases with increases in nanoparticle concentration and sonication time.

iii. The enhancement is also found to be almost linear with increase of temperature.

iv. The results shows that the thermal counductivity can be further improved either by increasing the nano particles concentration or by using newly developed nanoparticles like graphene flakes or multi wall carbon tubes.

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